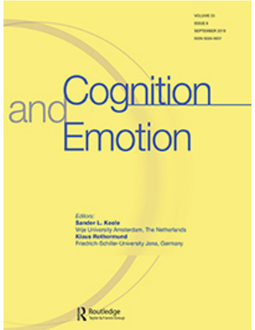

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The Effect of modality specific interference on working memory in recalling aversive auditory and visual memories*

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ABSTRACT
Both auditory and visual emotional memories can be made less emotional by loading working memory (WM) during memory recall. Taxing WM during recall can be *modality specific* (giving an auditory [visuospatial] load during recall of an auditory [visual] memory) or *cross modal* (an auditory load during visual recall or vice versa). We tested whether modality specific loading taxes WM to a larger extent than cross modal loading. Ninety-six participants undertook a visual and auditory baseline Random Interval Repetition task (i.e. responding as fast as possible to a visual or auditory stimulus by pressing a button). Then, participants recalled a distressing visual and auditory memory, while performing the same visual and auditory Random Interval Repetition task. Increased reaction times (compared to baseline) were indicative of WM loading. Using Bayesian statistics, we compared five models in terms of general and modality specific taxation. There was support for the model describing the effect on WM of dual tasking *in general*, irrespective of modality specificity, and for the model describing the effect of *modality specific* loading. Both models *combined* gained the most support. The results suggest a general effect of dual tasking on taxing WM and a superimposed effect of taxing in matched modality.

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Modality specific taxing; auditory memories; working memory taxation; random interval repetition task; Bayesian statistics; EMDR

Eye movement desensitization and reprocessing (EMDR) therapy is an evidence-based therapy for post-traumatic stress disorder (PTSD; e.g. Bisson et al., 2007; Bradley, Greene, Russ, Dutra, & Westen, 2005; Chen et al., 2014; Lee & Cuijpers, 2013; Seidler & Wagner, 2006). EMDR aims to reduce PTSD symptoms by decreasing the emotionality of intrusive memories. In EMDR therapy, the therapist asks the patient to simultaneously recall a distressing trauma-related memory and move the eyes back-and-forth horizontally, typically by following the fingers of the therapist who moves his/her hand back – and forth horizontally in front of the patient. The therapist checks approximately every 30 s what comes to the mind of the patient and consequently asks the patient to concentrate on what comes up. Every now and then the level of distress perceived by the trauma-related memory is checked. The procedure is repeated until the patient perceives no more distress when recalling the initial aversive trauma-related memory.

A meta-analysis by Lee and Cuijpers (2013) showed the added value of eye movements (EM) in EMDR in both clinical and analogue studies. Different theories were proposed in an attempt to provide an explanation for the underlying working mechanism(s) of EMDR therapy by stressing the horizontal direction of EM (e.g. evocation of the orienting response, Armstrong & Vaughan, 1996; enhanced interhemispheric functional connectivity, Bergmann, 1998; triggering of a rapid-eye-movement – like state that facilitates the processing of traumatic memories, Stickgold, 2002, 2008; depotentiating limbic fear memory synapses, Rasolkhani-Kalhorn & Harper, 2006;

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*SM and MvH developed the study concept. SM and KvS contributed to the study design, KvS programmed the RIR task, SM was responsible for data collection and SM and KvS for data analysis. SM drafted the manuscript, KvS and MvH provided critical revisions

dearousal, Aubert-Khalfa, Roques, & Blin, 2008). It should be noted that other tasks during recall yield comparable effects besides EM (e.g. spatial tapping, Andrade, Kavanagh, & Baddeley, 1997; playing Tetris, Engelhard, van Uijen & van den Hout, 2010; progressive counting, Greenwald, McClintock, Jarecki, & Monaco, 2015; auditory shadowing, drawing a complex figure, Gunter & Bodner, 2008; watching visual stimuli changing color, Kavanagh, Freese, Andrade, & May, 2001; counting, Kemps & Tiggemann, 2007; Van den Hout et al., 2010; attentional breathing, Van den Hout et al., 2011a; mental arithmetic, Engelhard, van den Hout & Smeets, 2011). The working memory (WM) taxation hypothesis provides an explanation for the beneficial effect induced by EM and other tasks that tax WM. According to WM theory there is a limited capacity system that is essential for temporary storage and manipulation of information (Baddeley, 2012). Thus, keeping a memory in mind after retrieval uses these limited capacity WM resources. The WM taxation hypothesis states that emotional memories in PTSD patients can be made less emotional by simultaneously recalling an emotional memory and performing a dual task, inducing competition between the two tasks which interferes with memory recall (Van den Hout & Engelhard, 2012). EM are considered such a dual task. The observation that memories become less disturbing and less vivid after execution of EM, but also after a range of other dual tasks therefore is consistent with the WM taxation hypothesis (Van den Hout et al., 2012).

