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The effects of dual-tasks on intrusive memories following analogue trauma

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ABSTRACT

Patients with post-traumatic stress disorder frequently and involuntarily experience intrusions, which are strongly linked to the trauma hotspot. Voluntary memory characteristics (i.e., vividness and unpleasantness) of this hotspot can be reduced by performing a dual-task, such as making horizontal eye movements, which is frequently used in Eye Movement Desensitization and Reprocessing. We tested whether such dual-task interventions would also reduce involuntary memory (i.e., intrusions). Moreover, we examined if changes in hotspot vividness and unpleasantness predicted intrusion frequency. Additionally, we examined whether the effects were dependent on dual-task modality. We tested this in three experiments. Participants watched a trauma film and performed one of the interventions 10-min post-film (1) Recall + Eye movements, (2) Recall + Counting, or (3) No-Task Control. Before and after the intervention, participants rated the hotspot vividness and unpleasantness. They recorded intrusive memories about the film in a diary for a week. Unexpectedly, we found that hotspot vividness and unpleasantness ratings were not affected by the intervention. However, the prolonged (experiment 2), but not standard (experiment 1), dual-task interventions resulted in a lower number of intrusions, regardless of modality. However, this effect was not replicated in experiment 3. We discuss potential explanations and present suggestions for future research.

1. Introduction

Most people experience a traumatic event at some point in their life (DSM-5; American Psychiatric Association, 2013). Approximately 8% of those people will develop post-traumatic stress disorder (PTSD) (Kilpatrick et al., 2013). One of the core symptoms of PTSD are intrusive, recurrent memories of the traumatic event, which typically take the form of highly visual images (Ehlers et al., 2002; Hackmann, Ehlers, Speckens, & Clark, 2004) that are easily triggered by environmental stimuli (e.g., Ehlers & Clark, 2000). Eye Movement Desensitization and Reprocessing (EMDR) is a treatment for PTSD that can be employed to target intrusive traumatic memories (e.g., World Health Organization, 2013). In EMDR, patients make eye movements (EM) by tracking a therapist's finger that moves horizontally in front of the patient's eyes while they simultaneously recall the “hotspot” of their traumatic memory. Meta-analyses support EMDR's evidence-based foundation for treating PTSD (e.g., Cusack et al., 2016). However, it is currently still unclear how crucial elements of EMDR treatment result into symptom change specifically, such as reductions of intrusive memories.

According to working memory theory (see Andrade Kavanagh, & Baddeley, 1997; Gunter & Bodner, 2008; van den Hout & Engelhard, 2012), EM and hotspot recall compete for limited working memory (WM) resources during the intervention. This competition impedes hotspot retrieval, which reduces the hotspot's vividness and/or unpleasantness. van den Hout and Engelhard (2012) have suggested that directly after the intervention the hotspot (which is now reduced in vividness and emotional intensity) is re-stored in long-term memory. This reduced hotspot is recalled during future recalls. A large body of research shows that making voluntary, horizontal EM simultaneously with hotspot recall indeed reduces self-reported hotspot vividness and/or unpleasantness (e.g., Maxfield, Melnyk, & Hayman, 2008; van den Hout, Eidhof, Verboom, Littel, & Engelhard, 2014; van Schie, van Veen, Klugkist, Engelhard, & van den Hout, 2016; van Veen et al., 2015; for a meta-analysis, see; Lee & Cuijpers, 2013). Making EM does not only affect autobiographical memories, effects are also present for a number of novel non-idiosyncratic materials, such as neutral and negative pictures (Andrade, Kavanagh, & Baddeley, 1997; van den Hout, Bartelski, & Engelhard, 2013), memories acquired during fear conditioning (Leer, Engelhard, Altink, & van den Hout, 2013; Leer et al., 2017), and memories acquired in virtual reality environments (Cuperus, Laken, van den Hout, & Engelhard, 2016, but see; Houben, Otgaar, Roelofs, & Merckelbach, 2018; Maxfield et al., 2008; van den Hout et al., 2011; van Schie, Engelhard, & van den Hout, 2015). Also, based on WM theory there is no a priori reason to assume that dual-task interventions

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would only be effective for autobiographical materials (Baddeley, 2012). Furthermore, the effects are not specific to making EM; other dual-tasks that sufficiently tax WM are equally effective, including drawing a complex figure (Gunter & Bodner, 2008), playing Tetris (Engelhard, van Uijen, & van den Hout, 2010), and counting backwards (van den Hout et al., 2010; Engelhard, van den Hout, & Smeets, 2011).

How WM taxation and changes in vividness and/or unpleasantness cascade into changes in PTSD symptoms is still a matter of debate (e.g., Gunter & Bodner, 2009). Theoretically, dual-tasks have the potential to affect the core symptom of intrusive memories. More specifically, dual-tasks target a voluntarily recalled memory hotspot, making the memory hotspot less vivid and less unpleasant. Research with PTSD patients has shown that the majority of intrusive images are related to this hotspot (Grey & Holmes, 2008; Holmes, Grey, & Young, 2005). Therefore, dual-tasks that reduce the excitable nature of the hotspot (i.e., vividness and unpleasantness) may also reduce the number of intrusive images. Although involuntary memory is disturbed in PTSD, thus far EMDR lab analogue studies primarily examined the effect on voluntary memory.

A paradigm that has been frequently used to experimentally investigate intrusion development is the trauma film paradigm (e.g., Horowitz, 1969; Holmes & Bourne, 2008; James, Lau-Zhu, Clark, et al., 2016). In a typical experiment, participants view a film of approximately 10 min depicting traumatic events (e.g., injury or death), which results in a novel "traumatic" memory. After the film and/or the manipulations, participants record their intrusive images of the film in a diary for a week. Interventions to prevent intrusion development in the paradigm typically focus on the manipulation of cognitive processes during or after film viewing. It is important to note that interventions aimed at intrusion modulation within the trauma film paradigm have been exclusively performed without simultaneous and deliberate hotspot recall (i.e., consecutive task interventions; James, Lau-Zhu, Clark, et al., 2016, also see van Schie, Kessler, van den Hout, & Engelhard, submitted), while interventions aimed at hotspot modulation by use of dual-task interventions have always incorporated this type of hotspot recall (e.g., van den Hout & Engelhard, 2012). The trauma film paradigm has never been used to test the effects of these dual-tasks on PTSD analogue symptoms. Moreover, this paradigm allows for investigating the relationship between commonly used voluntary memory measures (i.e., hotspot vividness/unpleasantness) and involuntary memory (i.e., intrusions).

