

# The impact of taxing working memory on negative and positive memories

Iris M. Engelhard\*, Sophie L. van Uijen and Marcel A. van den Hout

Clinical and Health Psychology, Utrecht University, Utrecht, The Netherlands

**Background:** Earlier studies have shown that horizontal eye movement (EM) during retrieval of a negative memory reduces its vividness and emotionality. This may be due to both tasks competing for working memory (WM) resources. This study examined whether playing the computer game “Tetris” also blurs memory.

**Method:** Participants recalled negative and positive memories in three conditions: recall only, recall with concurrent EM, and recall with playing Tetris. Before and after these conditions, vividness, emotionality, and physiological startle responses during recall were measured.

**Results:** A reaction time task showed that EM and Tetris both draw on WM, compared to no dual-task. Compared to recall only, EM and Tetris decreased reported emotionality and startle responses.

**Conclusions:** The effects of EM and Tetris did not differ, even though the tasks differed in the degree of taxing WM. This suggests that taxing WM and its effects on emotional memories may not be linearly related. Potential clinical implications are discussed.

Keywords: *Intrusive memory; EMDR; working memory; PTSD*

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Intrusive memories are considered a hallmark symptom of post-traumatic stress disorder (PTSD; APA, 1994) but also occur in other disorders like agoraphobia, social phobia, depression, bulimia nervosa, and psychosis (see Hackman & Holmes, 2004). Studies suggest that such memories typically take the form of vivid visual images (see Holmes & Bourne, 2008). Eye movement desensitisation and reprocessing (EMDR) targets vivid and negative emotional memories and has been shown to be an effective treatment for PTSD (e.g., Bisson et al., 2007). EMDR uses a dual-attention approach (Maxfield, Melnyk, & Hayman, 2008; Shapiro, 2001) in which the client imagines the traumatic event (along with related cognitions and emotions) while attending to an external stimulus. The latter typically involves visually tracking the therapist’s finger moving from side to side across the visual field, thus inducing horizontal eye movement (EM). The EM sets are

repeated until distress evoked by the memory has become negligible, and then the client replaces a negative cognition related to the memory with a positive one. It has been questioned whether the EM component of EMDR adds to the effects of the total EMDR protocol, but a recent meta-analysis suggests that it does (Lee & Cuijpers, 2010). These clinical data agree with findings from well-controlled laboratory-based studies showing that EM during recall of a distressing memory reduces image vividness and emotional intensity, compared to recall alone (see Engelhard, van den Hout, Janssen, & van der Beek, 2010; van den Hout et al., 2010). These effects raise questions about the mechanism: why is horizontal EM effective?

There is much experimental support for a working memory (WM) explanation of EM’s effectiveness. The WM model describes elements involved in the short-term processing of information (Baddeley, 1998). The

central executive is an attentional system that controls the actions of two subsystems: the visuospatial sketchpad which stores visual and spatial information, and the phonological loop which stores speech-based information. WM has a limited capacity, so two simultaneous taxing tasks will compete for limited-capacity resources, which will degrade performance. A WM explanation of the horizontal EM effects posits that EM and visual imagery compete selectively for limited-capacity visuospatial (see Andrade, Kavanagh, & Baddeley, 1997) and central executive (see Gunter & Bodner, 2008) resources. This will impair imagery, such that images become less vivid and emotional.

The theory implies that other (non-horizontal EM) dual-tasks that tax WM during memory recall will also reduce image vividness and emotional intensity. This is confirmed by studies showing efficacy of vertical EM (Gunter & Bodner, 2008), drawing a complex figure (Gunter & Bodner, 2008), mental arithmetic (Engelhard, van den Hout, & Smeets, 2011; van den Hout et al., 2010), and verbal arithmetic (Kemps & Tigge mann, 2007a). A simple spatial tapping task does not have benefits (van den Hout, Muris, Salemink, & Kindt, 2001), but a more complex task does (Andrade et al., 1997), which has been attributed to the latter requiring more WM resources (Gunter & Bodner, 2008). According to the theory, EM should not only affect vivid episodic memories for negative events, but *future*-oriented images about potential catastrophes (flash-forwards) as well. Again, this is confirmed (Engelhard et al., 2010). The theory describes general task load effects on visual imagery and additional modality-specific effects, such that visual imagery is impaired more by visual dual-tasks than by an auditory or verbal dual-task and the opposite for auditory images. This is also supported by experimental data (Baddeley & Andrade, 2000; Kemps & Tigge mann, 2007a).