An area of debate is how optimization of EMDR therapy can be achieved. One option may be "to do more" of WM loading (i.e. to increase WM loading). Maxfield, Melnyk, and Hayman (2008) conducted two experiments in which they asked participants to recall negative memories consecutively while engaging in three dual-attention tasks of increasing complexity (no EM, slow EM and fast EM). Slow EM and Fast EM decreased ratings of vividness, thought clarity, and emotional intensity. Moreover, fast EM resulted in larger decreases than the slow EM. In a study by Van Veen et al. (2015) participants were asked to recall three highly vivid aversive autobiographical memory images or three less vivid images under three conditions: fast EM, slow EM, or recall only. By use of an objective measure the fast EM were pre-established to have more WM interference than the slow EM. Participants were asked to conduct a discrimination reaction time task during the performance of different speeds of EM. Deceleration of reaction times was used as a measure of WM taxation and reaction times slowed down relatively more during the fast EM. The fast EM led to less emotional, less vivid and more difficult to retrieve images than the slow EM and recall only. Furthermore, the effects of slow EM were larger than for recall only. The authors concluded that dual-tasks that tax WM more result in larger decreases in the emotionality of aversive memories. Van Schie, van Veen, Engelhard, Klugkist, and van den Hout (2016) also asked participants to recall three emotional memories and rate vividness and emotionality before and after three conditions (recall only, recall + slow EM, recall + fast EM). The results showed dual tasks that taxed WM more, resulted in larger decreases in emotionality and vividness ratings of memories. Therefore, there appears to be a dose–response relation: the larger the WM loading, the larger the effects on emotionality and vividness ratings. Note however that there is also some evidence that this dose–response relationship may not necessarily be linear: it may follow an inverse U-curve. Engelhard, van den Hout, and Smeets (2011) manipulated the amount of WM loading by requiring participants to perform a simple, intermediate, complex mental subtraction task or no dual-task at all while holding a distressing memory in mind. For the emotionality scores, there was some support for an inverse U-curve dose–response relationship: a simple and intermediate mental arithmetic subtraction task showed more beneficial effects on emotionality scores than no task or the complex task. However, there was no support for an inverse U-curve for vividness.

Another possible way of optimizing EMDR therapy is by adjusting the modality of the dual task to the memory's modality. According to the WM model, modality-specific information is temporarily processed, stored and manipulated, in preferentially one of two subsystems: the visuospatial sketchpad, responsible for processing visual and spatial information and the phonological loop, responsible for auditory and verbal processing (Baddeley, 2012; Baddeley & Hitch, 1974). Therefore, the visuospatial sketchpad is involved in visual imagery and the phonological loop in auditory imagery (Kristjánsdóttir & Lee, 2011). The WM model (Baddeley & Hitch, 1974) also comprises a non-modal central executive, which is engaged when attention needs to be divided between tasks. On the one hand, it may be argued that changing modality specific memories will benefit from modality specific loading (vs. cross-modality loading). In other words, a visual dual-task will more effectively reduce emotionality of visual memories compared to an auditory task, and vice versa for auditory memories (e.g. Kemps & Tiggemann, 2007). Alternatively, one could argue that it is general task load – taxing the central executive – that reduces emotionality and vividness of emotional memories (Gunter & Bodner, 2008), and therefore any task that sufficiently taxes WM should be effective, regardless of modality.

There is evidence for both hypotheses. Some analogue studies have found (partial) support for the modality specificity account. Andrade et al. (1997) found that concurrent visuospatial tasks reduced emotionality and vividness ratings of visual images of personal memories. However, no concurrent phonological load on auditory personal memories was taken into account. Kemps and Tiggemann (2007) did take auditory memories into account and asked undergraduates to recall a specific visual or auditory image of a memory. They showed vividness and emotionality ratings were reduced to a greater extent with modality-specific loading. Apart from the modality-specific effect, they also found a large general effect of WM loading: vividness and emotionality ratings were reduced after a visuospatial condition (EM), verbal condition (counting), or a control condition.

Some analogue studies have only found support for the central executive account. Gunter and Bodner (2008) asked participants to hold distressing memories in mind while performing an auditory shadowing task (listening to a recording), or one of two visuospatial tasks (making EM or drawing a complex figure). They found that all dual tasks were effective in reducing the distress associated with negative memories, suggesting that the central executive was being taxed. Drawing figures was more effective in reducing distress than making EM or listening to a recording, leading them to suggest that drawing figures were more taxing on the central executive. In addition to this, they concluded there was no effect of modality-specific loading. Gunter and Bodner, however, did not specify how demanding the dual tasks were. Kristjánsdóttir and Lee (2011) asked participants to recall an unpleasant autobiographical memory while performing EM, listening to counting or a control condition (short exposure). They found that EM led to a greater decrease in vividness than listening to counting, that EM and listening to counting were equally effective in reducing emotionality and both effects were found irrespective of the modality of the memory. Kristjánsdóttir and Lee (2011) concluded that this supported the crucial role of the central executive.