Whether the modality of the intervention plays a role in modulation of hotspot vividness/unpleasantness and subsequently in changing involuntary experienced intrusive memories is still not clear. One account argues that a secondary task should be visuospatial because the traumatic memory is highly visual. Subsequently both hotspot recall and task tax WM's visuospatial sketchpad (e.g., Andrade et al., 1997). The other account states that a secondary task in any modality should be effective because WM's amodal central executive is taxed (Gunter & Bodner, 2008). Though there is evidence for both accounts, overall, research seems to suggest that decreasing hotspot vividness/unpleasantness may rely *more* on a general effect of taxation, than on modality specific taxation (e.g., Engelhard et al., 2011; Kemps & Tiggemann, 2007; Matthijssen, van Schie, & van den Hout, 2018; Tadmor, McNally, & Engelhard, 2016; van den Hout et al., 2010). This is also in line with later adaptations of PTSD theories that put less emphasis on modality and stress the importance of attentional resources that are relevant for conceptual processing of trauma information (e.g., Brewin & Burgess, 2014).

Because research on dual-task interventions has been concentrated primarily on voluntary memory, the first aim of the current research was to replicate previous work, but with newly formed (i.e., trauma film) memories. The second aim was to investigate whether dual-task interventions would reduce involuntary intrusive memories of the trauma film. Finally, we tested whether decreases in vividness/unpleasantness predict lower intrusion frequency. Modality of the dual-task (i.e., visuospatial EM or verbal counting) was included, though we did not expect differences between modalities. Participants viewed a trauma film and were then performed one of three interventions: Recall + EM, Recall + Counting, or No-Task Control (experiment 1 and 2); or one of four interventions including an additional Recall Only condition (experiment 3). The nature of voluntary memory was assessed by participants' self-reported hotspot vividness and unpleasantness before and after the dual-task intervention. Involuntary memory was operationalized by the number of intrusions participants recorded in their diary in the week following the film.

2. Experiment 1

2.1. Participants

Students from Utrecht University and the University of Applied Sciences took part in this study. After exclusion of nine participants (see the Appendix), the final sample consisted of 76 participants (22 men, 54 women; M_{age} = 21.1 years, Age range = 18–26 years) with 25, 26 and 25 participants, respectively, in Recall + EM, Recall + Counting, and No-Task Control groups. The Ethical Committee of the Faculty of Social and Behavioral Sciences at Utrecht University (FETC15-104) approved all experiments.

2.2. Material

2.2.1. Trauma film

The trauma film consisted of a 9min 24s excerpt with a coherent narrative from "Irréversible" (2002) produced by Gaspar Noé. The selected fragment showed a brutal murder in a dark nightclub with explicit violence using a fire extinguisher. It has been used in earlier studies (Nixon, Cain, Nehmy, & Seymour, 2009; Verwoerd, de Jong, & Wessel, 2008; Verwoerd, Wessel, de Jong, & Nieuwenhuis, 2009; Verwoerd, Wessel, de Jong, Nieuwenhuis, & Huntjens, 2011; Weidmann, Conradi, Gröger, Fehm, & Fydrich, 2009), and induced distress in a validation study (Arnaudova & Hagenaars, 2017). Participants watched the trauma film on a 23-inch computer screen in a darkened room, while the experimenter waited outside until the film was finished. Sound was played via over-ear headphones.

2.2.2. Dual-taxation task

In the Recall + EM and Recall + Counting group, participants recalled the memory's hotspot for 6 intervals of 24 s separated by 10-s breaks. Participants were seated approximately 60 cm from a 24-inch computer screen. In the Recall + EM group participants were additionally instructed to simultaneously follow a 1.2 Hz dot that moved horizontally across the screen by moving their eyes and keeping their head still (van Schie, van Veen, Engelhard, Klugkist, & van den Hout, 2016; van Veen et al., 2015). In the Recall + Counting group, participants counted back aloud from 450 in steps of 2 next to memory recall (van den Hout et al., 2010). Participants in the No-Task Control group were told that they had a short break, in which they were to stay seated and remain quiet. They were allowed to think about anything, without restrictions (see Holmes, James, Kilford, & Deeprose, 2010; James et al., 2015; James, Lau-Zhu, Tickle, et al., 2016; Hagenaars, Holmes, Klaassen, & Elzinga, 2017).

2.2.3. Random interval repetition (RIR) task

To quantify WM taxation of two different dual-tasks, participants performed a RIR task (see Vandierendonck, De Voogt, & Van der Goten, 1998). The RIR task was adapted from van den Hout et al. (2011). During the RIR task mild electrical stimuli were administered to the participant's wrist of the non-dominant hand. Participants were asked to select a stimulus that was clearly discernable, but not painful. Participants were instructed to press the button of a response box with the index finger of their dominant hand as soon as they felt the electrical stimulus. Half of the time the interstimulus interval (ISI) was 900 ms and the other half it was 1500 ms. The order of ISI was quasi-random, with no more than four consecutive ISIs of the same duration in a row. First, participants received a short practice in responding to 24 electrical stimuli. After practice, participants performed the RIR task in three conditions: RIR + EM, RIR + Counting or RIR only (i.e., no dual-task). The order of conditions was counterbalanced. During each 3-min block they received 148 electrical stimuli. The instructions for the dual-task conditions (EM or counting) in the RIR task were identical to the instructions for the dual-task conditions in the dual-taxation task. The slowing down of reaction times during dual-task conditions compared to no dual-task provides a valid and very sensitive measure of central executive taxation (Vandierendonck, De Vooght, & Van der Goten, 1998).

2.2.4. Intrusion Diary

Participants were first told what we meant with an "intrusion" (e.g., James et al., 2015). They were specifically told that intrusive memories of the film appeared spontaneously in their mind, and that intrusions could be experienced as mental images (e.g., pictures in the mind's eye, sounds, etc.), verbal thoughts in the form of words and phrases, or as an image-thought combination. Participants were instructed to register any intrusive memory they had in a pen-and-paper diary in the following week. They were instructed to record the content intrusive memories as soon as possible after they experienced it. Only intrusive memories with image-based content were scored (e.g., Holmes et al., 2010; Holmes, James, Coode-Bate, & Deeprose, 2009). In relation to the intrusion diary, participants rated their diary compliance on a visual analogue scale (VAS) from 0 (*not at all accurately*) to 100 (*extremely accurately*) when they handed in the diary.

2.2.5. Self-report questionnaires

Three questionnaires were used to assess the absence of differences at baseline: Beck-Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996); State Trait Anxiety Inventory – trait subscale (STAI-T; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983), and the Traumatic Experiences Questionnaire (TEQ; Foa, 1995). The Impact of Event Scale (IES; Horowitz, Wilner, & Alvarez, 1979) intrusion subscale was used to measure intrusive re-experiencing one week after seeing the film (for detailed descriptions see the Appendix).

