Universiteit Utrecht

Does modality-specific working memory taxation matter?

By Timothy John Antonio Thodé

Utrecht University

Faculty of Social Sciences

Master Thesis Clinical and Health Psychology

T.J.A. Thodé - 3734315

Supervisors: prof. dr. Marcel van den Hout
drs. Suzy Matthijssen

January 2018

Word count: 4772 (Excluding abstract, figures, references and appendices)

Abstract

This study investigated whether modality-specific dual tasks have more impact on the working memory (WM) during memory recall than a modality-non-specific dual task. The first model proposed that modality-specific dual task is superior to a modality-non-specific dual task in WM taxation. The second model proposed that modality-specific dual task and a modality-non-specific dual task have an equivalent impact on the WM. The third model proposed that there is a WM taxation regardless the modality of the dual task. The study had a three (Memory recall: Visual, Auditory and No memory recall) by two (Dual Task: responding to a Tone or Circle) within-subject design, with the reaction time (RT) as a dependent variable. Ninety-six participants were recruited at Utrecht University. The results showed that there was a WM taxation regardless of the modality of the dual task. The RT's on the dual tasks appears to slow down when participants held a memory in mind. This effect was substantial when there was a match between the nature of the dual task and the recalled memory. Furthermore, the Bayes Factor (BF) indicates that the data was approximately ten times (BF_{12} = 10.04) more likely to occur under the hypothesis 1 than under hypothesis 2. The outcomes of this study indicate that using a dual task during memory recall will have an impact on the WM taxation. Whilst taxing the appropriate subsystem of the WM with a modality-specific dual task will lead to a greater WM taxation.

Keywords: EMDR, Working memory taxation, Modality specificity

Does modality-specific cognitive loading matter during working memory taxation?

Post-traumatic stress disorder (PTSD) can develop after exposure to a life-threatening traumatic event. PTSD consists of symptoms such as intrusive flashbacks, hyperarousal, and avoidance of the reminders of the traumatic event (Prakash, Saha, Das, Srivastava & Shashikumar, 2016; Yehuda, 2002). An earlier study by the World Health Organization (WHO) has shown that approximately 3.6% of the world's population suffers from PTSD (WHO, 2013). The traumatic events may have a long-term negative impact on the wellbeing of the person suffering from PTSD (Tabrizi & Jansson, 2016), making PTSD clients an important group for effective treatment approaches.

A commonly used treatment for PTSD is "eye movement desensitization and reprocessing" (EMDR; Shapiro, 1996) introduced by Shapiro (1989). During an EMDR session, the client makes horizontal eye movements (EM) while simultaneously concentrating on an identified image of emotional disturbance, typically a traumatic episode (Shapiro, 1996). Shapiro (1989) studied the use of saccadic eye movements for the treatment of PTSD, with results showing that EM was enough to desensitize the traumatic memories. In more recent studies EMDR has been shown to be clinically effective in reducing traumatic stress symptoms (Bradley, Greene, Russ, Dutra & Westen, 2005; Lee & Cuijpers, 2013; Seidler & Wagner, 2006) compared to waitlist and usual care, in addition to being equally effective as exposure and cognitive behaviour therapy (Bisson & Andrews, 2007). Therefore, EMDR has been strongly recommended by the American Psychological Association (APA) PTSD treatment guideline as an evidence-based psychotherapy for the treatment of PTSD (APA, 2017).

The clinical treatment effects of EMDR have been modeled in controlled experiments, where healthy participants recalled negative memories either with-or-without performance of a dual task and rating their memories (before and after the intervention) in terms of vividness and emotionality (van den Hout & Engelhard, 2012). Studies have found a decrease in vividness and emotionality of the memory component when the participants performed a dual task while recalling the unpleasant memory, compared to a memory recall only (Andrade, Kavanagh, Baddeley, 1997; Kemps & Tiggemann, 2007; Maxfield, Melnyk & Hayman, 2008; van den Hout, Engelhard, Rijkeboer, Koekebakker, et al., 2011; van den Hout, Kindt, Muris & Salemink, 2001; van Veen, Engelhard & van den Hout, 2016). In a recent meta-analysis, Lee and Cuijpers (2013) included fourteen studies (consisting of clinical and student samples) comparing EM to no EM in full EMDR treatments. Lee and Cuijpers (2013) came to the conclusion that EM has an additional effect in processing emotional memories, in both treatment and laboratory contexts.