Clinical studies have shown comparable results to analogue studies. In a study by Matthijssen, Verhoeven, van den Hout, and Heitland (2017), PTSD patients recalled two disturbing memories, one mainly visual, the other one mainly auditory and rated the emotionality of the memories before being exposed to two alternating supposedly equally demanding conditions and one control condition (EM, counting out loud, staring at a non-moving dot). Both memories (visual/auditory) showed a decline in the emotionality of the memory in all conditions and there was no modality specific effect. Another study of Matthijssen, Heitland, Verhoeven, and van den Hout (2018) showed the emotionality of aversive auditory memories of auditory hallucinations in patients suffering from auditory hallucinations reduced after being exposed to either EM or counting, more so than by staring at a non-moving dot, but no modality specific effect was found. In summary, there are different hypotheses about WM loading: one led by the central executive account, another one by a modality specificity account, and a third one, which combines the two preceding accounts.

There is a crucial problem with many of the studies that have investigated the effects of modality-specific loading. Typically, tasks that are supposed to tax the visuospatial sketchpad or phonological loop have been compared on some outcome measure (e.g. vividness and/or emotionality). When different modality tasks are compared directly, such as EM or counting, it is often assumed that they tax WM to a comparable degree, but this assumption has never been tested. However, this can be tested with a Random Interval Repetition (RIR) task (Van den Hout et al., 2011a; 2011b; Vandierendonck, de Vooght, & van der Goten, 1998; see Methods; materials). In an RIR task participants respond as soon as possible to a stimulus while doing an additional task (e.g. making EM) or without this task. The difference in reaction time is a measure of WM loading of the additional task. The studies of Matthijssen et al. (2017; 2018) tried to take the amount of WM loading into account by selecting an auditory and visual taxing task previously used in other experiments and known to be comparable in reaction time delay. However, although these two tasks were considered as equally taxing on WM, they did not test this, nor did they test their control condition (staring at a non-moving dot) on the amount of WM loading. Stickgold (2008) has also pointed out a concern with the type of control condition used (i.e. that eye fixation could also have an effect). In summary, differences between tasks may be due not to their modality, but to the degree of WM loading. Additionally, finding a proper control condition is challenging and it is crucial that WM loading is either measured or preferably that participants are their own controls (i.e. by adding a baseline measurement of the taxing dual tasks used).

An unresolved debate is whether the modality of loading in EMDR (visual or auditory) should be matched to the (visual or auditory) modality of the memory to achieve the best results in reducing the emotionality of emotional memories? PTSD patients suffer from traumatic memories. These are predominantly visual, but other sensory modalities may also be involved (Ehlers et al., 2002; Hackmann, Ehlers, Speckens, & Clark, 2004). Gaining understanding on how to treat memories predominantly in other sensory modalities is therefore valuable. A first step in treatment optimization is to experimentally test whether autobiographical memories of different modalities do indeed tax modality specific subsystems of the WM model differentially. As mentioned, there appears to be a dose–response relationship between load and effect (Maxfield et al., 2008; Van Schie et al., 2016; Van Veen et al., 2015). For optimizing treatment it would be helpful to know, whether loads matched in modality tax WM more than cross modal loads. Therefore, the aim of the present study was to test whether modality matched loads taxed WM to a larger extent than cross modal loading. We used an objective measure (reaction time) to assess the degree of WM load. In line with the WM taxation hypothesis one would expect both a benefit of WM loading in general and a modality-specific dual taxing benefit.

Hypotheses

Five different models can be deduced from the literature. Model 1 states that dual tasking (recalling a memory and performing an RIR task) in general taxes WM. Thus, if recalling a memory while being engaged in an RIR task is more taxing for the WM, this should, irrespective of modality, result in larger delays in reaction times than being engaged in the RIR task solely. Model 1 is depicted in Figure 1 and maps on to general WM taxation studies (Van den Hout et al., 2010).

Model 2 states that a modality matched dual task is more taxing on WM, so larger reaction time delays are expected on modality matched RIR tasks than on cross-modal RIR tasks. This is depicted in Figure 2. Model 2 is in line with Kemps and Tiggemann (2007) who showed the modality-specific taxing effect.

Model 3, depicted in Figure 3 states that matched-modal and cross-modal dual tasks have an equivalent impact on the WM, therefore no difference should be expected in reaction time delays between recalling a memory while being engaged in a matched modality RIR task and recalling a memory while being engaged in a cross-modality RIR task. Model 3 is in line with e.g. Kristjánsdóttir and Lee (2011) who show no modality specific taxation effect.

Model 2 and 3 are specifically focused on modality specific taxation, exploring the impact of modality-matched vs. cross-modal dual taxing, while ignoring general taxation. Model 4 and 5 are similar to model 2 and 3 respectively but take into account the general taxation effect as depicted in model 1 (See Methods; data analysis for more detail). Model 4 and 5 are therefore combinations of results found in earlier studies. Model 4 combines general taxation (e.g. Van den Hout et al., 2010) and modality specificity (Kemps & Tiggemann, 2007), while model 5 combines the general taxing effect (e.g. van den Hout et al.,

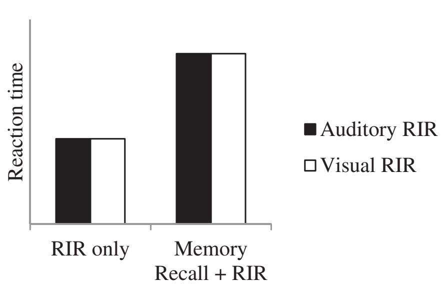

Figure 1. Model 1: Performing a RIR during memory recall results in larger reaction times than performing a RIR only.