2.2.6. Film-related questions

Mood (pre and post film) was rated on scales for sadness, happiness, horror, fear, anxiety, and depression. The VAS ranged from 0 (*not at all*) to 100 (*extremely*). A composite score was used to determine overall mood (e.g., Holmes et al., 2010; James et al., 2015). Happiness was reverse scored. On a VAS ranging from 0 (*not at all*) to 100 (*extremely*) participants rated distress ("how distressing did you find the film you just watched?") and attention paid to the film ("how much attention did you pay to the film you just watched?"). They indicated whether they had seen any part of the trauma film before by selecting *yes* or *no*.

2.2.7. Hotspot ratings

Participants rated the hotspot on two VAS; one for vividness and one for unpleasantness. Scales ranged from 0 (*not vivid/unpleasant*) to 100 (*very vivid/unpleasant*).

2.3. Procedure

On Day 1, participants gave written informed consent and completed the BDI-II, STAI-T, and TEQ. Next, participants rated their pre-film mood. They were then instructed to watch the trauma film as if there were a bystander at the scene. After the film, they completed the post-film mood scales and rated distress, attention and film familiarity. Subsequently, all participants performed a standardized 10-min filler task, during which 15 short fragments of classical music were rated for pleasantness (see Holmes et al., 2010, 2009; James et al., 2015). After the filler task, participants were instructed to select the worst mental image from the movie, which served as the memory's hotspot. After hotspot selection, participants were instructed to recall the hotspot for 10s. Subsequently they rated hotspot vividness and unpleasantness followed by the appropriate dual-taxation task. After each intervention, participants again recalled the hotspot and rated its vividness and unpleasantness. Finally, participants received instructions on how to complete the paper-and-pen diary in the following week.

On Day 8, participants returned to the lab and indicated their diary compliance and filled out the IES. Next, participants in the Recall + EM or Recall + Counting groups performed the RIR task. Participants in the No-Task Control group did not perform this task. Then, all participants received an extensive debriefing, in which the background of the film was explained including how the most aversive scenes were shot using latex dolls and visual effects. Part of this was that we showed participants a clip in which the special effects supervisor shows how the effects were created (http://bit.ly/2T3e4IG). A similar debriefing has been used in other research using a trauma film paradigm (Kindt, van den Hout, Arntz, & Drost, 2008). Finally, participants were reimbursed financially (€24) or received course credits for their participation.

2.4. Data analysis

Experimental variables were visually inspected for outliers. Outliers were defined as scores with more than three standard deviations from the group mean. These were corrected to a score with three standard deviations from the group mean (see van Schie et al., 2016). Intrusion frequency data were inspected for outliers using box plots as these data are usually not normally distributed. If the outlier was above the mean it was changed to one unit larger than the next most extreme score in the distribution (see Hagenaars, van Minnen, Holmes, Brewin, & Hoogduin, 2008; Holmes, Brewin, & Hennessy, 2004). Multivariate outliers (and influential data points) for correlations were determined using the Mahalanobis distance chi-square distribution ($p < .001$) and Cook's distance (> 1) (Tabachnick & Fidell, 2013). When detected these data points were excluded from the correlation analysis.

We used Bayesian statistics to analyze the data, because these statistics allow quantification of the amount of evidence in favor of the alternative hypothesis (H_1), but also in favor of the null hypothesis (H_0; Dienes, 2016), and we sometimes expected groups *not* to differ. Moreover, Bayesian statistics are increasingly used in the field of fear and traumatic stress (e.g., Krypotos, Blanken, Arnaudova, Matzke, & Beckers, 2017; Monden et al., 2016; Schweizer et al., 2017; Van De Schoot, Broere, Perryck, Zondervan-Zwijnenburg, & Van Loey, 2015; Yalch, 2016).

The data were analyzed with the software JASP (Version 0.9.2.0; JASP Team, 2019). This package determines a Bayes Factor (BF) per requested test, which expresses the relative likelihood of the data under H_1 and the H_0. Data in favor of the H_1 (relative to H_0) are presented as $BF_{10,}$ which can be interpreted as the BF of H_1 against H_0. BF_{01} represents the reversed interpretation, where the evidence is in favor of the H_0 (relative to H_1). $BF_{01} = 5$ means that the data are five times more probable under H_0 than under H_1. Because a BF is *relative*, the BF for the other hypothesis is easily determined by dividing 1 by a given BF (e.g., if BF_{01} is 5, BF_{10} is 1 divided by 5, hence 0.2). In JASP H_0 always states the absence of an effect. In all analyses, we used JASP's standard prior: a Cauchy distribution with scale $r = 0.707$ (i.e., medium prior).

Because generally three groups are compared, a Bayesian one-way ANOVA is performed first. Given sufficient evidence in favor of H_1, this is followed by individual comparisons using JASP's standard correction for multiple testing. In some instances, a two factor Bayesian ANOVA is performed (e.g., to test Group and Time effects). JASP then produces five models: a model for (1) the null, (2) a main effect of factor A, (3) a main effect of factor B, (4) a two main effects model: A + B, and (5) a two main effects model plus an A × B interaction. All models are compared to the null model; therefore all BFs state the relative probability against the null model. The relative probability amongst models 2–5 can be calculated by simply dividing model BFs. These relative probabilities can then again be interpreted following BF interpretation. In these analyses, we used JASP's default prior model probabilities of 0.2.

Scientific communication about how to interpret the BF can be facilitated by using categories of evidence (though the BF is by nature a continuous scale without arbitrary cut-offs). BFs around 1 represent (inconclusive) evidence that is not in favor of H_1 or H_0. BFs between 1 and 3 ($1 - 1/3$) represent anecdotal, 3–10 ($1/3 - 1/10$) substantial, 10–30 ($1/10 - 1/30$) strong, or 30–100 ($1/30 - 1/100$) very strong evidence relative to the other hypothesis. A BF above 100 (or below $1/100$) is interpreted as decisive evidence for one hypothesis relative to the other hypothesis (Jeffreys, 1961; Wetzels & Wagenmakers, 2012).

3. Results experiment 1

3.1. Baseline and film measures

There were no differences in baseline measures between groups. The film successfully increased participants' negative mood regardless of assigned group (see the Appendix).