The WM theory implies a dose-response relationship: the more demanding the task, the stronger the memory effects. Two studies examined such a dose-response relationship using a mental arithmetic manipulation. Van den Hout et al. (2010) first established that no dual-task, simple arithmetic, and complex arithmetic tax WM increasingly by using a visuospatial reaction time (RT) task. They then found that simple and complex arithmetic during recall had similar effects, relative to recall alone. The authors suggested that the complex task may have been too taxing to produce greater effects. Extremely taxing tasks may prevent the retrieval of the image or keeping it in mind, thus reducing effects. Similarly, Engelhard et al. (2011) used a RT task to establish that no dual-task and three mental arithmetic conditions tax WM increasingly, and found that the memory effects of taxing tend to drop when WM is “over-taxed.” It is unclear whether these arithmetic tasks tax central executive as well as visual WM resources. The

theory predicts that a visuospatial task that is more demanding than the usual horizontal EM manipulation is more effective. There is tentative support for this. Maxfield et al. (2008) assumed that fast EM is more taxing than slower EM and found that it produced less vividness/emotionality of negative memories. They did not, however, empirically assess whether fast EM really is more demanding. Gunter and Bodner (2008) compared EM, drawing a figure, and auditory shadowing; EM and shadowing produced similar decreases in memory ratings and the drawing task produced larger decreases. The authors suggest that the drawing task is more demanding but did not assess this. Thus, it is still unclear whether a visuospatial task that is more taxing than EM really is more effective.

One particularly interesting visuospatial task is playing the computer game “Tetris.” Tetris is quite demanding because it requires the player to decide if particular rotations of geometrical shapes are needed, and to actually carry out such rotations under time pressure. Accordingly it has the potential to have particularly large effects on emotional memories. To our knowledge, Tetris has not been used as a dual-task during memory reconsolidation. However, it has been shown to be effective during memory consolidation: Holmes, James, Coode-Bate, and Deeprose (2009) showed that playing Tetris shortly after viewing a film with traumatic material reduces unwanted, involuntary memory flashbacks of the film in the subsequent week. It remains to be seen whether Tetris is effective during memory reconsolidation as well.

There are some limitations of these prior studies. First, nearly all EM studies have focused on negative memories. Van den Hout et al. (2001) provide initial evidence that EM also affects positive memories, as WM models would predict, but did not assess whether EM taxes WM. This issue is clinically relevant, since EMDR includes a reinstatement of a positive cognition *during* EM (or other forms of bilateral stimulation). If this dual-task approach reduces vividness/emotionality of positive material, it may not be useful. On the other hand, positive/appetitive images appear to feature in some disorders, like bipolar disorder and addictions/craving (see Brewin, Gregory, Lipton, & Burgess, 2010). In such disorders, dual-tasks like EM may be beneficial (see May, Andrade, Panabokke, & Kavanagh, 2010). Second, nearly all prior studies have relied on self-reported vividness/emotionality, using visual analogue scales (VASs), which may be prone to demand characteristics. More objective measures are needed. A potential measure of interest is the fear-potentiated startle reflex, which is modulated by aversive state and arousal (Grillon & Baas, 2003). Miller, Patrick, and Levenston (2002) showed that for personalized emotional scripts about past experiences, startle responses were augmented during imagery of arousing pleasant and unpleasant experiences, compared

to neutral experiences. It can, therefore, be expected that startle responses will be reduced when image vividness and emotionality reduce.

The aim of this study was to replicate the effects of EM on negative memories and extend prior studies in three ways: (1) besides negative memories, we also focused on positive ones; (2) besides self-report ratings of vividness and emotionality, we used fear-potentiated startle responses; and (3) besides EM, we included a “Tetris” condition. Using an auditory RT task, we first established that EM and Tetris tax WM, compared to no dual-task. Then the memory experiment was conducted in which participants recalled negative or positive memories in three conditions: Recall only, Recall with EM, or Recall with Tetris. Before and afterwards they recalled the memory to collect vividness/emotionality ratings and startle responses. We expected that (1) EM and Tetris would tax WM, relative to no dual-task; and (2) EM and Tetris during image recall would decrease vividness, emotionality, and startle responses, relative to recall alone.

## Method

### Participants

Sixty students (34 females) from Utrecht University with a mean age of 21.9 ( $SD = 3.5$ ) participated for course credit or a financial reward. Exclusion criteria were prior knowledge about EMDR, current psychiatric disorder, hearing impairment, uncorrected visual impairment, and use of medication that might influence attention or memory.