The reduction of memory emotionality and vividness in clinical and experimental studies can be explained by the working memory (WM) theory (Andrade et al., 1997; Kemps & Tiggemann, 2007; van den Hout & Engelhard, 2012). WM consists of different subsystems such as the central executive (CE), the visuospatial sketchpad (VSSP) and the phonological loop (PL). The CE provides high cognitive functions, that allocates and divides attention. The VSSP processes and stores spatial and visual information, whereas the PL processes and stores the verbal or auditory information (Baddeley, 1998; Kristjánsdóttir & Lee, 2011; Maxfield et al., 2008; Vandierendonck et al., 1998). The WM model of Baddeley and Hitch (1974) postulates that an individual temporarily stores information that is directly active and is used to perform cognitive operations (Maxfield et al., 2008; van den Hout & Engelhard, 2012). Van den Hout and Engelhard (2012) stated that simultaneously performing Task A (e.g. a reaction time (RT) task) and Task B (e.g. dual task) would decrease the RT compared to the initial RT in Task A. The degree of delay produces a quantitative index of the amount of the WM taxation (van den Hout & Engelhard, 2012). Performing a cognitive operation during memory recall and increasing the complexity of this cognitive operation will increase the WM taxation (Engelhard, van den Hout & Smeets, 2011; van Veen et al., 2016), thus increasing the RT on more complex cognitive operations.

In addition to the WM taxation, is it relevant to discuss the stressful (or traumatic) experience; an important component of the traumatic memory. Individuals diagnosed with PTSD suffer from distressful memories that cause a re-experience of the traumatic event in daily thoughts of the individual, referred to as an intrusion (Sadock, Sadock & Ruiz, 2014). The intrusive memories can manifest themselves in the form of visual intrusions, auditory intrusions, bodily sensations, smell, actions or thoughts (Ehlers, Hackmann, Steil, Clohessy et al., 2002; Ehlers & Steil, 1995; Salyards, 2005). Focusing more on the content of the distressful memory, it is important to consider the sensory modality of the distressful memory and distraction task (Bourne, Frasquilho, Roth and Holmes, 2010). There is some evidence for stimulus modality and dual task, where a (mis)match between the memory and the dual task (that is carried out during memory recall) has an impact on the memory experience (e.g. vividness ratings). Visual memories were degraded more by visual dual task (e.g. visual patterns, visuospatial tapping, modeling clay) than by auditory dual tasks (Baddeley & Andrade, 2000; Bourne et al., 2010; Maxfield et al., 2008; Stuart, Holmes, Brewin, 2006), whereas auditory memories were more degraded by an auditory dual task (e.g. counting aloud, beeps) relative to visuospatial dual tasks (Baddeley & Andrade, 2000; Tabrizi & Jansson, 2016). Nevertheless, there are also studies (Gunter & Bodner, 2008; Kristjánsdóttir & Lee, 2011) that have found no evidence for modality specificity. Gunter and Bodner (2008) found that taxation of the CE during a dual task (EM, auditory or drawing task), whilst holding a memory in mind, decreased the vividness and emotionality rating of the memory. The auditory shadowing task used in this study had the same effect as the EM condition. The effect occurred even when the VSSP was not taxed, suggesting that memory degradation was a result of CE taxation rather than the VSSP alone (Gunter & Bodner, 2008). Furthermore, Gunter and Bodner (2008) concluded that using a more demanding task (e.g. the Rey complex figure task) have greater memory rating reduction than EM or auditory shadowing, as a result of using the CE resources. Kristjánsdóttir and Lee (2011) found that EM and counting task led to a significant decrease in vividness and emotionality of the distressing memory, compared to the control group (which did not perform a dual task). EM led to the greatest reduction in vividness and emotionality independent of the sensory modality of the distressing memory.