3.2. WM taxation

There were differences between conditions on the RIR task, $BF_{10} = 1.09 \times 10^{31}$. Follow-up tests showed that cognitive load of RIR + EM ($M = 394.2$, $SD = 74.07$) and RIR + Counting ($M = 426.1$, $SD = 87.68$) was higher than RIR Only ($M = 234.5$, $SD = 65.33$), $BFs_{10} > 2.81 \times 10^{17}$. There was insufficient evidence that cognitive load was higher for RIR + Counting than for RIR + EM, $BF_{10} = 1.55$.

3.3. Hotspot vividness and unpleasantness

Hotspot vividness and unpleasantness were analyzed separately with a mixed Bayesian ANOVA with factors Time (pre vs. post-intervention) as within-subjects factor and Group as between-subjects factor, to assess whether changes in these ratings differed between groups (see Table 1). The analysis shows the largest BF for a main effect model of Time, $BF_{10} = 27{,}178$. Inclusion of Group as additional main effect or as interaction with Time reduced the BF compared to the main effect model of Time, $BF_{10} = 12{,}046$ and $BF_{10} = 3{,}275$ respectively. A main effect model of only Group is less probable than the null model, $BF_{10} = 0.425$. Unpleasantness ratings displayed a somewhat similar pattern; again, there was decisive evidence for a main effect model of Time, $BF_{10} = 1.15 \times 10^6$. Addition of Group as main effect or interaction with Time decreased the BF compared to the main effect model of Time, $BF_{10} = 817{,}412$ and $BF_{10} = 757{,}736$ respectively. However, these models only slightly underperform to a main effect model of Time. A main effect model of only Group performs worse compared to a null model, $BF_{10} = 0.643$. Overall, the results from hotspot vividness and unpleasantness suggest that ratings largely decreased from pre to post-intervention irrespective of intervention type.

3.4. Intrusive memories

On average, participants reported 3.92 intrusions ($SD = 3.41$) in their diary (see Table 1). There were no differences between groups ($BF_{01} = 6.16$). Groups also reported similar re-experiences retrospectively on the IES (intrusion subscale), $BF_{01} = 2.85$, though the evidence here was weak. Diary compliance was high and did not differ between groups, $BF_{01} = 5.87$.

3.5. Relationship between WM taxation, hotspot vividness/unpleasantness, and intrusive memories

According to WM theory, the degree of slowing down on the RIR task during Counting or during EM (relative to RIR Only) should be positively related to changes in scores for hotspot vividness and unpleasantness. To assess this, we first calculated a pre-post difference score for each participant on hotspot vividness and unpleasantness scores and then correlated this with the index of WM taxation. For each participant, this index was the difference between RIR only performance and the relevant experimental RIR condition (EM or Counting). WM taxation was not related to decreases in vividness, $r = -.19$, $BF_{01} = 12.60$, or unpleasantness, $r = -.04$, $BF_{01} = 6.90$.[1]

Additionally, we hypothesized that decreases in hotspot vividness and unpleasantness ratings should be related to fewer intrusive memories. However, diary intrusions were not related to hotspot vividness, $r = 0.06$, $BF_{01} = 10.04$ or unpleasantness, $r = .01$, $BF_{01} = 12.21$. The intrusion subscale of the IES was also not related to hotspot vividness, $r < .01$, $BF_{01} = 7.19$ or unpleasantness, $r < .01$, $BF_{01} = 7.19$.

4. Discussion

Dual-tasks have been proven to be successful in reducing the vividness and unpleasantness of voluntary memories. Experiment 1 was set up to test whether they would also affect *involuntary* memory (i.e., intrusions of analogue trauma), and whether changes in hotspot vividness and unpleasantness of voluntary memories would predict intrusion frequency. Against expectations, either dual-task did not affect intrusion frequency. Surprisingly, the dual-tasks also did not result in drops in vividness and unpleasantness, although each task was clearly more taxing on WM than no task. The most likely explanation for the lack of effects may be the intervention's duration. While the duration was in line with previous studies employing dual-tasks (e.g., Kearns & Engelhard, 2015; van Schie et al., 2016; van Veen et al., 2015), it was significantly shorter than consecutive task interventions frequently used within the trauma film paradigm, which usually last for about 10 min (e.g., Holmes et al., 2010, 2009; James, Lau-Zhu, Tickle, et al., 2016). Also, longer durations for dual-tasks have resulted in stronger effects on vividness and unpleasantness in previous studies (Leer, Engelhard, & Van Den Hout, 2014; van Veen, Engelhard, & van den Hout, 2016). Alternatively, it is possible that dual-tasks, indeed, do not affect the number of intrusions, but only affect qualitative characteristics of an intrusion. After all, dual-task interventions are known to affect memory characteristics that are *voluntarily* retrieved and assessed such as vividness and unpleasantness (e.g., Lee & Cuijpers, 2013). We therefore prolonged the intervention in experiment 2 and added additional measures for intrusion characteristics.

5. Experiment 2

5.1. Participants

Students from Utrecht University and the University of Applied Sciences took part in this study. After exclusion of seven participants (see the Appendix), the final sample consisted of 74 participants (24 men, 50 women; $M_{age} = 20.85$ years, Age range = 18–29 years), with 25, 24 and 25 participants, respectively, in Recall + EM, Recall + Counting, and No-Task Control groups.

[1] The relationship between WM taxation and decreases in vividness/unpleasantness might be characterized by a quadratic relationship (see Engelhard et al., 2011) instead of a linear relationship (see van Schie et al., 2016; van Veen et al., 2015; Littel et al., 2017 & Littel & van Schie, 2019). Visual inspection of the data showed homogenous scatterplots indicative of no relationship (linear or quadratic) between these variables (for all experiments).

Table 1
Means and standard deviations for the groups in experiment 1.

	No-Task Control	Recall + EM	Recall + Counting
Pre-intervention hotspot vividness	59.97 (27.12)	69.56 (27.95)	69.44 (24.16)
Post-intervention hotspot vividness	52.95 (31.85)	64.76 (27.38)	55.89 (24.43)
Pre-intervention hotspot unpleasantness	86.72 (21.19)	86.47 (16.06)	82.05 (17.45)
Post-intervention hotspot unpleasantness	75.60 (24.08)	79.50 (15.18)	65.09 (22.95)
Intrusion frequency	4.44 (3.86)	3.52 (3.39)	3.81 (3.02)
Diary compliance	75.92 (16.06)	76.76 (12.66)	72.96 (12.73)
IES (intrusion subscale)	8.52 (6.46)	7.32 (5.39)	5.92 (4.20)

5.2. Procedure

The same procedure as experiment 1 was followed with some adjustments. The intervention duration was prolonged from 6 × 24s (total duration: 3.23 min) to 16 × 24s (total duration: 8.9 min; van Veen et al., 2016), resembling the duration of consecutive task interventions used in the trauma film paradigm. Consequently, participants in the Recall + Counting group were instructed to count back from 1000 (cf. Engelhard et al., 2011), instead of 450, to avoid that they would reach 0. Additionally, participants rated each intrusion in the diary on distress, unpleasantness, and vividness from 0 (*not at all*) to 10 (*extremely*). They also rated intervention compliance, pleasantness, and difficulty on a VAS from 0 (*not at all*) to 100 (*extremely*) directly after the post-rating of vividness/unpleasantness (e.g., Hagenaars et al., 2017). Results for these three scales can be found in the Appendix.

