Dual-tasking during recall of negative memories or during visual perception of images: Effects on vividness and emotionality

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ABSTRACT

Background and objectives: Several treatments are effective in reducing symptoms of post-traumatic stress disorder. We tested the effectiveness of an experimental intervention that consists of elements from two of these: virtual reality (VR) exposure therapy and eye movement desensitization and reprocessing. The latter is characterized by a dual-task approach: the patient holds a traumatic memory in mind while simultaneously making voluntary eye movements, resulting in reduced vividness and emotionality of the traumatic memory. If the experimental intervention is effective, it could provide a useful approach for highly avoidant individuals.
Methods: Participants recalled negative memories induced by a VR paradigm. The experimental group viewed VR screenshots that represented these negative memories while carrying out a dual-task. One control group recalled negative memories while carrying out the same dual-task (a standard dual-task condition) and another merely viewed the VR screenshots. Pre-to-post changes in self-rated memory vividness/emotionality were measured.
Results: The results indicate that viewing a screenshot only was outperformed by both dual-task interventions in terms of reductions in vividness/emotionality. Furthermore, the dual-task interventions had a comparable impact on vividness, but the screenshot variant led to greater decreases in emotionality.
Limitations: Changes in memory vividness/emotionality were only assessed shortly after the interventions and no measures of avoidance behavior were included in the study.
Conclusions: Looking at an image in VR that represents a memory while carrying out a dual-task may be at least as effective as recalling the memory during the dual-task. Interestingly, visually supporting a negative memory does not seem to prevent memory degrading by dual-tasking.

1. Introduction

Exposure to actual or threatened death, serious injury, or sexual violence may lead to the development of post-traumatic stress disorder (PTSD). Symptoms include the persistent re-experiencing of the traumatic event, persistent avoidance of stimuli associated with the trauma, hyperarousal, and negative alterations in cognitions and mood (American Psychiatric Association, 2013). There are several treatments that are effective in reducing these symptoms (for meta-analyses see e.g., Cusack et al., 2016; Watts et al., 2013). In the present study we aimed to test the effectiveness of an experimental intervention that

consists of elements from two of these treatments: virtual reality exposure therapy (VRET) and eye movement desensitization and reprocessing (EMDR). This was done using a lab model of these interventions in a group of healthy participants, as has been done in previous studies (see van den Hout & Engelhard, 2012).

Exposure therapy involves exposing patients with anxiety conditions to fear-eliciting stimuli in order to decrease their threat expectancy, fear, and avoidance behavior. VRET is an increasingly common alternative to in vivo and in vitro exposure, in which exposure takes place in virtual environments that resemble feared real-life situations. Several meta-analyses showed that it is an efficacious method

of treating anxiety disorders (Morina, Ijntema, Meyerbröker, & Emmelkamp, 2015; Opriş et al., 2012; Parsons & Rizzo, 2008; Powers & Emmelkamp, 2008). Although most research involves effects of VRET in the context of specific phobias, research indicates that the use of virtual environments can effectively reduce PTSD symptoms as well (e.g., Beck, Palyo, Winer, Schwagler, & Ang, 2007; Gerardi, Rothbaum, Ressler, Heekin, & Rizzo, 2008; Rothbaum, Hodges, Ready, Graap, & Alarcon, 2001). VRET might be an interesting alternative in the context of PTSD treatment, because it allows for control over trauma-related exposure stimuli in a safe environment. Moreover, unlike in vivo exposure, it potentially allows the user to visually re-experience an entire traumatic event.