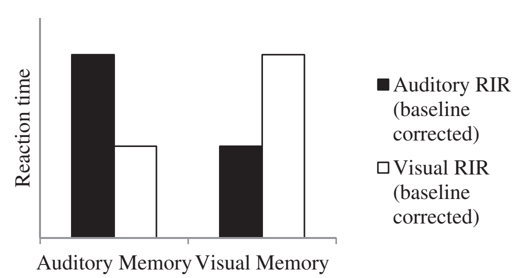

Figure 2. Model 2: Modality matched RIR + memory recall results in larger reaction times than RIR + cross modality memory recall.

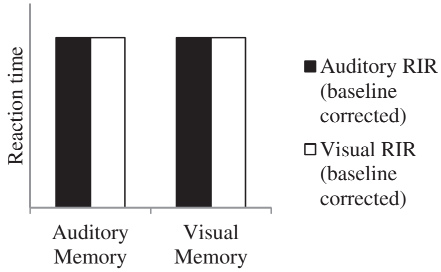

Figure 3. Model 3: Modality matched RIR + memory recall results in equal reaction times as RIR + cross modality memory recall.

2010) with the absence of a modality-specific effect (Kristjánsdóttir & Lee, 2011) (Figures 4 and 5).

Methods

Participants

The study was approved by the Ethics Committee of the Faculty of Social and Behavioral Sciences at the Utrecht University (FETC16-095). Ninety-six individuals took part (65 women, 31 men, $M = 22.04$, $SD = 2.51$, range 18-32). Participants were recruited at Utrecht University and participated in return for course credits or financial compensation.

Design

The study had a 2 × 3 design with and Load (Visual RIR vs. Auditory RIR) and Memory (No memory vs. Visual Memory vs. Auditory Memory) as within subject factors. Reaction time in milliseconds (ms) was measured by means of an RIR Task (see below). All participants selected one visual and one auditory memory and performed both a visual and an auditory RIR-task three times: once during a baseline phase (RIR

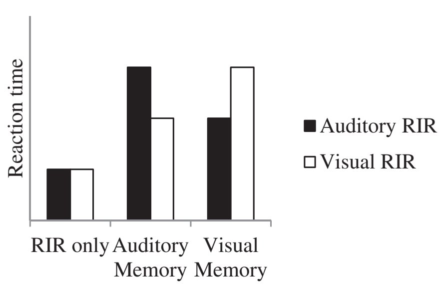

Figure 4. Model 4: Performing a RIR during memory recall results in larger reaction times than performing a RIR only & modality matched RIR + memory recall results in larger reaction times than RIR + cross modality memory recall.

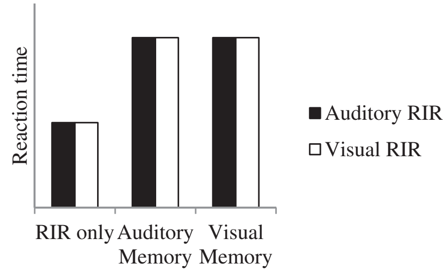

Figure 5. Model 5: Performing a RIR during memory recall results in larger reaction times than performing a RIR only & modality matched RIR + memory recall results in equal reaction times as RIR + cross modality memory recall.

only; no memory recall), once while recalling a visual memory and once while recalling an auditory memory (see procedure). Counterbalancing was used both for the sequence of the memory (auditory/visual) and the load (auditory/visual RIR task), resulting in 16 conditions to which participants were randomly assigned.

Materials

Modality specific RIR task

The RIR (Vandierendonck et al., 1998) task was adapted from van den Hout et al. (2011a; 2011b) and was presented using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). In the RIR task participants were instructed to press the letter B on the keyboard with the index finger of their dominant hand as soon as they detected a stimulus. The nature of this stimulus depended on the modality of the RIR task (auditory or visual). In the auditory RIR task participants listened to a 200 Hz beep that was played via headphones for a duration of 50 ms. In the visual RIR task participants saw a white circle that was 2 centimeters in diameter and was presented on a black computer screen for a duration of 500 ms. Stimuli from visual and auditory RIR tasks were presented in separate blocks (i.e. not intermixed). The interstimulus interval (ISI) was either 900 ms or 1500 ms (and included the time of stimulus presentation which was presented at the start of the ISIs) and no more than four consecutive ISIs of the same duration were used in a row, to prevent any expectation or prediction and to rule out automated responses. By adding different response intervals we created an unexpected pattern of when short or long intervals were presented, which means that the participant had to keep paying attention in order to respond to each presented stimulus. If only one length of the interval would have been offered, this could have created an automated response pattern. It is important to note that the difference in the duration of the presentation of the auditory and visual stimulus did not interfere with the possibility to respond during the stimulus. Participants could respond during the presentation of the stimulus and the remainder of both ISIs. This resulted in an equal opportunity to respond to both stimuli in all the RIR tasks.