6. Results

6.1. Baseline and film measures

Groups were equivalent at baseline. Negative mood increased as a result of the film regardless of assigned group (see the Appendix).

6.2. WM taxation

The RIR task showed clear group differences, $BF_{10} = 3.19 \times 10^{16}$. Follow-up showed that RIR + EM (M = 390.0, SD = 86.32) and RIR + Counting (M = 438.7, SD = 89.23) were more taxing than RIR Only (M = 267.7, SD = 88.31), $BFs_{10} > 7.48 \times 10^{6}$. Additionally, RIR + Counting was more taxing than RIR + EM, $BF_{10} = 16.85$.

6.3. Hotspot vividness and unpleasantness

There was conclusive evidence for a main effect model of Time for vividness, $BF_{10} = 378{,}851$, showing that ratings decreased from pre to post-intervention regardless of Group. All other models received lower BFs compared to the main effect model of Time: $BF_{10} = 0.48$ (Group), $BF_{10} = 224{,}751$ (Time + Group), and $BF_{10} = 77{,}969$ (Time + Group + Time × Group interaction). Unpleasantness ratings displayed a similar pattern compared to vividness. Again, there was decisive evidence for a main effect model of Time, $BF_{10} = 1.59 \times 10^{9}$, showing that all groups experienced similar decreases in unpleasantness ratings from pre to post-intervention, and all other models received lower BFs compared to the main effect model of Time: $BF_{10} = 0.33$ (Group), $BF_{10} = 7.03 \times 10^{8}$ (Time + Group), and $BF_{10} = 1.39 \times 10^{8}$ (Time + Group + Time × Group interaction). Overall, the hypothesized interaction was not observable in the ratings of either hotspot vividness or unpleasantness.

6.4. Intrusive memories

There were group differences in the number of diary memories, $BF_{10} = 27.69$ (see Table 2 and Fig. 1). Follow-up tests show that both Recall + EM and Recall + Counting reported fewer intrusions compared to No-Task Control, $BF_{10} = 7.02$ and $BF_{10} = 13.96$, respectively. There was no difference between Recall + EM and Recall + Counting in the number of intrusions, $BF_{01} = 5.98$. Moreover, participants reported high compliance in reporting intrusions in their diary (M = 74.38, SD = 12.05), but the evidence about the absence or presence of any group differences in compliance was inconclusive, $BF_{01} = 1.29$. Finally, we did not observe sufficient evidence for group differences on retrospectively reported intrusions on the IES, $BF_{10} = 1.66$ (see Fig. 2).

Participants with at least one intrusion in the diary were included in the analyses of intrusion characteristics. For each participant the average score for an intrusion characteristic was used. We observed no group differences on distress ($BF_{01} = 5.93$) or unpleasantness ($BF_{01} = 4.62$). The evidence for vividness was inconclusive ($BF_{01} = 1.60$) (see Table 2).

6.5. Relationship between WM taxation, hotspot vividness/unpleasantness and intrusive memories

Similar to experiment 1, we did not find correlations between WM taxation and changes in vividness, r = -.03, $BF_{01} = 6.27$ or unpleasantness, r = 0.08, $BF_{01} = 3.48$. Additionally, changes in vividness and unpleasantness ratings were inconsistently related to intrusive memories in general. Some correlations showed evidence in favor of the null hypothesis, such as unpleasantness and diary intrusions, r = -.01, $BF_{01} = 6.31$, and unpleasantness and intrusions on the IES r = -.09, $BF_{01} = 3.36$, while other correlations did not support the alternative or the null hypothesis: vividness and diary intrusions, r = -.21, and $BF_{01} = 0.69$, vividness and intrusions on the IES, r = -.13 $BF_{01} = 2.16$.

We also calculated correlations between drops in scores for vividness and unpleasantness, and, self-reported intrusion characteristics of vividness, unpleasantness, and distress. Larger drops should be related to lower scores on intrusion characteristics. For both vividness and unpleasantness, we observed evidence that was largely in favor of the null hypothesis, rs between -.11 and .08, BFs_{01} between 2.82 and 10.34. Thus, vividness/unpleasantness of voluntary memories was not related to memory characteristics of involuntary memory.

7. Discussion

In experiment 2, we prolonged the duration of all interventions to match the duration of typical 10-min consecutive task interventions within the trauma film paradigm and we added diary measures that reflect how intrusions are qualitatively experienced. We observed that prolonged dual-tasks – regardless of modality – resulted in a lower number of intrusions compared to the no-task control condition. However, performing a dual-task still did not affect memory vividness and unpleasantness ratings, compared to control, although it – again – taxed WM more than control. Importantly, vividness and unpleasantness ratings of the hotspot were not related to intrusion frequency or intrusion characteristics. This may suggest that dual-task interventions may not target intrusive memories via changes in vividness or unpleasantness.

However, it is possible that continuous hotspot recall during the

Table 2
Means and standard deviations for the groups in experiment 2.

	No-Task Control	Recall + EM	Recall + Counting
Pre-intervention hotspot vividness	73.16 (21.92)	74.00 (20.28)	68.64 (20.93)
Post-intervention hotspot vividness	62.70 (22.63)	56.98 (22.12)	47.20 (21.70)
Pre-intervention hotspot unpleasantness	82.96 (19.90)	78.65 (30.16)	88.88 (12.11)
Post-intervention hotspot unpleasantness	62.52 (24.84)	64.25 (30.60)	71.35 (25.07)
Intrusion frequency	5.52 (2.89)	3.04 (2.76)	3.00 (2.25)
Intrusion distress[a]	2.55 (1.60)	2.91 (2.10)	3.03 (2.11)
Intrusion unpleasantness[a]	3.89 (2.11)	4.74 (2.80)	4.45 (2.27)
Intrusion vividness[a]	5.58 (1.58)	5.27 (1.86)	4.45 (2.23)
Diary compliance	71.28 (12.48)	78.52 (11.98)	73.29 (10.88)
IES (intrusion subscale)	9.47 (5.11)	7.28 (5.05)	5.91 (3.94)

[a] Seven participants were excluded from these analyses, because they reported no intrusions. This changed the number of participants in each group slightly: No-Task Control ($n = 24$), Recall + EM ($n = 20$), and Recall + Counting ($n = 23$).

dual-task interventions was the driving force behind intrusion modulation in experiment 2. Both active conditions differed from the no-task control condition not only in the presence of a secondary task (EM or counting), but also in the extent to which the memory's hotspot was recalled. To address this limitation and to replicate the results, experiment 3 will incorporate a Recall Only control condition. recall of the memory's hotspot will be assessed by having participants (in all conditions) report *after* the intervention the extent to which they recalled the memory's hotspot *during* the intervention.