Unlike exposure therapy, EMDR was specifically introduced as a treatment for PTSD (Shapiro, 1989). One of its key components is a dual-task approach: the patient holds a traumatic memory in mind while simultaneously making voluntary eye movements by tracking the therapist's finger as it moves horizontally across the patient's visual field (Shapiro, 2001). Several theories have been proposed to explain the effects of this 'eye movement' component, but the present state of research points towards an explanation based on working memory (WM) as the most solid theory. According to this theory, keeping a memory in mind and making voluntary eye movements both tax the limited capacity of WM. As a result of this, the memory becomes less vivid and less emotional (Andrade, Kavanagh, & Baddeley, 1997; Gunter & Bodner, 2008; Smeets, Dijs, Pervan, Engelhard, & van den Hout, 2012) and is stored as such into long-term memory (van den Hout & Engelhard, 2012). This implies that keeping a memory in mind while carrying out another task that taxes working memory should also decrease memory vividness and emotionality. Indeed, studies showed that tasks such as copying the Rey complex figure (Gunter & Bodner, 2008), mental arithmetic (van den Hout et al., 2010), and playing the computer game Tetris (Engelhard, van Uijen, & van den Hout, 2010) are effective as well. In contrast, passive tasks, such as listening to tones, are barely taxing and are less effective (van den Hout et al., 2012). We aimed to investigate whether a dual-task intervention in which the recall element is replaced by a VRET element can reduce vividness and emotionality too. That is, instead of thinking of a memory, individuals look at an image in virtual reality (VR) that represents a memory while carrying out the dual-task. If this approach is effective, it could be clinically useful when patients show signs of avoidance behavior with respect to their traumatic memories during therapy. In those cases, (visual) retrieval cues might be particularly important for an intervention to take effect, because memories are only susceptible to updating when (re)activated (see Visser, Lau-Zhu, Henson, & Holmes, 2018).

In order to test this idea, we induced negative memories in a group of healthy participants by letting them play a VR game of the horror genre (cf. Cuperus, Klaassen, Hagenaars, & Engelhard, 2017; Cuperus, Laken, van den Hout, & Engelhard, 2016). Like the well-established 'trauma film paradigm' (for a meta-analysis, see James et al., 2016), a benefit of this VR paradigm over the use of autobiographical memories is that it allows for experimental control. Furthermore, compared to the trauma film paradigm, VR can induce a greater 'feeling of presence' and allows interaction with the environment (for a comparison of both paradigms, see Cuperus et al., 2017). An obvious downside of both paradigms, however, is that personal relevance is still limited compared to actual events in which one's actions may have important consequences. In the present study, three-dimensional screenshots of participants' VR experience were recorded while they played the game (from participants' point of view). After playing, participants viewed the images of the gameplay moments that they found the most unpleasant, while they did a non-visual dual-task. This 'shape sorter' task consisted of putting wooden figures into matching holes in a box without visual feedback (Cuperus et al., 2016). We compared the effects of the experimental 'screenshot + dual-task' condition with two control conditions: a standard dual-task condition in which participants

recalled the negative memories while carrying out the shape sorter task ('recall + dual-task') and a condition in which participants merely viewed the VR screenshots ('screenshot only'). Before and after the intervention, participants recalled the most unpleasant memory of the VR game and rated how vivid and unpleasant it was. The dependent variables were the changes over time in vividness and emotionality of the targeted gameplay memories.

We tested three competing hypotheses. The first hypothesis, based on WM theory, was that both dual-task interventions would be more effective than the screenshot only intervention. We did not expect effects of habituation in any of the interventions, because the exposure periods were short (cf. Engelhard, van den Hout, Dek et al., 2011). However, there is substantial overlap in neural activation during visual imagery and perception (Ganis, Thompson, & Kosslyn, 2004; Holmes & Mathews, 2010). One may therefore argue that a VR image that represents a negative memory serves as a strong retrieval cue. Therefore, the second hypothesis was that the screenshot + dual-task intervention would be more effective than recall + dual-task. Alternatively, viewing the VR image may prevent the mental image from becoming less vivid and emotional. A previous study suggests that listening to an audio recording of a negative event may negate the blurring effects of the dual-task (Kearns & Engelhard, 2015). Therefore, the third hypothesis was that recall + dual-task would outperform both screenshot interventions. These three hypotheses were evaluated using Bayesian analysis (Hoijtink, 2012; Mulder, Hoijtink, & de Leeuw, 2012):

H_1. screenshot + dual-task = recall + dual-task > screenshot only

H_2. screenshot + dual-task > recall + dual-task > screenshot only

H_3. recall + dual-task > screenshot + dual-task = screenshot only

2. Methods

2.1. Participants

Participants, mostly students, were recruited via social media and flyers. They had to be at least 18 years old to be eligible and individuals with a self-reported medical history of heart disease or epilepsy were excluded. A total of 84 participants (40 male, 44 female) with a mean age of 23.7 years (range 18–35; SD = 3.5) were evenly distributed over the different conditions.