Procedure

After signing an informed consent, a screening checklist was completed to check age, education level, sex and also to check if no exclusion criteria were met. Participants were excluded when they reported one of the following: (1) visual impairment, (2) hearing impairment, (3) being under influence of sedative drugs, alcohol or drug intoxication, (4) current psychological complaints interfering with response latency (e.g. depressive symptoms), (5) severe fatigue, or (6) extreme stress. Participants were seated in front of a computer and were instructed to perform two short practice blocks of the RIR task in which they responded to 8 auditory and 8 visual stimuli. Participants read the following instruction on the screen: "When you see the white circle (hear the beep) press the letter B as quickly as possible." RIR practice block order (visual/auditory) was counterbalanced. Participants always wore headphones during the RIR tasks. Following practice, participants performed an auditory and a visual RIR only with the order of blocks (visual/auditory) counterbalanced. In each block, participants were presented with 48 stimuli. There was a 30s interval between each block. After the RIR only phase participants turned away from the computer screen and were instructed by the experimenter to recall two emotional memories that were at least one week old; one predominantly visual in nature and the other predominantly auditory. Participants were asked: "Try to recall a for you, vivid, negative memory from an event that made you anxious or sad for example and that still has an emotional impact on you when you recall it. It must be a memory that still, at this moment, gives you a nasty feeling or tension, and it must be a memory that you mainly see (hear)." They were asked to write down a few key words of these memories and to indicate if the memory was at least 50% visual respectively auditory in content. Emotionality of the memories was rated by the participants by giving a number ranging from 0 (*not at all unpleasant*) to 100 (*very unpleasant*). In the present context, vividness was not taken into consideration. The purpose was to select memories that were aversive in nature, and vividness is not discriminating between non-aversive and aversive memories. Emotional valence was therefore considered an important factor. Furthermore, in EMDR-therapy, as opposed to scientific research on traumatic memories, vividness is never measured nor asked for at the patient. To stay close to the nature of EMDR therapy the only emotionality was therefore taken into consideration. Memories rated below 60 were excluded and participants were asked to select another memory in the same modality. This could potentially have led to a demand effect, meaning that participants would subsequently rate another selected memory as more emotional than actually perceived, although participants were unaware of the consequences of not selecting a more emotional memory. If the emotionality of memories was overestimated as a result of a demand effect, this may imply that results were harder to find. Assuming that more emotional memories are more taxing on WM and thereby enlarge WM interference, a smaller effect on WM would be assumed when less emotional memories were recalled. If a demand effect was present this would therefore potentially imply more robust results. The researchers are unaware of the number of memories rated below 60, because they were not registered. After selecting two memories with an emotionality score of 60 or higher, participants started with one of the two and were instructed to describe the memory roughly, select the memory's hotspot (worst sound for an auditory memory; worst image for a visual memory) and to label the hotspot with a working title and write this working title down. Then, the experiment was set up, the experimenter entered the working title and participants turned their chair again to sit facing the computer. Participants were instructed to recall the image of the visual (auditory) memory and to focus on what they saw (heard) in the image (fragment) and to simultaneously respond as quickly as possible when the visual (auditory) stimulus was presented. The working title appeared shortly on the screen cueing the participant to recall the auditory (visual) memory hotspot. Subsequently, the auditory and visual RIR tasks were performed while recalling the auditory (visual) memory hotspot. After this, participants completed the same tasks (selecting the worst part, specify a working title and conducting both RIR tasks while recalling the hotspot) for the visual (auditory) memory. The order of memories was fully counterbalanced. After completing the RIR tasks participants were given a debriefing. Lastly, participants received monetary compensation or course credits. The experiment lasted approximately 30 min.