8. Experiment 3

8.1. Participants

Students from Erasmus University Rotterdam participated in this study. After exclusion of 13 participants (see the Appendix), the final sample consisted of 100 participants (34 men, 66 women; $M_{age} = 20.93$ years, Age range = 18–33 years). Participants were equally divided over the groups Recall + EM, Recall + Counting, Recall Only, and No-Task Control.

8.2. Procedure

Experiment 3 was identical to Experiment 2 with one crucial added Recall Only control condition. Additionally, after rating post-intervention hotspot vividness and unpleasantness, participants were asked to rate the extent to which they thought of the memory during the intervention on a scale from 0 (*never*) to 100 (*always*).

9. Results

9.1. Baseline and film measures

Again, there were no differences between groups at baseline. The film successfully increased participants' negative mood in all groups (see the Appendix).

9.2. WM taxation

Taxing of WM showed decisive evidence for between condition differences, $BF_{10} = 1.01 \times 10^{63}$. Follow-up showed that all conditions differed from each other, $BFs_{10} > 63{,}440$ with RIR + Counting ($M = 459.0$, $SD = 95.19$) as most taxing followed by RIR + EM ($M = 401.8$, $SD = 84.61$), and then RIR Only ($M = 235.2$, $SD = 61.34$).

9.3. Hotspot vividness and unpleasantness and hotspot recall

The data for hotspot vividness largely supported a main effect model

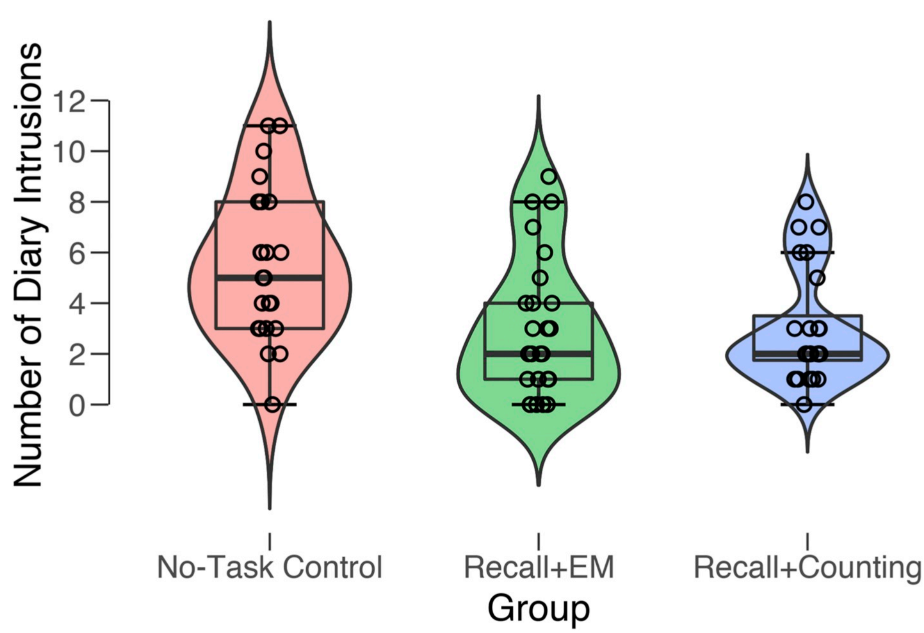

Fig. 1. Kernel density distributions for the number of intrusions with individual data points (circles) and boxplots superimposed for each experimental condition for experiment 2.

Table 3
Means and standard deviations for the groups in experiment 3.

	No-Task Control	Recall Only	Recall + EM	Recall + Counting
Pre-intervention hotspot vividness	74.60 (21.57)	69.76 (27.02)	70.15 (22.35)	78.98 (17.15)
Post-intervention hotspot vividness	60.10 (25.69)	63.97 (32.37)	59.88 (23.43)	70.41 (20.00)
Pre-intervention hotspot unpleasantness	81.46 (17.96)	76.43 (23.66)	73.11 (30.25)	77.83 (23.93)
Post-intervention hotspot unpleasantness	65.17 (22.57)	59.23 (25.62)	55.43 (26.56)	69.60 (25.11)
Hotspot recall	49.08 (26.12)	82.20 (25.93)	75.60 (18.75)	72.28 (15.50)
Intrusion frequency	3.52 (2.83)	3.12 (3.21)	2.60 (1.85)	2.04 (2.15)
Intrusion distress[a]	3.24 (2.01)	2.39 (1.73)	3.64 (2.19)	3.57 (2.40)
Intrusion unpleasantness[a]	5.19 (1.89)	3.90 (2.13)	4.67 (2.55)	4.94 (2.80)
Intrusion vividness[a]	5.12 (1.63)	5.93 (1.99)	6.10 (1.64)	5.73 (2.42)
Diary compliance	71.72 (16.18)	78.88 (10.04)	79.48 (13.77)	74.40 (20.38)
IES (intrusion subscale)	7.12 (4.60)	5.12 (4.17)	6.20 (6.32)	4.92 (4.77)

[a] Seventeen participants were excluded from these analyses, because they reported no intrusions. This changed the number of participants in each group slightly: No-Task Control (*n* = 22), Recall Only (*n* = 20), Recall + EM (*n* = 23), and Recall + Counting (*n* = 18).

of Time, BF_{10} = 1825.69, showing that ratings decreased from pre to post-intervention regardless of Group (see Table 3). All other models received lower BFs compared to the main effect model of Time: BF_{10} = 0.241 (Group), BF_{10} = 506.67 (Time + Group), and BF_{10} = 63.92 (Time + Group + Time × Group interaction). Hotspot unpleasantness ratings showed a similar pattern compared to vividness. Again, the main effect model of Time was mostly supported by the data, $BF_{10} = 7.739 \times 10^6$. All other models received lower BFs compared to the main effect model of Time: BF_{10} = 0.222 (Group), $BF_{10} = 2.254 \times 10^6$ (Time + Group), and BF_{10} = 363,502 (Time + Group + Time × Group interaction). Overall, all groups experienced similar decreases in hotspot vividness and unpleasantness ratings from pre to post-intervention.