2.2. Materials

The VR game we used in this study was 'Affected' version 1.55 (Fallen Planet Studios; Southport, United Kingdom). Visuals were provided through an Oculus Rift Development Kit 2 head-mounted display (Oculus VR; Menlo Park, California) and audio was provided through a Sennheiser SD 449 headphone (Sennheiser electronic GmbH & Co. KG; Wedemark, Germany). Participants moved through the game using an Xbox 360 controller (Microsoft; Redmond, Washington). Screenshots were recorded with Fraps 3.5.99 (Beepa Pty Ltd.; Melbourne, Australia). The PC was equipped with an NVIDIA GeForce GTX 980 graphics card (NVIDIA; Santa Clara, California) and an Intel Core i5-4690 processor (Intel; Santa Clara, California). The shape sorter used in the dual-task conditions was made by Jouéco (Waddinxveen, The Netherlands) and the Sudokus were extracted from 1sudoku.net (level 'easy').

2.3. Conditions

2.3.1. Screenshot + dual-task

During the intervention phase, participants in the screenshot + dual-task condition viewed a three-dimensional screenshot of the moment from the VR game that they labelled as most unpleasant after playing it. This screenshot was shown through the head-mounted

display for 24 s, four times in a row, with 10 s intervals during which the screen turned black (cf. the procedure of van den Hout, Muris, Salemink, & Kindt, 2001). While focusing on the image, participants carried out the shape sorter task.

2.3.2. Recall + dual-task

The procedure of the recall + dual-task condition was the same as the screenshot + dual-task procedure. Instead of viewing a screenshot while carrying out the shape sorter task, participants were instructed to retrieve and visualize the moment they labelled as the most unpleasant memory during the 24 s periods.

2.3.3. Screenshot only

The screenshot only condition was identical to the screenshot + dual-task condition but did not contain the shape sorter task; participants merely viewed the screenshot they selected.

2.4. Procedure

After providing written consent, participants put on the head-mounted display and headphone and received the game controller. The VR game Affected started, as well as the Fraps application that recorded gameplay screenshots with 1 s intervals. The game contains an abandoned old mansion with several jump scares (e.g., a cabinet suddenly falls over and a poltergeist spawns near the participant; see Fig. 1 for screenshots). Participants were instructed to reach the last of a series of rooms using the game controller, without a time limit (cf. Cuperus et al., 2016). The experimenter left the room during the game and re-entered it when participants gave a signal that they finished the game. Participants were then asked to remember and describe the most unpleasant moment of the game. The experimenter wrote down their description. They then carried out a paper-and-pencil Sudoku puzzle with the instruction to complete as much of the puzzle as possible within 90 s. This distractor task was used to make sure that any remaining gameplay visuals were removed from WM (Tadmor, McNally, & Engelhard, 2016). In the screenshot conditions, the experimenter used this time to look up the screenshot that best matched the most unpleasant moment that was described by the participant. Then, in a memory pre-test, participants were instructed to visualize the moment they labelled as most unpleasant and keep an image of it in mind for 10 s. They then rated its vividness and emotionality on two 100 mm visual analogue scales (VAS) that ranged from 0 (not vivid/unpleasant at all) to 100 (extremely vivid/unpleasant; Engelhard, van den Hout, & Smeets, 2011). Next, depending on the condition, participants were

subjected to the screenshot + dual-task, recall + dual-task, or screenshot only intervention. They then carried out another Sudoku puzzle for 90 s, followed by a memory post-test that was identical to the pre-test. Finally, participants were debriefed and offered a mindfulness session of approximately 5 min to reduce potential residual stress (cf. Engelhard, van den Hout, Dek et al., 2011).

2.5. Data analyses

Our hypotheses were evaluated using a Bayesian model selection criterion based on the Bayes factor (BF; Kass & Raftery, 1995). The BF is the primary outcome in a Bayesian framework and states the likelihood of one hypothesis relative to another hypothesis. For instance, $BF_{12} = 5$ means that the data are five times more probable under H_1 than under H_2. BIEMS is a software program that can be used to evaluate competing hypotheses based on the BF (e.g., Mulder, Hoijtink, & Klugkist, 2010). By default, BIEMS computes a BF for each constrained hypothesis against the same unconstrained hypothesis. A constrained hypothesis is made up of a collection of restrictions that specify the relationships between conditions (e.g., A > B > C or A = B < C), while an unconstrained hypothesis does not specify these relationships and only states that there are means in the hypothesis (i.e., A, B, C). As a result, A BF of 1 means that compared to an unconstrained hypothesis, the constrained hypothesis receives equal support. BF > 1 indicates that the constrained hypothesis outperforms the unconstrained hypothesis and BF < 1 means the opposite. Because the BFs for all constrained hypotheses are determined at the same time and all are relative to the same unconstrained hypothesis, the relative support for one constrained hypothesis over another can be determined simply by dividing the BFs of these hypotheses (Béland, Klugkist, Raîche, & Magis, 2012).