Data preparation

Reaction times were operationalized as the time between stimulus onset and a participant's response to the (auditory or visual) stimulus. It should be noted that participants could respond to a stimulus while it was being presented, or in the ISI following stimulus display. All individual reaction times were plotted to establish a lower bound cutoff-point for the reaction time. Visual inspection of the data showed a random distribution of reaction times below 139 ms and a smooth trend of rising reaction times from 139 ms. Therefore all reaction times below 139 ms were considered as errors and were deleted (cf. van den Hout et al., 2011a). One could argue the reaction times below 139 ms are a reflection of the expectancy the stimulus, but this is also considered an error since it does not reflect the true response to the presented stimulus. Due to a programming error, no data were obtained in a part of the short ISI of the visual RIR. It should be noted that participants could respond during the presentation of the stimulus in all RIR conditions and in the remainder of the ISI. In the latter case (short ISI), this meant that participants could only respond during stimulus display (i.e. the white circle: 500 ms) but not in the remainder of the short ISI (400 ms). As a consequence of the programming error, reaction times above 500 ms in this condition were not recorded. We decided to remove the short trials all together instead of discarding only the data above 500 ms. This strict measure was taken because of the ex-Gaussian distribution of reaction times, in which the tail has a large effect on mean reaction time (Schmiedek, Oberauer, Wilhelm, Süß, & Wittmann, 2007; Shahar, Teodorescu, Usher, Pereg, & Meiran, 2014). Discarding data below 139 ms resulted in deleting 29 (0.42%) visual reaction times and 34 (0.49%) auditory reaction times of the 1500 ISI. Also there were 109 (1.58%; 17 during baseline, 17 during recall of the auditory memory and 41 during recall of the visual memory) missings in the visual reaction times and 75 (1.09%; 11 during baseline, 55 during recall of the auditory memory and 43 during recall of the visual memory) missings in the auditory reaction times. A missing refers to the absence of a response to the visual/auditory stimulus. Participants either failed to press on time (during stimulus display or within the ISI) or did not press the button at all, so no reaction time was recorded.

Data analysis

The hypotheses were defined in five models (and exact constraints can be found in the appendix): Model 1 tested whether recalling any kind of memory together with any kind of RIR task was more taxing than only performing the RIR task. Therefore, this model tested an effect of general loading. Model 2 tested whether simultaneously performing memory recall and an RIR task in the same modality (corrected for baseline) was more taxing than performing memory recall and an RIR task in a different modality (corrected for baseline). Therefore, this model specifically tested whether modality specific loading (independent of the effect of general loading) was more taxing than cross-modality loading. Model 3 tested whether simultaneously performing memory recall and an RIR task in a different modality (corrected for baseline) was equally taxing than performing memory recall and an RIR task in the same modality (corrected for baseline). Therefore, this model specifically tested whether cross-modal loading (independent of the effect of general loading) was equally taxing than matched modality loading. Model 4 is a combination of model 1 and 2. Therefore, this model specifically tested whether dual loading taxed WM more and whether modality specific loading was more taxing than cross modality loading. Model 5 is a combination of model 1 and 3. Therefore, this model specifically tested whether dual loading taxed WM more and whether cross-modality loading was equally taxing as matched modality loading.

Given the fundamental limitations in null hypothesis testing (Gliner, Leech, & Morgan, 2002; William, 2000) and given the fact that in this study a set of a priori hypotheses was set, Bayesian statistics were used to derive strength of evidence for these models. In contrast to the frequentist statistics, which depends on dichotomous decisions, Bayesian model selection provides relative support for a prespecified model or models (Klugkist, Laudy, & Hoijtink, 2005). Furthermore, it has the advantage that different models can be tested at once, which allows data in support of competing hypotheses to be compared (Béland, Klugkist, Raîche, & Magis, 2012). The results of the Bayesian model selection are expressed in terms of Bayes factors (BFs). A BF represents the level of evidence for one model compared to another and the higher this factor, the more support for the pre-specified model. A BF value greater than 1 indicates that the data support the model or hypothesis. A BF value less than 1, indicates no support for the model or hypothesis. Support for an informative hypothesis is evaluated against a model without constraints. One can also compare two informative hypotheses mutually by computing the ratio of the two BFs for the informative hypotheses against the unconstrained model. Analyses were performed using the software BIEMS (see Mulder, Hoijtink, & de Leeuw, 2012; Mulder, Hoijtink, & Klugkist, 2010). Though the BF is a continuum it may be categorized to facilitate scientific communication. According to Lee and Wagenmakers (2013), a BF between 1 and 3 may be interpreted as "anecdotal" support, between 3 and 10 as "moderate", larger than 10 can be interpreted as "strong" support and a BF larger than 30 as "very strong support". BFs above 100 is viewed as "extreme" support.

Results

Observed reaction times

Data from 96 participants were used for the analyses. Originally, data were obtained from 98 participants, however, data from two participants were excluded. Both participants suffered from tinnitus, and it was unclear how much this affected the results. The average emotionality score for the auditory memory was 76.93 (*SD* = 10.35) and for the visual memory, it was 78.26 (*SD* = 9.72). Examples of auditory memories that were reported were: being "booed" of the stage while giving a performance, a screaming mother after hearing the news that grandfather past away and hearing the gun that was used at a robbery at work. Visual memories reported were for example: being left alone at the school yard and standing alone there crying against the fence, seeing a conductor of the orchestra die during a performance on stage and being involved in an accident. Reaction times are shown in Table 1 and the mean reaction times while recalling an auditory memory and visual memory with baseline scores subtracted are visualized in Figure 6. Both Table 1 and Figure 6 show that in the case of auditory memories (left bars in Figure 6) responses on the auditory RIR were slower than on the visual RIR and the pattern was reversed for the visual memory (right bars).

Table 1. Mean reaction times and standard deviations on the visual and auditory RIR tasks at baseline and during auditory and visual memory recall.