A study by Kemps and Tiggemann (2007) showed the effects of concurrent visual and auditory interference on emotive imagery. In their first experiment, participants recalled a pleasant and a distressing visual or auditory memory whilst looking at a black computer screen (control group) or performing the dual task (EM or articulatory suppression (AS): counting aloud). Both vividness and emotional response were significantly lower in the EM or AS condition than recall only condition (control group). The dual task can reduce vividness and intensity of emotive images, loading the VSSP or PL. In the second experiment, participants were randomly assigned to form one visual or auditory imagery of both a pleasant and distressing memory. Vividness and emotiveness ratings of the visual images were reduced to a greater extent by the EM task than by AS task, whereas auditory imagery was less vivid and emotive during the AS task than during the EM task. Kemps and Tiggemann (2007) suggest the concurrent articulation has an impact on the vividness and emotionality through competition for limited PL resources, whilst EM has an impact on the vividness and emotionality through the competition for limited VSSP capacity. The findings of Kemp and Tiggemann (2007) suggest that individuals experiencing a modality-specific trauma (visual or auditory) would benefit more from modality specific concurrent tasks (visual memory and visual task or auditory memory and auditory task), reducing the distress of the traumatic memory.

The findings of Kemps and Tiggemann (2007) were supported by other studies (Lilley, Andrade, Sabin-Turpin, Farrell & Holmes, 2009; Tabrizi & Jansson, 2016) showing that modality-specific taxation had more effect than modality-non-specific taxation. These studies show that participants who perform a PL task (e.g. counting) had a decrease in vividness and emotionality of the auditory intrusions compared to VSSP task (e.g. shaping clay models) (Tabrizi & Jansson, 2016), whilst vividness and emotionality of the visual intrusion were greater reduced during the EM-task than during the verbal task (e.g. counting) (Lilley et al., 2009).

Research has shown that modality-specific cognitive loading has more impact on recalled memories, but on the other hand, there is also evidence for the modality-non-specific cognitive loading. Thus, there is still controversy regarding the importance of modality-specific cognitive loading. The present study uses the WM framework to investigate whether modality-specific dual tasks have more impact on the WM during memory recall than a modality-non-specific dual task. Based on previous studies (Baddeley & Andrade, 2000; Bourne et al., 2010; Kemps & Tiggemann, 2007; Stuart et al., 2006; Tabrizi & Jansson, 2016) it is expected that the modality-specific dual task will be superior in WM taxation compared to the modality-non-specific dual task. Thus, a visually dual task should have more impact on the WM during a visual memory recall, whereas an auditory dual task should have more impact on the WM during an auditory memory recall. On the contrary, based on other studies (Gunter & Bodner, 2008; Kristjánsdóttir & Lee, 2011) it is expected that the modality-specific dual task and modality-non-specific dual task have an equivalent impact on the WM. Lastly, it is also expected that there will be a WM taxation, regardless of the modality of the dual task. Bayesian statistics will be used to evaluate the hypotheses formulated above, to directly compare the informative expectations of multiple group means (Béland, Klugkist, Raîche & Magis, 2012).

Method

Participants

Ninety-six students were recruited at Utrecht University (31 men, 65 women, M_{age} = 22.04, *SD* = 2.51). Level of education ranged from middle vocational education (MBO) to university (WO), as presented in *table 1*. Participants were excluded if they met the following criteria: having a visual or hearing impairment, being under influence of sedative drugs, alcohol or drug intoxication, having a psychological impairment and suffering from severe fatigue or extreme stress. Each participant received course credits or financial compensation. Counterbalancing was used to order the sequence of the independent variables (memory recall and dual-task). The experiment consisted of 16 conditions. The order of the conditions was balanced, wherein six participants were randomly assigned to one of each condition (*see appendix A)*.

Table 1. *Socio-demographic characteristics of the sample (N = 96)*

Education level	% Sample
Middle vocational education (MBO)	1.04
Higher vocational education (HBO)	2.08
University (WO)	96.88

Design

The study had a three (Memory recall: Visual, Auditory and No memory recall) by two (Dual Task: reacting to a Tone or Circle) within-subject design. Participants were tested in both memory modality recall and dual tasks. The study design assessed the impact of the modality-(non)-specific dual task on the WM during memory recall, with the RT as a dependent variable. All participants selected one visual and one auditory memory and were randomly assigned to a visual and an auditory dual task.