3. Results

Table 1 shows BFs for each constrained hypothesis, Table 2 shows mean vividness and emotionality scores before and after the three interventions, and Fig. 2 illustrates changes in vividness and emotionality. It shows greater decreases in vividness and emotionality as a result of both dual-task conditions compared to screenshot only. This is reflected in the Bayesian analyses, which show that hypotheses 1 and 2 are more likely than model 3 for both variables. Fig. 2 further shows that screenshot + dual-task yields the greatest decreases, but the difference with recall + dual-task is greater for emotionality than for vividness. This difference is emphasized in the strengths of evidence (i.e.,

Fig. 1. Screenshots of the VR game ('Affected') that participants played.

Table 1
Bayes factors (BF) for vividness and emotionality, for each constrained hypothesis.

Hypothesis	$BF_{vividness}$	$BF_{emotionality}$
1. screenshot + dual-task = recall + dual-task > screenshot only	6.38	3.37
2. screenshot + dual-task > recall + dual-task > screenshot only	3.21	5.06
3. recall + dual-task > screenshot + dual-task = screenshot only	0.03	0.03

the size of the BF); hypothesis 1 is more likely compared to hypothesis 2 for vividness, while the reverse is true for emotionality.

4. Discussion

According to WM theory, the voluntary eye movement component of EMDR is effective because keeping a memory in mind and making (endogenously generated) eye movements both tax the limited capacity of WM. As a result of this, the memory becomes less vivid and less emotional (Andrade et al., 1997; Gunter & Bodner, 2008) and is stored as such (van den Hout & Engelhard, 2012). In line with this theory, the results indicate that screenshot only was outperformed by both dual-task interventions in terms of reductions in self-rated memory vividness and emotionality. Self-reports are prone to demand bias, but studies using physiological measures and memory performance measures found similar results (see Leer et al., 2017). The finding adds to the evidence that the VR paradigm may provide a useful method of inducing negative memories (Cuperus et al., 2016, 2017). Furthermore, it seems that the dual-task conditions had the same impact on vividness, but that screenshot + dual-task led to greater decreases in emotionality.

It is unlikely that the difference between the dual-task conditions in terms of reductions in emotionality was caused by effects of habituation due to VR exposure, because periods of exposure were very short (Engelhard, van den Hout, Dek et al., 2011). A more probable explanation for the difference may lie in the finding that the dual-task we used is much more taxing than the eye movements that are typically used in the clinical practice of dual-task desensitization (Cuperus et al., 2016). That is, extremely taxing tasks may prevent the retrieval or maintenance of an image (Engelhard, van den Hout, & Smeets, 2011), which may have led to a slight underperformance of recall + dual-task. In the screenshot + dual-task condition, on the other hand, the image was constantly presented through the VR headset, which likely facilitates memory activation. Thus, whereas the link between taxing WM and the effect on memory vividness and emotionality may have the form of an inverted U for interventions with self-initiated memory recall (i.e., tasks being too taxing or not taxing enough both having little or no effect; Engelhard, van den Hout, & Smeets, 2011), this may not be the case for screenshot + dual-task, where memory recall may be more automatic. Instead, here the link may be linear, meaning that the more WM is taxed by carrying out a dual-task, the greater the effect on vividness and emotionality. Note that it is assumed that presenting a screenshot always captures attention and taxes WM. Such a finding could be useful in a clinical context, so further investigation of this hypothesis is warranted.