### Materials

Participants were seated about 60 cm in front of a computer screen. In the Recall only and EM conditions, E-Prime 1.2 software was used to present a fixation point. In Recall only, a stationary white dot was shown in the middle of a black background, and in EM, the white dot moved from left to right and back across the black screen, at one cycle per s. Participants were told to watch the dot. Tetris was played using TetrisZone 1.2.1 (0075; Tetris Holding, 2007, downloaded from <http://www.tetris.com>), “Marathon” version, and started at level 1, normal game play. The RT task was presented and recorded using Presentation 14.2 software on a second monitor. Auditory stimuli (beeps) were presented through headphones. Vividness and emotionality were rated on 0–100 VASs (from “not at all” to “extremely”) in E-Prime. Eyeblink startle responses were measured by recording EMG activity from the orbicularis oculi beneath the left eye, to loud tones [50 ms, 95 db(A)] which were presented through headphones, with instant rise and fall time. During an 11-s interval, three probes were presented with an interstimulus interval (ISI) from 2- to 4-s. Each

participant received 24 probes (six before the experiment and three in each pre/post-test; see procedure below).

### Startle EMG recording and quantification

Electrode placement for measurement of startle responses followed published guidelines (Blumenthal et al., 2005). Raw EMG activity was recorded using 2 Ag/AgCl electrodes (4 mm sensor) placed over the orbicularis oculi region of the left eye. A third electrode in the middle of the forehead served as a ground. The EMG signal was amplified (10 K) using a Coulbourn V75-04 Isolated Bioamplifier with Bandpass Filter, using 13 Hz high-pass and 150 Hz low-pass filters, sampled at 1,000 Hz for 240 ms, and processed using Startle Analyser 10.20 software. The baseline period was from 40 ms before onset to 10 ms after onset of the probe. Startle magnitude was defined as the amplitude of the first peak in the recorded signal, within 15–75 ms latency window. Peak blink amplitudes were corrected for the baseline. Of the three startle responses, the second and third of each pre/post-test were averaged due to a large response to the first probe, which was insensitive to modulation. The ISIs differed slightly between conditions, but this did not affect the magnitude of these startle amplitudes.

### Procedure

After obtaining informed consent, the EM, Tetris, and control condition (eyes stationary) were introduced and shown. All participants were familiar with Tetris; they were shown which keys to use, told to play with their dominant hand, and “*Try to play as well as you can. If the game is over, it will be restarted.*” After a practise trial for each condition, the RT task was administered. It comprised categorising 34 high and 34 low 1-s beeps by responding with “high” or “low” as fast as possible. Beeps were presented in semi-random order, with no more than four consecutive presentations of the same beep. After a practise trial, the RT was carried out in the three conditions in a random counterbalanced order for 3 min each.

In the memory experiment, participants were asked to recall three *negative* occasions that had made them feel very fearful or distressed, like going to an exam unprepared or witnessing an accident, or three *positive* occasions that had made them feel very happy, like passing an important test or hearing good news, and still had some emotional impact (cf. van den Hout et al., 2001). They were asked to form an image of each occasion, write down a label to identify it, and rate how emotional it was on a 0–10 scale (0 = not emotional at all, 10 = extremely emotional). All memories were rated at least 4, and they were ranked in terms of emotionality. The order of conditions and assigned

memories to conditions was counterbalanced within each memory valence group. Then the EMG electrodes were applied, and six probes were presented with a 2-s ISI to enhance habituation.

Three phases followed. In phase 1, participants were given a memory label, and were instructed: “*Form an image of the memory, 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.*” They were instructed to press the space bar when the memory was vivid and to keep it in mind for 11s. During this time, three startle probes were presented. Participants had been told to try to ignore the probes as much as possible. Next, participants rated vividness, emotionality, and difficulty recalling the memory. In phase 2, participants were told to retrieve and imagine the memory while keeping their eyes stationary (Recall only), making EM (Recall+EM), or playing Tetris (Recall+Tetris). Each condition comprised four sets of 24s, with 10-s breaks in-between. Phase 3 was identical to phase 1. There were brief breaks between the phases, in which instructions were given. Finally, EMG electrodes were removed. Participants were debriefed and given their reward.

#### Data reduction and analysis

Outliers were changed into  $M \pm 2.5 SD$ . Two participants had missing EMG data. EMG data and vividness of positive memories were transformed by square root to a normal distribution. First, to assess whether EM and Tetris tax WM, relative to no dual-task, RTs were compared with non-parametric tests, as  $SD$  increased with task complexity. Second, to assess whether the dual-tasks affect memory,  $2 \times 3$  repeated measures ANOVAs were performed with Time (pre-test, post-test) and Condition (Recall only, EM, Tetris) as within-subjects factors. Dependent variables were vividness, emotionality, and startle responses. Finally, correlations were computed between RTs and changes in vividness, emotionality, and startle responses. Positive and negative memories were analysed separately. Alpha was 0.05. When the direction of differences was predicted, one-tailed  $p$  values are reported.