	RIR only	Auditory Memory	Visual Memory
Visual RIR task	290.19 (34.62)	338.66 (79.17)	351.02 (80.80)
Auditory RIR task	270.72 (45.86)	341.42 (108.83)	317.41 (93.86)

Bayesian analyses of reaction times

The strength of evidence for the models is presented in Table 2. Model 1 stated that dual taxing in general – performing any kind of RIR task and recalling any kind of memory – would result in larger delays in reaction time than performing a single task (RIR only). The results supported this, and showed the impact of general loading. ($BF_1 = 8.75$). Model 2 stated that matched modality taxing would result in larger reaction times than cross modal taxing. This pattern was supported by a BF of 5.36. Model 3 stated that that matched taxing would result in equal reaction time delays as cross modal taxing. There was no support for this model ($BF_3 = 0.32$). Comparing model 2 and 3 ($BF_{23} = 16.75$) showed there was substantially more relative support for a benefit of modality-specific taxing. Model 4 was supported with a BF of 39.96. This suggests very strong evidence for loading in

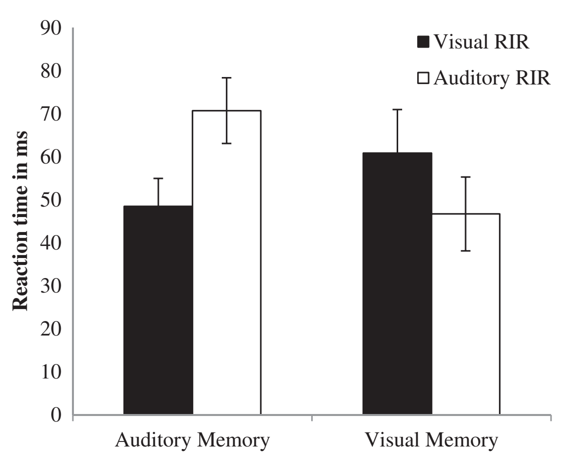

Figure 6. Mean (with ± 1SEM) reaction times in ms while recalling an auditory memory and visual memory with baseline scores subtracted.

Table 2. Strength of evidence represented by the Bayes Factor (BF) per model.

	BF
Model 1 (general taxation)	8.75
Model 2 (modality specificity)	5.36
Model 3 (no modality specificity)	0.32
Model 4 (general taxation + modality specificity)	39.96
Model 5 (general taxation + no modality specificity)	1.05

general combined with a modality specificity effect: there was a larger delay in reaction time when the RIR task and memory were in the same modality, compared to when they were in different modalities and a large delay in reaction time when performing a dual task in general. No support was found for model 5 – which combined general WM loading and equal effects for modality-specific and cross-modal taxing – ($BF_5 = 1.05$). Comparing model 4 and 5 resulted in very strong evidence for a general WM loading effect with a modality-specific effect superimposed on that ($BF_{45} = 38.06$).

Discussion

We tested whether performing a dual task in the same modality as a recalled emotional memory was more taxing than performing a dual task in cross modality in order to explore ways to improve the effects of EMDR. This was assessed by letting participants recall a visual and an auditory emotional memory while performing a visual and an auditory RIR task. The results were clear: a larger impact on WM (operationalized in stronger effects on delay in reaction time) was found when the RIR task was performed in the same modality as the recalled memory than when the RIR task was performed in cross-modality ($BF_2 =$ 5.36). The results also showed an impact of dual tasking on WM in general – regardless of the modality in which the dual task was performed ($BF_1 = 8.95$). The strongest evidence was found for the model in which dual tasking, in general, was *combined* with the model that showed a greater effect of modality-specific loading ($BF_4 = 39.96$). It should be noted this does not imply anything about the size of the effect, only about the support for the model. The results showed that dual-tasking during memory recall, in general, had an impact on WM (which is in line with the central executive account), and that there was a larger effect of modality-specific dual-tasking compared to cross-modality loading (which is in line with the modality specificity account). The findings are surprisingly consistent with earlier research by Kemps and Tiggemann (2007), which demonstrated a large benefit of WM loading in general and a smaller and super-imposed modality-specific benefit. The BF of both general taxing ($BF_1 = 8.95$) and modality-specific taxing ($BF_2 = 5.36$) combined was 39.96, indicating *very strong* support of the combined value of both general and modality-specific loading (Lee & Wagenmakers, 2013). This indicates that the central executive account and the modality specificity account are *complementary* and thus suggests that the used dual tasks both tax the central executive and subsystems; the visuospatial sketchpad in case of the visual RIR and the phonological loop in case of the auditory RIR.