For hotspot recall there were clear differences between groups, BF_{10} = 4604.56. The No-Task control group showed the lowest hotspot recall compared to other three groups, BFs_{10} > 28.80, while these three groups did not differ from each other BFs_{01} > 7.06.

9.4. Intrusive memories

Unexpectedly, there was substantial evidence for no group differences in number of diary intrusions, BF_{01} = 3.33 (see Table 3 & Fig. 2). The groups did not differ in their self-reported diary compliance, BF_{01} = 3.90, nor did they differ on retrospectively reported intrusions on the IES, BF_{01} = 5.97. Analyses of intrusion characteristics showed no group differences on distress (BF_{01} = 3.05), unpleasantness (BF_{01} = 4.55), or vividness (BF_{01} = 4.74).

9.5. Relationship between WM taxation, hotspot vividness/unpleasantness, and intrusive memories

There were no (one-sided) correlations between WM taxation and changes in hotspot vividness, *r* < .01, BF_{01} = 5.18 or unpleasantness, *r* = -.10, BF_{01} = 8.36. Moreover, changes in hotspot vividness and unpleasantness ratings were not related to intrusive memories (respectively, *r* = -.08, BF_{01} = 3.65, *r* = -.05, BF_{01} = 5.42), or to intrusions on the IES (respectively, *r* = -.08, BF_{01} = 3.96, *r* = -.12, BF_{01} = 2.35). Changes in hotspot vividness and unpleasantness were also not correlated with self-reported intrusion characteristics of vividness, unpleasantness, and distress (*r*s between -.13 and .04, BFs_{01} between 2.07 and 9.14), except for hotspot vividness and intrusion vividness, *r* = -.32, BF_{10} = 19.76. This shows that a drop in hotspot vividness is related to lower reported intrusion vividness.

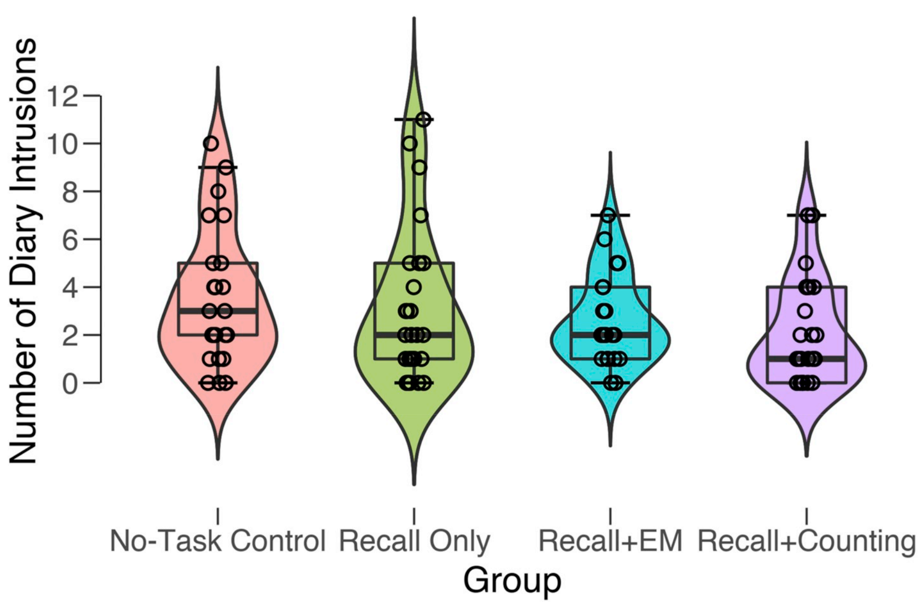

Fig. 2. Kernel density distributions for the number of intrusions with individual data points (circles) and boxplots superimposed for each experimental condition for experiment 3.

10. General discussion

In three experiments we tested whether dual-task interventions (of different modalities) reduced voluntary memory characteristics (i.e., hotspot vividness/unpleasantness) and involuntary memory (i.e., intrusions). We also examined if reductions in voluntarily recalled hotspot vividness/unpleasantness predicted intrusion frequency and intrusion qualities. We used a trauma film paradigm with visuospatial and verbal dual-task interventions applied 10 min post-trauma. Unexpectedly, we found – despite clear WM taxation in the dual-task conditions – that dual-task conditions did not differ from the control condition(s) on voluntary hotspot vividness and unpleasantness. In experiment 2, prolonged dual-task interventions (regardless of modality) resulted in a lower number of intrusions compared to the No-Task Control condition. This effect was not replicated in experiment 3. Interestingly, ratings of voluntary hotspot vividness/unpleasantness and involuntary intrusions were consistently not related.

Regarding voluntary memory, although not hypothesized, it was found previously that experimental conditions (i.e., Recall + EM, Recall + Counting) did not result in greater decreases in hotspot vividness/unpleasantness compared to a control condition (i.e., Recall Only). In fact, this was found mostly in studies that tested memory for novel materials (e.g., pictures, film clips) compared to studies testing (consolidated) memory for autobiographical events (e.g., Andrade et al., 1997; Houben et al., 2018; Maxfield et al., 2008; van den Hout et al., 2011; van Schie et al., 2015; van Schie & Leer, 2019, but see; Cuperus et al., 2016; Leer et al., 2017, 2013; van den Hout et al., 2013). Possibly, taxing WM may work differently under consolidation and reconsolidation processes. In addition, the fact that we did not find the expected decrease in hotspot vividness/unpleasantness may also be explained by differences in the intervention's duration and the type(s) of control condition. A recent study has shown that a dual-task intervention primarily produces short-lived effects (i.e., after the first 4 × 24s intervals), which slowly disappear when the intervention's duration is lengthened (to 32 × 24s intervals; van Veen, van Schie, van de Schoot, van den Hout, & Engelhard, 2019). These short-lived effects are partly the result of an increase in scores for the Recall Only condition to which the dual-task condition was compared. Indeed, an increase from pre to post intervention (e.g., Engelhard et al., 2010; Leer et al., 2014; van den Hout et al., 2010) or no change (e.g., Leer et al., 2013; Littel, Remijn, Tinga, Engelhard, & van den Hout, 2017; van Veen et al., 2016) is the typical effect of a Recall Only condition on hotspot ratings, especially when the duration is relatively brief. Our longer Recall Only intervention resulted in a decrease, in line with van Veen et al. (2019). In addition, hotspot ratings also dropped in the No-Task Control condition, which is in line with one study that also found these effects for this condition (Asselbergs et al., 2018), but contradicts with another study that found no change (Littel, Kenemans, et al., 2017). Though note, this latter study used a short intervention duration (6 × 24s intervals).