**Table 1.** Means (SD) of vividness and emotionality ratings before and after recall only, recall with eye movements (EM), and recall with Tetris for negative and positive memories

		Recall only		Recall+EM		Recall+Tetris	
		Vividness	Emotionality	Vividness	Emotionality	Vividness	Emotionality
Negative	Pre	62.5 (14.8)	55.7 (18.6)	62.5 (14.3)	61.5 (14.1)	62.0 (15.1)	58.7 (17.4)
	Post	63.1 (13.3)	58.9 (18.2)	60.8 (15.0)	58.2 (14.6)	62.6 (14.8)	55.9 (18.1)
Positive	Pre	62.9 (19.1)	60.2 (19.3)	64.9 (19.1)	60.5 (19.3)	66.0 (19.5)	60.2 (22.6)
	Post	67.7 (18.4)	65.3 (21.2)	65.9 (20.4)	57.8 (22.0)	63.3 (22.1)	61.9 (20.9)

## Results

### Manipulation check

The RTs differed between the conditions, Friedman’s  $H(2) = 76.79$ ;  $p < 0.001$  (Fig. 1). Wilcoxon tests showed that all conditions differed from one another, with the three conditions taxing WM in a dose-dependent way, smallest  $z = 5.03$ ;  $p < 0.001$ : RT only < EM < Tetris. The number of non-responses also differed, Friedman’s  $H(2) = 19.66$ ;  $p < 0.001$ . The RT task only and EM did not differ, but RT task only and EM both differed from Tetris, smallest  $z = 2.36$ ;  $p < 0.05$ .

### Memory experiment

Of the negative memories, 45% described a loss event (e.g., loss of loved one), 26% a threatening event (e.g., an accident, being threatened), and 29% another type of event (e.g., financial problems). Of the positive memories, 46% described a fun event (e.g., party, festival), 32% hearing good news (e.g., passing exam, getting a job), 19% a love event (e.g., first kiss, reunion with a relative), and 3% moving (e.g., moving out, going abroad). Table 1 displays means ( $SD$ ) of vividness/emotionality ratings before and after the three conditions. At the pre-test, the conditions did not significantly differ in easiness of recall, vividness, emotionality, and startle responses, all  $F(2,56) < 1$ .

First, the analyses are reported for *negative* memories. For vividness ratings, there were no significant main effects for Time,  $F(1,29) < 1$ , and Condition,  $F(2,58) < 1$ , and the Time  $\times$  Condition interaction was not significant either,  $F(2,58) < 1$ . This indicates that the three conditions did not affect image vividness differently. For emotionality ratings, there were also no significant main effects for Time,  $F(1,29) < 1$ , and Condition  $F(2,58) < 1$ , but the crucial Time  $\times$  Condition interaction was significant,  $F(2,58) = 2.90$ ;  $p < 0.05$ ,  $\eta_p^2 = 0.18$ . As Fig. 2 shows, emotionality increased over time for Recall only,  $t(29) = 2.36$ ;  $p < 0.05$ , while, relative to Recall only, emotionality decreased for Recall+EM,  $t(29) = 2.15$ ;  $p < 0.05$  and for Recall+Tetris,  $t(29) = 1.86$ ;  $p < 0.05$ . EM and Tetris effects did not differ,  $t(29) < 1$ .