Procedure and Materials

This study was approved by the committee of scientific research of the faculty of social sciences at the Utrecht University. The participants received an oral and written information about the experiment. Participants that decided to participate gave a written informed consent. The participants sat in front of a computer and wore a headphone during the computer task. Eprime 2.0 (by Psychology Software Tools, Inc.) was used to present the stimuli (circle or tone) during the dual task. The visual stimuli “Circle” and auditory stimuli “Tone” (200-Hz) were administered at a random frequency. During the visual dual task, a circle (*see appendix B*) was shown for 500 ms and the inter-stimulus interval (ISI) for the visual dual task ranged between 400 and 1000 milliseconds. During the auditory dual task, a tone (*see appendix C*) was present for 50 ms and the ISI for the auditory dual task ranged between 850 and 1450 milliseconds. Participants reacted to the stimuli by pressing the “*B*” button on the computer keyboard with their dominant index finger and were requested to respond as quickly as possible.

The experiment consisted of a practice trial, followed by a baseline, visual and auditory memory recall trial, with a 30 s interval between each trail. The practice trial consisted of the visual dual task with a series of 8 circles and the auditory dual task with a series of 8 tones. This was followed by the baseline trial consisting of the visual dual task with a series of 48 circles and the auditory dual task with a series of 48 tones (*see appendix D*). The participants were randomly assigned (during the baseline trial) to start with either the visual or auditory dual task. There was no memory recall during the practice and baseline trial.

After the practice and baseline trial participants recalled a distressful visual and auditory memory, which had an emotional influence. They chose a past memory from at least one week or several years ago, that needed to be more than 50% visual or auditory. Keywords about the recalled memory were written down and the unpleasantness of the memory was rated, ranging from 0% (*not at all unpleasant*) to 100% (*very unpleasant*). Participants who scored a memory below 60% were requested to recall a more unpleasant memory. The average unpleasantness score was 76.93 (*SD* = 10.35) (auditory memory) and 78.26 (*SD* = 9.72) (visual memory). After recalling the memory participants indicated how long ago the situation occurred and chose a specific fragment of their recalled memory (mental imagery or specific sound) and recorded one or multiple keywords for this specific fragment. Afterwards, the participants were randomly assigned to the visual and auditory memory recall trial, consisting of a visual dual task with a series of 48 circles and an auditory dual task consisting of 48 tones. Participants were reminded (by the title that was provided) at the beginning of each trial to focus on the specific fragment whilst performing the auditory or visual dual task (*see appendix E*). The participants were randomly assigned to begin with either the visual memory recall trial, followed by the auditory memory recall trial or vice versa. The researcher was present in the same room as the participant during the whole experiment.

Data preparation

The lower cutoff-point for the RT-trials was formed by investigating the RT normal distribution. The RT normal distribution has shown a lower tail at 139 ms and therefore all RTs below 139 ms were deleted. A programming error has been found in the visual dual task data. A wrong key was programmed for the short inter-stimulus interval (900 ms). This had a consequence that the total missing was higher for the visual dual task compared to the auditory dual task, therefore all RTs over 500ms were deleted. A total of two thousand, four hundred and forty-two (8.83%) RTs were removed from the dataset after the error correction.

Data analysis

The hypotheses were evaluated by using the Bayesian model selection criterion. In contrast to the frequentist statistics, which assume that there is one true population parameter of interest to be unknown and fixed, the Bayesian framework views all unknown parameters as uncertain, by incorporating background knowledge in their analyses (van den Schoot, Kaplan, Denissen, Asendorpf et al., 2014), comparing the support in data for the alternative hypothesis against the competing hypothesis or inequality constraints (Béland, Klugkist, Raîche & Magis, 2012). A Bayes Factor (BF) value greater than 1, indicated that the data supports the alternative hypothesis over the null hypothesis. A BF value lesser than 1, indicated that the data supports the null hypothesis over the alternative hypothesis. A BF value approximately or equal to 1, indicated that both hypotheses are equally supported by the data (Diens, 2011). The data analyses were performed using the software BIEMS (Mulder, Hoijtink & de Leeuw, 2012).