Aside from this possible benefit over recall-based interventions, a screenshot + dual-task approach might be clinically useful when patients show signs of avoidance behavior with respect to their traumatic memories during therapy. It would be interesting to test whether
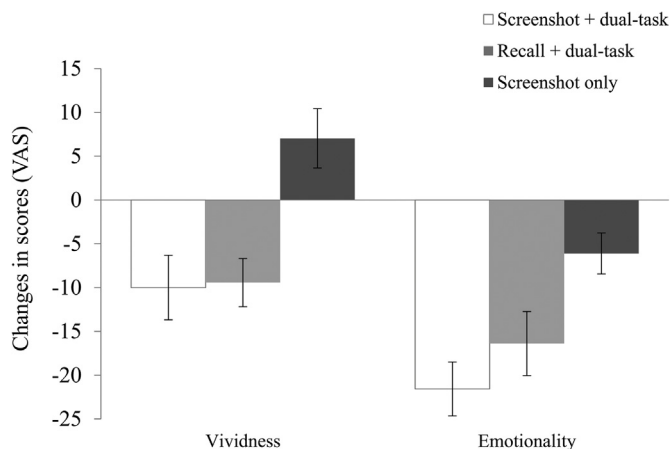

Fig. 2. Changes in vividness and emotionality for each intervention. The error bars represent standard errors of the difference scores.

avoidance moderates the effects of the interventions, and if individuals with strong avoidance tendencies benefit most from screenshot + dual-task. In practice, however, images of a traumatic event are usually not available, let alone three-dimensional VR images. Therefore, future studies should also investigate whether viewing (VR) images that trigger a negative/traumatic memory while carrying out a dual-task yields positive effects as well. This could be done in a group of patients or healthy participants with negative autobiographical memories, by letting them select triggering images (cf. the Virtual Iraq exposure therapy system; Rizzo, Reger, Gahm, Difede, & Rothbaum, 2009).

5. Conclusions

Taken together, we conclude that looking at an image in VR that represents a memory while carrying out a dual-task may be at least as effective as the recall variant. Interestingly, visually supporting a negative memory does not seem to prevent the beneficial effects of dual-task processing on an emotional memory. Further investigation of the practical utility of this approach is warranted and the idea that it might especially be efficacious for patients that show signs of avoidance behavior with respect to their traumatic memories during therapy requires further testing.

Conflicts of interest

None of the authors of this paper has a financial or personal relationship with other people or organizations that could inappropriately influence or bias the content of the paper.

Table 2
Mean vividness and emotionality scores (*SD*) before (pre-test) and after (post-test) the interventions.

	Screenshot + dual-task		Recall + dual-task		Screenshot only	
	Vividness	Emotionality	Vividness	Emotionality	Vividness	Emotionality
Pre-test	63.07 (18.17)	54.64 (20.89)	56.93 (14.12)	44.79 (23.75)	60.14 (22.72)	50.46 (23.24)
Post-test	53.07 (25.30)	33.07 (23.62)	47.50 (17.73)	28.39 (16.84)	67.18 (21.45)	44.36 (25.58)

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References

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, DC: American Psychiatric Press.

Andrade, J., Kavanagh, D., & Baddeley, A. (1997). Eye-movements and visual imagery: A working memory approach to the treatment of post-traumatic stress disorder. *British Journal of Clinical Psychology, 36*(2), 209–223. https://doi.org/10.1111/j.2044-8260.1997.tb01408.x.

Beck, J. G., Palyo, S. A., Winer, E. H., Schwagler, B. E., & Ang, E. J. (2007). Virtual reality exposure therapy for PTSD symptoms after a road accident: An uncontrolled case series. *Behavior Therapy, 38*(1), 39–48. https://doi.org/10.1016/j.beth.2006.04.001.

Béland, S., Klugkist, I., Raîche, G., & Magis, D. (2012). A short introduction into Bayesian evaluation of informative hypotheses as an alternative to exploratory comparisons of multiple group means. *Tutorials in Quantitative Methods for Psychology, 8*(2), 122–126. https://doi.org/10.20982/tqmp.08.2.p122.

Cuperus, A. A., Klaassen, F., Hagenaars, M. A., & Engelhard, I. M. (2017). A virtual reality paradigm as an analogue to real-life trauma: Its effectiveness compared with the trauma film paradigm. *European Journal of Psychotraumatology, 8*(sup1), 1–8. https://doi.org/10.1080/20008198.2017.1338106.

Cuperus, A. A., Laken, M., van den Hout, M. A., & Engelhard, I. M. (2016). Degrading emotional memories induced by a virtual reality paradigm. *Journal of Behavior Therapy and Experimental Psychiatry, 52*, 45–50. https://doi.org/10.1016/j.jbtep.2016.03.004.