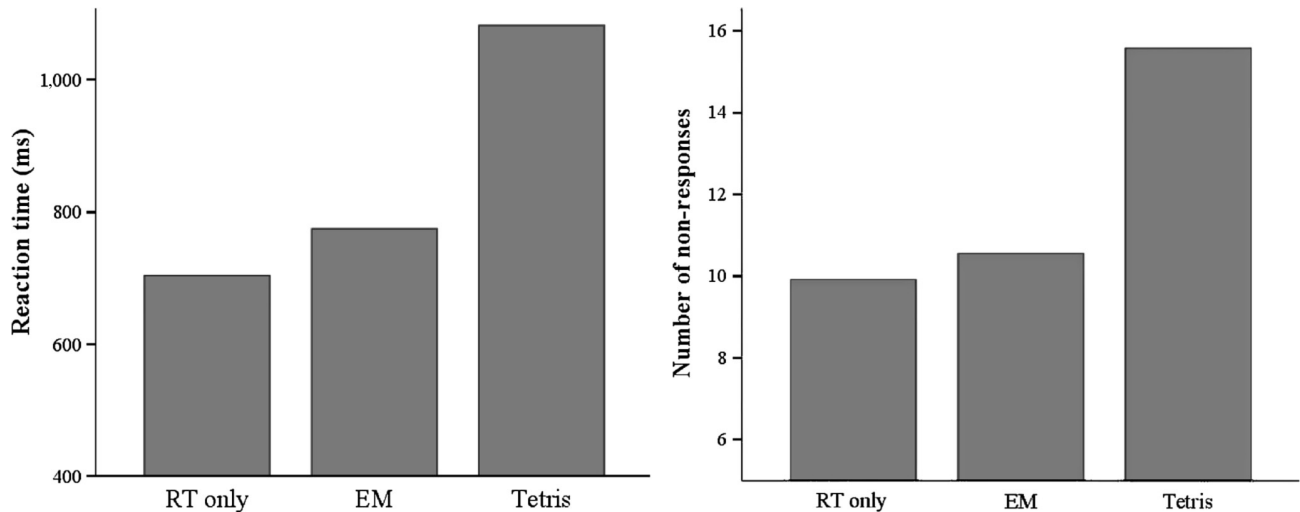


Fig. 1. Mean reaction time (RT) in ms and number of non-responses for RT task only, eye movement (EM), and Tetris conditions.

Regarding startle responses, there were no main effects for Time,  $F(1,27) < 1$ , and Condition,  $F(2,54) < 1$ , but, again, the crucial Time  $\times$  Condition interaction was significant,  $F(2,54) = 3.52$ ,  $p < 0.05$ ,  $\eta_p^2 = 0.12$ . As Fig. 3 illustrates, Recall only showed an increase in startle responses, but this was not significant. Relative to Recall only, Tetris showed a significant decrease,  $t(28) = 2.79$ ;  $p < 0.05$ , but EM did not  $t(27) < 1$ . Change scores did not differ between EM and Tetris,  $t(27) < 1$ .

In connection with *positive memories*, vividness showed no main effects for Time,  $F(1,29) < 1$ , and Condition,  $F(1.47,42.60) < 1$ , but the crucial Time  $\times$  Condition interaction was significant,  $F(2,58) = 2.85$ ;  $p < 0.05$ ,  $\eta_p^2 = 0.09$ . Recall only showed a significant increase in vividness compared to EM,  $t(29) = 2.04$ ;  $p < 0.05$ , and Tetris showed a significant decrease compared to Recall only,  $t(29) = 1.83$ ;

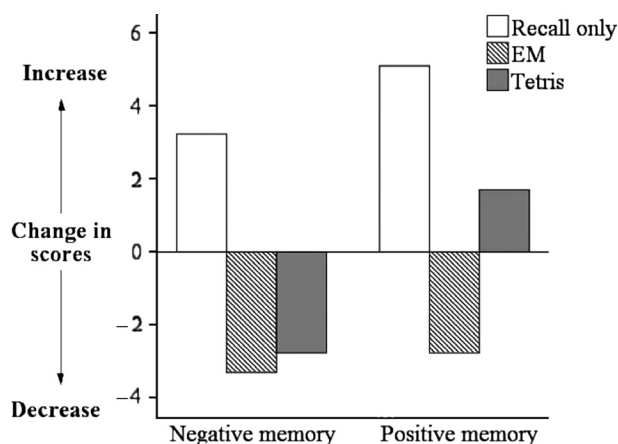


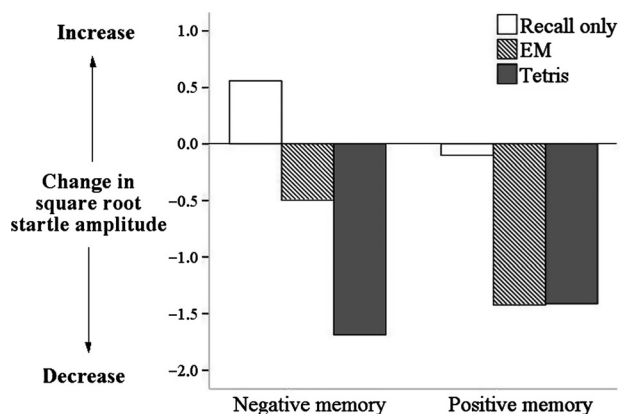
Fig. 2. Changes in emotionality of negative and positive memories in the three conditions.

$p < 0.05$ . The effects between EM and Tetris did not differ significantly,  $t(29) < 1$ .