Results

The data analyzed in BIEMS was computed by subtracting the average RT in the baseline condition (dual task only) from the average RT in the visual and auditory memory recall condition (dual task with memory recall). A large difference between the average RT indicates a high (slower) RT in the visual and auditory memory recall condition than the baseline condition. Whilst, a small difference between the average RT indicates a low (faster) RT in the baseline condition than the visual and auditory memory recall condition. Figure 1 shows that the average RT was slower during the auditory memory recall condition, whilst performing the auditory dual task. Whereas the average RT was slower during the visual memory recall condition, whilst performing the visual dual task (*see figure 1*). The average RT of each condition is graphically depicted in figure 2, showing a slower average RT for both the visual and auditory dual task, regardless of the memory recall (visual or auditory) condition.

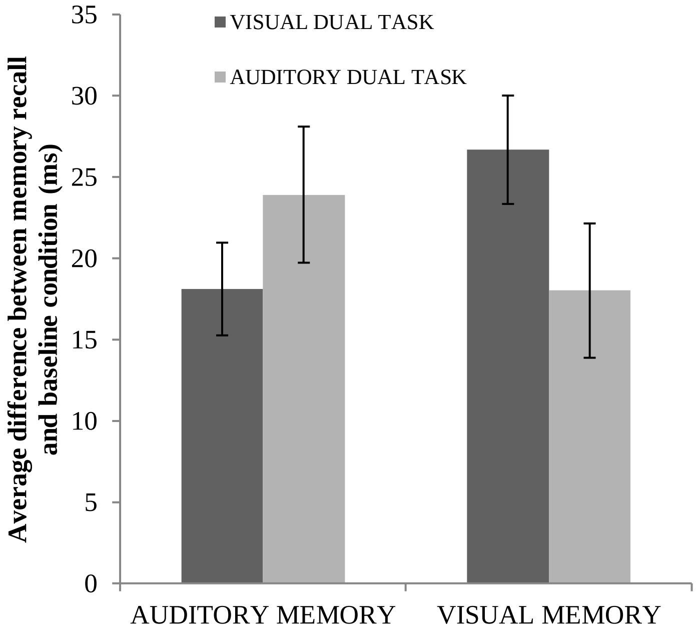

Figure 1. The Average difference between (visual or auditory) memory recall and baseline condition (ms) representing the difference in detection speed for each dual task (visual or auditory). The difference was computed by subtracting the average RT in the baseline from the (visual and auditory) memory recall condition. Error bars denote one standard error around the mean.

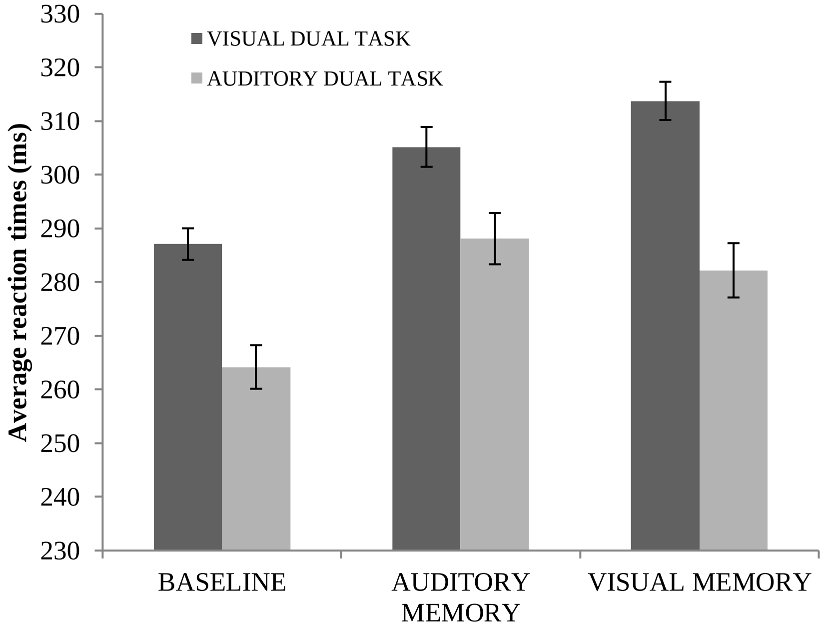

Figure 2. Average reaction time (ms) representing detection speed for each dual task (Visual or Auditory) in the different condition (baseline, auditory and visual memory recall condition). Error bars denote one standard error around the mean.