Cusack, K., Jonas, D. E., Forneris, C. A., Wines, C., Sonis, J., Middleton, J. C., et al. (2016). Psychological treatments for adults with posttraumatic stress disorder: A systematic review and meta-analysis. *Clinical Psychology Review, 43*, 128–141. https://doi.org/10.1016/j.cpr.2015.10.003.

Engelhard, I. M., van Uijen, S. L., & van den Hout, M. A. (2010). The impact of taxing working memory on negative and positive memories. *European Journal of Psychotraumatology, 1*, 1–8. https://doi.org/10.3402/ejpt.v1i0.5623.

Engelhard, I. M., van den Hout, M. A., Dek, E. C., Giele, C. L., van der Wielen, J. W., Reijnen, M. J., et al. (2011). Reducing vividness and emotional intensity of recurrent "flashforwards" by taxing working memory: An analogue study. *Journal of Anxiety Disorders, 25*(4), 599–603. https://doi.org/10.1016/j.janxdis.2011.01.009.

Engelhard, I. M., van den Hout, M. A., & Smeets, M. A. (2011). Taxing working memory reduces vividness and emotional intensity of images about the Queen's Day tragedy. *Journal of Behavior Therapy and Experimental Psychiatry, 42*(1), 32–37. https://doi.org/10.1016/j.jbtep.2010.09.004.

Ganis, G., Thompson, W. L., & Kosslyn, S. M. (2004). Brain areas underlying visual mental imagery and visual perception: An fMRI study. *Cognitive Brain Research, 20*(2), 226–241. https://doi.org/10.1016/j.cogbrainres.2004.02.012.

Gerardi, M., Rothbaum, B. O., Ressler, K., Heekin, M., & Rizzo, A. (2008). Virtual reality exposure therapy using a virtual Iraq: Case report. *Journal of Traumatic Stress, 21*(2), 209–213. https://doi.org/10.1002/jts.20331.

Gunter, R. W., & Bodner, G. E. (2008). How eye movements affect unpleasant memories: Support for a working-memory account. *Behaviour Research and Therapy, 46*(8), 913–931. https://doi.org/10.1016/j.brat.2008.04.006.

Hoijtink, H. (2012). *Informative hypotheses. Theory and practice for behavioral and social scientists.* Boca Raton: Chapman & Hall/CRC.

Holmes, E. A., & Mathews, A. (2010). Mental imagery in emotion and emotional disorders. *Clinical Psychology Review, 30*(3), 349–362. https://doi.org/10.1016/j.cpr.2010.01.001.

van den Hout, M. A., & Engelhard, I. M. (2012). How does EMDR work? *Journal of Experimental Psychopathology, 3*(5), 724–738. https://doi.org/10.5127/jep.028212.

van den Hout, M. A., Engelhard, I. M., Smeets, M. A. A. M., Horsnveld, H., Hoogeveen, E., de Heer, E., et al. (2010). Counting during recall: Taxing of working memory and reduced vividness and emotionality of negative memories. *Applied Cognitive Psychology, 24*, 303–311. https://doi.org/10.1002/acp.1677.

van den Hout, M., Muris, P., Salemink, E., & Kindt, M. (2001). Autobiographical memories become less vivid and emotional after eye movements. *British Journal of Clinical Psychology, 40*(2), 121–130.

van den Hout, M. A., Rijkeboer, M. T., Engelhard, I. M., Klugkist, I., Hornsveld, H., & Toffolo, M. (2012). Tones inferior to eye movements in the EMDR treatment of PTSD. *Behaviour Research and Therapy, 50*, 275–279. https://doi.org/10.1016/j.brat.2012.02.001.

James, E. L., Lau-Zhu, A., Clark, I. A., Visser, R. M., Hagenaars, M. A., & Holmes, E. A. (2016). The trauma film paradigm as an experimental psychopathology model of psychological trauma: Intrusive memories and beyond. *Clinical Psychology Review, 47*, 106–142. https://doi.org/10.1016/j.cpr.2016.04.010.

Kass, R. E., & Raftery, A. E. (1995). Bayes factors. *Journal of the American Statistical Association, 90*(430), 773–795. https://doi.org/10.1080/01621459.1995.10476572.