For emotionality, there were no main effects for Time,  $F(1,29) < 1$ , and Condition,  $F(1.56,45.27) < 1$ , but there was a trend for the Time  $\times$  Condition interaction,  $F(1.48,43.01) = 2.46$ ;  $p = 0.06$ ,  $\eta_p^2 = 0.08$ . Fig. 2 shows an increase in emotionality for Recall only, but this was not significant,  $t(29) < 1$ . Relative to Recall only, emotionality scores tended to decrease for EM,  $t(29) = 2.12$ ;  $p < 0.05$ , but not for Tetris,  $t(29) < 1$ . The difference between EM and Tetris was not significant,  $t(29) = 1.88$ ;  $p = 0.07$ .

Regarding startle responses, there was a main effect for Time,  $F(1,29) = 7.26$ ,  $p < 0.05$ ,  $\eta_p^2 = 0.20$ ; but not for Condition,  $F(2,58) < 1$ ; and the crucial Time  $\times$  Condition interaction was significant,  $F(2,54) = 3.52$ ,  $p < 0.05$ ,  $\eta_p^2 = 0.12$ . Relative to Recall only, startle responses tended to decrease for EM,  $t(29) = 1.78$ ;  $p < 0.05$  and for Tetris,  $t(29) = 1.64$ ;  $p = 0.06$  (Fig. 3). These decreases did not differ between EM and Tetris,  $t(29) < 1$ .

Finally, correlations were computed between RTs (indicating degree of taxing WM) and post minus pre-test scores in memories. For EM, RTs correlated significantly with emotionality of negative memories,  $r = -0.43$ ;  $p < 0.05$ , after removal of one outlier, and positive memories,  $r = -0.51$ ;  $p < 0.01$ , such that a higher RT (more slowing down due to EM) was related to a larger decrease in emotionality, as WM theory would predict. For Tetris, RTs correlated significantly with vividness for negative memories, but in the opposite direction,  $r = 0.53$ ;  $p < 0.05$ , such that the more the slowing down due to Tetris, the less reduction in vividness. Other correlations were not significant (largest  $r = 0.33$ ,  $p = 0.11$ , between RTs Tetris and changes in startle responses).



**Fig. 3.** Changes in square root startle amplitudes for negative and positive memories and three conditions.

## Discussion

The main findings can be summarised as follows. First, using an auditory RT task, we found that EM and Tetrts both tax WM, as evidenced by increased RTs compared to no dual-task. Tetrts resulted in larger RTs than EM. Second, for negative memories, EM and Tetrts during memory recall decreased emotionality but not vividness, and Tetrts also reduced startle responses compared to Recall only. The effects on emotionality and startle responses did not differ between EM and Tetrts. Third, for positive memories, EM and Tetrts decreased startle responses compared to Recall only. In addition, EM decreased emotionality but Tetrts did not, and Tetrts decreased vividness but EM did not. Again, the effects on vividness, emotionality, and startle responses did not differ between EM and Tetrts.

The effects of EM on negative memories are in line with findings of many prior studies (see van den Hout et al., 2010), and its effects on *positive* memories are consistent with at least one prior study (van den Hout et al., 2001). Tetrts' effectiveness fits nicely with studies showing that non-EM dual-tasks reduce vividness/emotionality of negative autobiographical memories (e.g., verbal arithmetic, Kemps & Tiggemann, 2007a; drawing a complex figure, Gunter & Bodner, 2008; mental arithmetic, van den Hout et al., 2010; Engelhard et al., 2011), and with the study of Holmes et al. (2009) who used Tetrts during memory consolidation. It also fits with WM theory which suggests that any secondary task that uses up WM resources during memory recall reduces vividness and emotionality of emotional memories. The correlational analyses showed that more taxing of WM during EM was associated with more reductions in emotionality, but it should be noted that there was no effect for vividness.

The effects of EM and Tetrts on negative and positive memories did not differ, even though Tetrts taxed WM to

a greater extent than EM. This is inconsistent with studies showing additional effects of fast EM compared to slow or no EM (Maxfield et al., 2008), and of copying a complex figure compared to EM (Gunter & Bodner, 2008). However, these studies did not measure taxing of WM. As stated in the introduction, the studies of van den Hout et al. (2010) and Engelhard et al. (2011) suggest that the link between taxing WM and its effects may not be linear. Van den Hout et al. (2010) found that complex mental arithmetic taxed WM to a greater degree than simple arithmetic, but did not show extra effects on memory vividness/emotionality. The authors suggested that the complex task may have been too taxing to produce extra benefits. In fact, effects may diminish when taxing becomes too extreme (Engelhard et al., 2011). The same may hold true in the present study for Tetrts. The positive correlation between the extent to which Tetrts taxed WM and reductions in vividness is in line with such an explanation: more slowing down due to Tetrts was related to less reduction in vividness.