The first hypothesis that modality-specific dual task is superior to modality-non-specific dual task in taxing the WM was imported in BIEMS as constraint model 1 (M1: $\mu_{\text{modality specific}} > \mu_{\text{modality-non-specific}}$). The second hypothesis that the modality-specific dual task and modality-non-specific task have an equivalent impact on the WM was imported in BIEMS as constraint model 2 (M2: $\mu_{\text{modality specific}} = \mu_{\text{modality-non-specific}}$). The third hypothesis that expected a taxation of the WM was imported in BIEMS as constraint model 3 (M3: $\mu_{\text{modality specific}} > \mu_{\text{Baseline}};$ $\mu_{\text{modality-non-specific}} > \mu_{\text{Baseline}}$).

The constraint models mentioned above consisted of the average RT of each participant per baseline, modality-specific or modality-non-specific (visual or auditory memory recall, with visual or auditory dual task) condition (*See table 2*). The BF value of M1 compared to the unconstrained model (M0) was ($BF_1 = 5.32$). The BF value of M2, compared to M0 was ($BF_2 = 0.53$). The BF value of M3 compared to M0 was ($BF_3 = 8.76$).

Table 2. *Constraints models imported in BIEMS*

Models	**Constraints**	**Bayes Factor (BF)**
Model 1	1.5 – 1.1 > 1.6 – 1.2 1.4 – 1.2 > 1.3 – 1.1	5.32
Model 2	1.5 – 1.1 = 1.6 – 1.2 1.4 – 1.2 = 1.3 – 1.1	0.53
Model 3	1.5 > 1.1 1.3 > 1.1 1.4 > 1.2 1.6 > 1.2	8.76

Note. 1.1 = Average baseline visual dual task, 1.2 = Average baseline auditory dual task, 1.3 = Average auditory memory recall and visual dual task, 1.4 = Average auditory memory recall and auditory dual task, 1.5 = Average visual memory recall and visual dual task, 1.6 = Average visual memory recall and auditory dual task.

Figure 1 shows that in line with hypothesis 1, but in contrast to hypothesis 2, modality-specific dual tasks were superior to modality-non-specific dual task in WM taxation. The superiority of the modality-specific dual task was also supported by the BF value for the comparison of hypothesis 1 with hypothesis 2 (BF_{12} = 10.04). The BF indicates that the data was approximately ten times more likely to occur under the hypothesis 1 than under hypothesis 2. Using the scale of evidence of Jeffreys (1961), the data indicates a strong evidence for hypothesis 1. Additionally, figure 2 shows that in line with hypothesis 3, there is a taxation of the WM, regardless of the modality of the dual task. Hypothesis 3 was also supported by the BF value for the comparison of M3 with M0. This resulted in a BF greater than 1 (BF_3 = 8.76). According to Jeffreys (1961), the data indicates a substantial evidence for hypothesis 3. Nevertheless, it is meaningful to mention that according to figure 2 there is a large general effect between the visual and auditory dual task, where the RT was slower irrespectively of the nature of the dual task. Implicating that a large general effect shows a smaller modality specificity effect.