The current study adds important information compared to earlier ones (e.g. Gunter & Bodner, 2008; Kemps & Tiggemann, 2007; Kristjánsdóttir & Lee, 2011; Matthijssen et al., 2017a, 2018). Both the *degree* of WM loading and the *modality* of loading were taken into account. Earlier studies often failed to test the presence and degree of WM loading and have concluded – where there was no modality-specific effect in the presence of dual tasks in different modalities that the effect was due to taxing the central executive. This, in fact, could be just a consequence of difference in degree of task loading (e.g. Gunter & Bodner, 2008; Kristjánsdóttir & Lee, 2011; Matthijssen et al., 2017a, 2018). Furthermore, no modality specificity can be inferred if WM loading is not taken into account and where only one memory modality (e.g. visual memory) is employed (e.g. Andrade et al., 1997). Kemps and Tiggemann (2007) inferred modality specificity without assessing the amount of WM loading by using a design in which both modalities were used for the selection of the memory and dual task.

Although a programming error led to our decision to delete all responses in the short ISIs and discard half of the data, such a measure was justified to be able to take reaction times in the tail of the distribution into account. It is not likely that the taken measure affected the results, because there were more than enough reaction times. A potential limitation of the study, however, is that the emotionality of the memory was only obtained at memory selection, so no definite conclusions can be drawn about the effect of the more demanding loading on emotionality of the memories. Both measures (emotionality scores and reaction time) should be taken into account in future research. Another important limitation is that, although the degree of taxation is taken into account per modality specific RIR, it is not known to what extent the both RIR tasks tax the modality-specific subsystems and to what extent motor interference plays a role. Onderdonk (2016) for example point out that the effects of EM on overall WM taxation and changing memory vividness are not exclusively the result of visual information occupying the visuospatial sketchpad. They conclude it is rather a combination or interaction between visual information occupying the visuospatial sketchpad and motor movements. Motor interference could also play a role in the current study. On the other hand, if motor interference contributed largely to the RT in this study, this was the case for all conditions. Still, it is plausible that the extent of motor interference interacts differently with RIR tasks in different modalities. Future research should address this point.

The outcome of this study may have implications for the understanding and practice of EMDR therapy. One way to optimize EMDR therapy could be by taxing WM more during memory recall. Earlier studies have shown a larger effect of a higher load of WM taxation on the decrease of emotionality of aversive memories (Maxfield et al., 2008; Van Schie et al., 2016; Van Veen et al., 2015). Another option could be to tax WM differently during memory recall, thereby inducing interruption in the specific WM subsystem (visuospatial sketchpad or phonological loop) causing more loading, which was investigated in this study. Baddeley and Hitch had already proposed an effect of modality-specific interference, suggesting that performing two tasks in the same modality is more taxing than performing two tasks in a different modality. This study adds evidence in favour of this modality specific interference hypothesis in dual tasking while recalling *emotional* memories. The aim of this study, however, was not to assess the emotionality and/or vividness but to assess whether adapting the modality of dual tasking could lead to optimizing WM taxation. With this effect, one could potentially have a clinically relevant tool for optimizing EMDR therapy, since the data suggest a potential modality-specific concurrent task effect in EMDR therapy: focusing on the specific memory modality and targeting the specific WM subsystem, could therefore possibly lead to more WM taxation and consequently a more effective treatment. However, at the present time, this is a suggestion based on the outcome of experimental studies on reaction time data and lacks validation on emotionality ratings and in clinical studies. Further research should investigate the relationship between taxation of WM subsystems and clinically relevant outcome measures. Nevertheless, it may be assumed that, to the extent that the results generalize to traumatic imagery, patients with predominantly auditory intrusions (e.g. remembering the sound of a crash or somebody screaming) would benefit from concurrent auditory dual tasks (e.g. counting aloud) during memory recall, whereas patients with predominantly visual intrusions would benefit from engaging in visual loading (e.g. EM).

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Appendix

Model 1: Memory Recall + RIR > RIR only

(Auditory Memory + Auditory RIR) > Baseline Auditory RIR
(Auditory Memory + Visual RIR) > Baseline Visual RIR
(Visual Memory + Auditory RIR) > Baseline Auditory RIR
(Visual Memory + Visual RIR) > Baseline Visual RIR

Model 2: (modality matched memory recall + RIR) − baseline RIR > (cross modality memory recall + RIR) − baseline RIR

(Auditory Memory + Auditory RIR) − Baseline Auditory RIR > (Auditory Memory + Visual RIR) − Baseline Visual RIR

(Visual Memory + Visual RIR) − Baseline Visual RIR > (Visual Memory + Auditory RIR) − Baseline Auditory RIR

Model 3: (modality matched memory recall + RIR) − baseline RIR = (cross modality memory recall + RIR) − baseline RIR

(Auditory Memory + Auditory RIR) − Baseline Auditory RIR = (Auditory Memory + Visual RIR) − Baseline Visual RIR

(Visual Memory + Visual RIR) − Baseline Visual RIR = (Visual Memory + Auditory RIR) − Baseline Auditory RIR

Model 4: (memory recall + RIR > baseline RIR) & (modality matched memory recall + RIR) − baseline RIR > (cross modality memory recall + RIR) − baseline RIR

All constraints of model 1 & model 2.

Model 5: (memory recall + RIR > baseline RIR) & (modality matched memory recall + RIR) − baseline RIR = (cross modality memory recall + RIR) − baseline RIR.

All constraints of model 1 & model 3.