An unexpected finding was that EM and Tetrts did not affect *vividness* of negative memories, although several studies have shown decreases in vividness after EM and other distracting tasks during recall. It is unclear why these effects were not replicated, but it should be noted that some other studies also found effects for emotional intensity but not for vividness (or vice versa; see Engelhard et al., 2011).

The decrease in startle responses after EM and Tetrts compared to Recall only suggests that the effects of drawing on WM during retrieval are not only due to demand characteristics. An earlier study also showed that EM, compared to no-EM, during recall of a negative memory reduced electrodermal arousal (Barrowcliff, Gray, Freeman, & MacCulloch, 2004), a more general measure of emotionality. However, Merckelbach, Hogervorst, Kampman, and de Jongh (1994, exp. 2, cited in Muris & Merckelbach, 1999) did not find effects of EM on facial EMG activity in the corrugator muscle. It is unclear how this might be reconciled with the present findings regarding eyeblink startle responses. Besides these different physiological indices, other methodological differences limit a comparison: Merckelbach and colleagues focused on memories about a shameful situation, whereas the current study focused on threatening/distressing memories.

For negative memories, there was a decrease in startle responses after Tetrts but not after EM, although the decrease in emotionality for these conditions was similar. This may reflect the fact that physiological responses and subjective self-reports are loosely coupled, and that negative memories may to some degree still have been aversive and arousing, which potentiates startle responses (Grillon & Baas, 2003).

There were limitations of the current study. First, the findings suggest that eyeblink startle responses may be useful in providing a more objective indicator of changes in memory, but the procedure of collecting the startle data was not optimal as only a few probes were included. Future research may provide a more reliable procedure (using more probes). Second, it is unclear whether the effects of Tetris were (partly) caused by a positive mood after the computer game. Third, we focused on relatively short-term effects: the post-test took place after each condition but within one experimental session. Long-term effects of EM have been found (e.g., one week; Gunter & Bodner, 2008, exp. 2) and deserve more attention. Finally, this study included a non-clinical sample, and generalisability of the findings to a clinical population also awaits future research.

Nevertheless, there are potential clinical implications of the findings. This study adds to other research showing that EM during image recall is not the only way to reduce image vividness/emotionality, and suggests that any taxing task may be superior to a non-taxing task. Degree of WM taxing in the EM condition was related to more effects. This implies that people with a higher WM capacity should benefit from more demanding dual-tasks. It seems important to adjust the degree of WM taxing to an individual patient, and there appear to be no theoretical or empirical reasons to use EM rather than other taxing tasks. Depending on the patient, more complex tasks may be used. Moreover, in the EMDR protocol positive cognitions are installed, and while the patient tries to concentrate on such cognitions, the therapist uses a secondary task like EM. This may undermine the intervention. Finally, the findings on positive memories, together with the earlier ones that EM affects flash-forwards as well as flashbacks (Engelhard et al., 2010), suggest that EM and related procedures may be useful in the treatment of problematic appetitive thoughts or images (e.g., during drug-craving, in bipolar disorder, etc.; APA, 1994; Brewin et al., 2010). There is indeed evidence that a visual or olfactory imagery task reduces craving for food (Kemps & Tiggemann, 2007b), and a visual imagery task reduces craving for cigarettes (May et al., 2010).

In summary, this study found that EM and playing Tetris draw on WM, and decrease vividness and/or emotional intensity of emotionally arousing memories during recall (Baddeley & Andrade, 2000). The effects of EM and Tetris did not differ even though the tasks differed in degree of WM taxing, which suggests that the taxing of WM and its effects may not be linearly related.