Discussion

The aim of this study was to use the Working Memory (WM) framework to test whether modality-specific dual tasks had more impact on the WM during memory recall than a modality-non-specific dual tasks. Two distressing modality-specific memories (visual and auditory) were recalled and held, whilst performing a visual (circle) dual task and an auditory (tone) dual task. We observed that the Reaction Time (RT) on the dual tasks slowed down when participants held a memory in mind, regardless of the modality of the dual tasks. This result confirms the third alternative that there will be a WM taxation, regardless of the modality of the dual tasks. In line with our first alternative (the modality-specific dual task will be superior in WM taxation compared to the modality-non-specific dual task), we found that the WM taxation was greater when there was a match between the nature of the dual task (visual or auditory) and the nature of the recalled memory (visual or auditory). This finding was in contradiction to the second alternative (the modality-specific dual task and modality-non-specific dual task have an equivalent impact on the WM). The participants in the visual memory recall condition reacted slower on the visual dual task compared to the auditory dual task; whereas during the auditory memory recall condition participants reacted slower on the auditory dual task, compared to the visual dual task. The findings of the present study are consistent with prior studies that reported evidence in favor of interference from modality dual tasks (Baddeley & Andrade, 2000; Bourne et al., 2010; Kemps & Tiggemann, 2007; Maxfield et al., 2008; Stuart, Holmes, Brewin, 2006; Tabrizi & Jansson, 2016).

While the underlying mechanisms of Eye Movement Desensitization and

Reprocessing (EMDR) have been frequently investigated, the present study sheds more light on the underlying mechanisms of EMDR through directly testing the modality-specific and modality-non-specific WM taxation. The outcome of this study has implications for the understanding and practice of EMDR. During an EMDR session, the client performs a dual task, while simultaneously concentrating on an identified image of emotional disturbance, typically a traumatic episode (Shapiro, 1996). The current findings have established that using a dual task during memory recall, will have an impact on the WM taxation. Furthermore, the current findings indicate that a modality-specific dual task will have more impact on the WM taxation; which according to the WM model of Baddeley and Hitch (1974), an auditory recalled memory and auditory dual task competes for the same limited phonological loop resources. Whilst, a visual recalled memory, and visual dual task compete for the same limited visuospatial sketchpad capacity. As established by Kemps and Tiggemann (2007), we also found that the participants RT's were slower during the auditory (visual) memory recall and the auditory (visual) dual task.

Moreover, Kemps and Tiggemann (2007) mentioned that it is essential to tax the appropriate subsystem of the WM, which may reduce the distressful memory experience. The distressful memory experience is at the beginning of the therapy unprocessed, where the memory experience has developed into the basis of the current dysfunctional reactions and intrusive symptoms of the patient. The eye movements and other dual task improve the information processing by treating the unprocessed sensory, affective, and cognitive elements of the traumatic memory (Shapiro & Maxfield, 2002). Using the appropriate dual task during the WM taxation will lead to a greater WM taxation which enhances the information processing through desensitization of the traumatic memory (Shapiro & Maxfield, 2002). This will individualize the therapy, focusing more on the specific memory modality and targeting the specific WM subsystem, which eventually leads to a more effective treatment.

On the other hand, it is important to critically discuss the usage of the dual task. Based on the present findings is it recommended to use a dual task (visual or auditory) that is supported by empirical evidence to have an impact on the WM capacity. Earlier studies (Baddeley & Andrade, 2000; van den Hout, Engelhard, Rijkeboer, Koekebakker et al., 2011; Kristjánsdóttir & Lee, 2011; Lee & Cuijpers, 2013) have supported the evidence for the effectiveness of using EM as a dual task to decrease the quality of the traumatic memory. Other studies like van den Hout, Engelhard, Rijkeboer, Koekebakker and colleagues (2011), van den Hout, Rijkeboer, Engelhard and colleagues (2012) and de Jongh, Ernst, Marques and Hornsveld (2013) have found that beeps are inferior to EM. So, it is speculated that using beeps may lead to a poor therapeutic outcome. Therefore, it is assumed that not every dual task is equally demanding during WM taxation. As a result, it is more convenient and recommended to use auditory distractors that are more demanding on the WM (phonological loop) capacity. Alternative auditory dual tasks that may have more impact on the PL taxation are for instance counting aloud (Kemps & Tiggenmann, 2007; Kristjánsdóttir & Lee 2011; Tabrizi & Jansson, 2016) and auditory shadowing task (Gunter & Bodner, 2008), where the individual is more active during these tasks. In addition, literature also suggests that using more complex distractor task during WM taxation, such as subtraction task (Engelhard, van den Hout & Smeets, 2011), auditory shadowing or drawing the Rey complex figure (Gunter & Bodner, 2008) are more effective than EM. So, it is important to be meticulous when selecting a specific dual task during the therapy.