Kearns, M., & Engelhard, I. M. (2015). Psychophysiological responsivity to script-driven imagery: An exploratory study of the effects of eye movements on public speaking flashforwards. *Frontiers in Psychiatry, 6*(115), 1–9. https://doi.org/10.3389/fpsyt.2015.00115.

Leer, A., Engelhard, I. M., Lenaert, B., Struyf, D., Vervliet, B., & Hermans, D. (2017). Eye movement during recall reduces objective memory performance: An extended replication. *Behaviour Research and Therapy, 92*, 94–105. https://doi.org/10.1016/j.brat.2017.03.002.

Morina, N., Ijntema, H., Meyerbröker, K., & Emmelkamp, P. M. (2015). Can virtual reality exposure therapy gains be generalized to real-life? A meta-analysis of studies applying behavioral assessments. *Behaviour Research and Therapy, 74*, 18–24. https://doi.org/10.1016/j.brat.2015.08.010.

Mulder, J., Hoijtink, H., & de Leeuw, C. (2012). BIEMS: A fortran 90 program for calculating Bayes factors for inequality and equality constrained models. *Journal of Statistical Software, 46*(2), 1–39. https://doi.org/10.18637/jss.v046.i02.

Opriş, D., Pintea, S., García-Palacios, A., Botella, C., Szamosközi, Ş., & David, D. (2012). Virtual reality exposure therapy in anxiety disorders: A quantitative meta-analysis. *Depression and Anxiety, 29*(2), 85–93. https://doi.org/10.1002/da.20910.

Parsons, T. D., & Rizzo, A. A. (2008). Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: A meta-analysis. *Journal of Behavior Therapy and Experimental Psychiatry, 39*(3), 250–261. https://doi.org/10.1016/j.jbtep.2007.07.007.

Powers, M. B., & Emmelkamp, P. M. (2008). Virtual reality exposure therapy for anxiety disorders: A meta-analysis. *Journal of Anxiety Disorders, 22*(3), 561–569.

Rizzo, A., Reger, G., Gahm, G., Difede, J., & Rothbaum, B. (2009). Virtual reality exposure therapy for combat-related PTSD. In J. LeDoux, T. Keane, & P. Shiromani (Eds.). *Posttraumatic stress disorder* (pp. 375–399). New York: Humana Press. https://doi.org/10.1007/978-1-60327-329-9_18.

Rothbaum, B. O., Hodges, L. F., Ready, D., Graap, K., & Alarcon, R. D. (2001). Virtual reality exposure therapy for Vietnam veterans with posttraumatic stress disorder. *Journal of Clinical Psychiatry, 62*(8), 617–622. https://doi.org/10.4088/jcp.v62n0808.

Shapiro, F. (1989). Eye movement desensitization: A new treatment for posttraumatic stress disorder. *Journal of Behavior Therapy and Experimental Psychiatry, 20*(3), 211–217.

Shapiro, F. (2001). *Eye movement desensitization and reprocessing: Basic principles, protocols, and procedures* (2nd ed.). New York: Guilford.

Smeets, M. A. M., Dijs, M. W., Pervan, I., Engelhard, I. M., & van den Hout, M. A. (2012). Time course of eye movement-related decrease in vividness and emotionality of unpleasant autobiographical memories. *Memory, 20*(4), 346–357. https://doi.org/10.1080/09658211.2012.665462.

Tadmor, A., McNally, R. J., & Engelhard, I. M. (2016). Reducing the negative valence of stressful memories through emotionally valenced, modality-specific tasks. *Journal of Behavior Therapy and Experimental Psychiatry, 53*, 92–98. https://doi.org/10.1016/j.jbtep.2014.11.001.

Visser, R. M., Lau-Zhu, A., Henson, R. N., & Holmes, E. A. (2018). Multiple memory systems, multiple time points: How science can inform treatment to control the expression of unwanted emotional memories. *Philosophical Transactions of the Royal Society B, 373*(1742), 1–15. https://doi.org/10.1098/rstb.2017.0209.

Watts, B. V., Schnurr, P. P., Mayo, L., Young-Xu, Y., Beeks, W. B., & Friedman, M. J. (2013). Meta-analysis of the efficacy of treatments for posttraumatic stress disorder. *Journal of Clinical Psychiatry, 74*(6), e541–e550. https://doi.org/10.4088/jcp.12r08225.