It is possible that effects on voluntary recalled hotspot vividness/unpleasantness may have been obscured by participants' individual differences. WM capacity could theoretically have affected the dual-task intervention's effectiveness. However, two studies showed WM capacity was not associated with effectiveness of a dual-task (van Schie et al., 2016; van Veen et al., 2019). Alternatively, anxiety might have influenced cognitive performance. Indeed, there is literature showing that anxiety may impair two central executive functions: inhibition and shifting (e.g., Eysenck, Derakshan, Santos, & Calvo, 2007). Either of these functions has been suggested to be at the heart of the competition for WM resources during the dual-task intervention (see van Veen et al., 2015). However, note that trait anxiety scores overall were relatively low and comparable between conditions in all experiments (see the Appendix). Still, it does not preclude that the dual-task intervention is unaffected by different levels of anxiety per se.

Regarding involuntary memory, the results from experiment 2 tentatively suggest that dual-tasks may have the potential to reduce intrusions, but only when a prolonged intervention is used. This indicates that interventions following the trauma film need to be of a sufficient duration to modulate intrusions; a duration that is comparable to typical 10-min consecutive task interventions within the trauma film paradigm, such as playing Tetris or finger tapping (e.g., Deeprose, Zhang, DeJong, Dalgleish, & Holmes, 2012; Holmes et al., 2010, 2009; James, Lau-Zhu, Tickle, et al., 2016). The comparable effects for a visuospatial and verbal dual-task in experiment 2 give the impression that intrusion modulation is dependent on a general taxation effect of the intervention (also see Hagenaars et al., 2017; Krans, Näring, & Becker, 2009; Pearson & Sawyer, 2011). However, there may be involvement of modality specific processing as well as the visuospatial dual-task intervention was generally less taxing on WM (see Kemps & Tiggemann, 2007; Matthijssen et al., 2018).

The effect found in experiment 2 was not replicated in experiment 3, although numerically the pattern was similar (fewer intrusions in the dual-task conditions). Note that the evidence for an effect in experiment 2 was strong, whereas the evidence for no effect in experiment 3 was only substantial. Possibly, the lack of dual-task effects in experiment 3 may be explained by the intrusion frequency in the No-Task Control condition (3.52), which was substantially lower than in experiment 2 (5.52) or previous studies (e.g., Asselberg et al., 2018, Exp 2; Brühl, Heinrichs, Bernstein, & McNally, 2019; Holmes et al., 2009; 2010). It is also possible that sample differences (i.e., students from two different universities) have somehow affected intrusion frequency. Alternatively, dual-task interventions may simply not have the same reliable effects as consecutive task interventions (e.g., Tetris *after* memory (re)activation; Asselbergs et al., 2018; Brewin, 2014, but see van Schie, Kessler, van den Hout, & Engelhard, submitted), which have recently been argued to also tax WM (e.g., James, Lau-Zhu, Tickle, et al., 2016; Lau-Zhu, Holmes, Butterfield, & Holmes, 2017). Future research may disentangle exact similarities and differences between these approaches, as well as unravel primary active ingredients.

Regardless of the absence of differences between conditions on either voluntary memory or involuntary memory, one would still expect to find correlational evidence supporting a theoretical relationship between changes in hotspot vividness/unpleasantness and intrusive memories. This is also based on a premise grounded in EMDR treatment that drops in subjective units of distress should result in the amelioration of PTSD symptomatology. Yet, in all three experiments, correlations between hotspot vividness/unpleasantness and intrusions were consistently absent. It has been argued before that different mechanisms may affect involuntary and voluntary memories differently (see Berntsen, 1998; Schlagman & Kvavilashvili, 2008). Indeed, there are two studies that show that reductions in voluntary hotspot vividness and unpleasantness not necessarily coincide with differences in intrusion frequency between conditions (Asselbergs et al., 2018; Cuperus, Klaassen, Hagenaars, & Engelhard, 2017). Interestingly, although reduced hotspot vividness/unpleasantness may explain the efficacy of EM in EMDR, there may be other or additional mechanisms. For example, a dual-task intervention (such as making EM) may lead to a division of attention, thereby creating reappraisal opportunities, because attention is taken away from the traumatic memory's “here-and-now” quality (see also Ehlers & Clark, 2000). It is also possible that voluntary evocation of these memories may impart a sense of control over them, further boosting therapeutic benefits exemplified by reduction in the frequency of their subsequent involuntary recollection.

A few limitations about the series of experiments in this paper should be noted. As a pragmatic first step in investigating if dual-tasks are able to reduce intrusive memories, trauma exposure and intervention occurred on the same day. Thus, all used interventions intervened with memory consolidation, while EM in EMDR treatment supposedly capitalize on memory *re*consolidation. However, although these two processes are characterized by distinctive features (e.g., different brain areas), they also share overlapping (molecular) mechanisms (Alberini, 2005), which may suggest why interventions during consolidation and reconsolidation can be equally effective in targeting aversive memories (e.g., Holmes et al., 2009; James, Lau-Zhu, Clark, et al., 2016; van den Hout & Engelhard, 2012). Second, one could argue that examining intrusive memories in patients would have been better given that a “traumatic” film barely compares to real life trauma. For example, a first line of enquiry could be to see if changes in subjective units of distress within or between EMDR treatment sessions are indeed predictive for changes in PTSD symptomatology, symptom networks, or trajectories. This may provide insights into whether and how changes in voluntary memory characteristics affect outcome variables in treatment settings.

To conclude, because the path to changes in (analogue) PTSD symptoms has been relatively unexplored in EMDR research (e.g., Gunter & Bodner, 2009; Maxfield, 2008), we examined in a series of experiments whether dual-task interventions would reduce involuntary intrusive memories. The results are inconclusive: Prolonged dual-task interventions strongly affected intrusive memories in experiment 2, but there was only substantial evidence for no effect in experiment 3. We made a first step in relating changes in voluntary hotspot vividness/unpleasantness and involuntary intrusive memories, which were consistently not related. This may suggest that other (substitutionary or complementary) mechanisms might be at play when modulating intrusions (e.g., memory reappraisal). Further research aimed at elucidating the working mechanisms of EMDR treatment and its effects on PTSD symptomatology is warranted, because optimizing treatment is best done by capitalizing on its mechanisms of action.

Author contributions

KvS developed the study concept. All authors contributed to the study design. KvS was responsible for data collection and analysis. KvS drafted the manuscript and SCvV and MAH provided critical revisions.

Conflicts of interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2019.103448.

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