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## References

- American Psychiatric Association. (1994). *Diagnostic and statistical manual of the mental disorders*. Washington, DC: Author.
- 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*, 209–223.
- Baddeley, A. D. (1998). *Human memory: Theory and practice*. Needham Heights, MA: Allyn & Bacon.
- Baddeley, A., D., & Andrade, J. (2000). Working memory and the vividness of imagery. *Journal of Experimental Psychology: General, 129*, 126–145.
- Barrowcliff, A. L., Gray, N. S., Freeman, T. C. A., & MacCulloch, M. J. (2004). Eye movements reduce the vividness, emotional valence and electrodermal arousal associated with negative autobiographical memories. *Journal of Forensic Psychiatry and Psychology, 15*, 325–345.
- Bisson, J. I., Ehlers, A., Matthews, R., Pilling, S., Richards, D., & Turner, S. (2007). Psychological treatments for chronic post-traumatic stress disorder: Systematic review and meta-analysis. *British Journal of Psychiatry, 190*, 97–104.
- Blumenthal, T. D., Cuthbert, B. N., Filion, D. L., Hackley, S., Lipp, O. V., & Van Boxtel, A. (2005). Committee report: Guidelines for human startle eyeblink electromyographic studies. *Psychophysiology, 42*, 1–15.
- Brewin, C. R., Gregory, J. D., Lipton, M., & Burgess, N. (2010). Intrusive images in psychological disorders: Characteristics, neural mechanisms, and treatment implications. *Psychological Review, 117*, 210–232.
- Engelhard, I. M., van den Hout, M. A., Janssen, W. C., & van der Beek, J. (2010). Eye movements reduce vividness and emotionality of images about feared future events. *Behaviour Research and Therapy, 48*, 442–447.
- Engelhard, I. M., van den Hout, M. A., & Smeets, M. A. M. (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*, 32–37. DOI:10.1016/j.jtep.2010.09.004.
- Grillon, C., & Baas, J. (2003). A review of the modulation of the startle reflex by affective states and its application in psychiatry. *Clinical Neurophysiology, 114*, 1557–1579.
- Gunter, R. W., & Bodner, G. E. (2008). How eye movements affect unpleasant memories: Support for a working-memory account. *Behaviour Research and Therapy, 46*, 913–931.
- Hackman, A., & Holmes, E. (2004). Reflecting on imagery: A clinical perspective and overview of the special issue of memory on mental imagery and memory in psychopathology. *Memory, 12*, 389–402.
- Holmes, E. A., & Bourne, C. (2008). Inducing and modulating intrusive emotional memories: A review of the trauma film paradigm. *Acta Psychologica, 127*, 553–566.
- Holmes, E. A., James, E. L., Coode-Bate, T., & Deerprouse, C. (2009). Can playing the computer game "Tetris" reduce the build-up of flashbacks or trauma? A proposal from Cognitive Science. *PLoS ONE, 4*, 1–6.
- Kemps, E., & Tiggemann, M. (2007a). Reducing the vividness and emotional impact of distressing autobiographical memories: The importance of modality-specific interference. *Memory, 15*, 412–422.
- Kemps, E., & Tiggemann, M. (2007b). Modality-specific imagery reduces cravings for food: An application of the elaborated intrusion theory of desire to food craving. *Journal of Experimental Psychology: Applied, 13*, 95–104.

- Lee, C. W., & Cuijpers, P. (2010). A meta-analysis of the contribution of eye movements in processing emotional memories. Manuscript submitted for publication.
- May, J., Andrade, J., Panabokke, N., & Kavanagh, D. (2010). Visuospatial tasks suppress craving for cigarettes. *Behaviour Research and Therapy*, 48, 476–485.
- Maxfield, L., Melnyk, W. T., & Hayman, C. A. G. (2008). A working memory explanation for the effects of eye movements in EMDR. *Journal of EMDR Practice and Research*, 2, 247–261.
- Merckelbach, H., Hogervorst, E., Kampman, M., & de Jongh, A. (1994). Eye-movement desensitization heeft geen effect of emotionele reactiviteit van 'normale' proefpersonen. [Eye-movement desensitization has no effect on emotional reactivity of 'normal' subjects]. *Gedragstherapie*, 27, 33–49.
- Miller, M. W., Patrick, C. J., & Levenston, G. K. (2002). Affective imagery and the startle response: Probing mechanisms of modulation during pleasant scenes, personal experiences, and discrete negative emotions. *Psychophysiology*, 39, 519–529.
- Muris, P., & Merckelbach, H. (1999). Traumatic memories, eye movements, phobia, and panic: A critical note on the proliferation of EMDR. *Journal of Anxiety Disorders*, 13, 209–223.
- Shapiro, F. (2001). *Eye movement desensitization and reprocessing: Basic principles, protocols, and procedures*. New York: Guilford Press.
- Tetris® & © TETRIS game and tetris.com, zone.tetris.com © 2007 Tetris Holding, LLC Game Design by Alexey Pajitnov. The Tetris game is a registered trademark of Tetris Holding, LLC and was obtained from Blue Planet Software (Honolulu, HI).
- Van den Hout, M. A., Engelhard, I. M., Smeets, M. A. M., Hornsveld, 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.
- 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, 121–130.

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**\*Iris M. Engelhard**

Clinical and Health Psychology  
Utrecht University  
PO Box 80140  
NL-3508 TC, Utrecht  
The Netherlands  
Tel: +31 30 2531470  
Fax: +31 30 2534718  
Email: i.m.engelhard@uu.nl