The present study has some limitations. First, the present study has not measured the unpleasantness score after the intervention. The current findings can only provide insight in the change of the RT (a variable used to measure the impact of the dual task on the WM taxation) and cannot establish any insight regarding the effectiveness of the intervention and the reduction of the unpleasantness score of the recalled memory. This is important for the clinical reduction of the vividness and emotionality of the memory. Future research is needed to determine the effectiveness of the intervention. Second, participants recalled two memories that were more than 50 percent visual or auditory. This self-report can vary per individual and is very subjective, meaning that it cannot be verified if a memory is truly more than 50 percent visual or auditory. Both memory information stored in the memory networks contains related thoughts, images, emotions and sensations; with connections between the associated memory networks (Shapiro & Maxfield, 2002). Hence, it is speculated that the recalled memories can be more than 50 percent visual or auditory. However, it could be possible that these memories have been anchored in different modalities. Perhaps that the temporarily activated memory component could be auditory dominant (e.g. explosion), whilst the individual had a (visual) memory-anchor of the environment (e.g. blue color of the sky), where the recalled memory is connected to the anchor. So, in this example recalling the explosion (auditory memory) will automatically associate the recalled memory with the mental picture of the blue sky. This could possibly lead to a bias towards interpreting other information around the anchor, which can have an impact on the memory (modality) perception of the participant. However, there is still evidence found for modality specificity. This limitation can only advocate the power of the effect. Third, participants had to rate the unpleasantness of their reported memory, using a scale between 0 to 100 percent. This is also a very subjective rating, which could lead to inaccurate recall and evaluations of the unpleasantness of the reported memory and also biased results. Participants could have used a strategy, in which the participant had rated the recalled memory with a 100 (50) percent, while the actual rating should be 50 (100) percent. Meaning that perhaps the recalled memory was not that impactful and did not limit the WM capacity, to the extent that it did not compete with the dual task for the WM capacity. This could have an effect on the current findings. Furthermore, the findings of the present study could also be influenced by the participant sample. Although the naturalistic sample of the participants recruited, it could limit the generalizability of the findings. The participants included in this study were healthy individuals whom did not suffer from any psychological impairment. So, it can be speculated that compared to a clinical sample the recalled memory by the current sample may have not been traumatic enough, as it could be in a PTSD patients. Perhaps that a different result may be found in a clinical sample consisting of PTSD patients. It could be expected that PTSD patients recalling an emotional traumatic memory, whilst performing a dual task will have a stronger delay (during the dual task) compared to healthy individuals; where a larger effect of the dual task could be expected. Nevertheless, this remains a matter for future research.

Lastly, the present study did not investigate the long-term effectiveness of the dual tasks. As Kemps and Tiggemann (2007) have mentioned it is important to consider the possible long-term consequences of modality-specific dual tasks. Hence, it is essential that future research investigate the long-term effectiveness of the dual tasks.

The current study provided a clearer understanding of the underlying mechanism of EMDR. The present study demonstrated the importance of applying a modality-specific dual task to a modality-specific memory. These findings support the working memory model and have practical implications for the treatment of distressful memory experiences. The current findings indicate that using a dual task during memory recall will have an impact on the WM taxation. Whilst taxing the appropriate subsystem of the WM with a modality-specific dual task will lead to a greater WM taxation, which enhances the information processing through desensitization of the traumatic memory, leading to a more effective treatment. To sum up, it could be concluded that modality-specific working memory taxation does matter.

Acknowledgements

I express my gratitude to my supervisors: prof. dr. Marcel van den Hout and drs. Suzy Matthijssen for their time, support, energy and constructive feedback. Thank you.

References

American Psychological Association. (2017). *Clinical Practice Guideline for the Treatment of Posttraumatic Stress Disorder (PTSD) in Adults*. Retrieved from https://www.apa.org/ptsd-guideline/ptsd.pdf

Andrade, J., Kavanagh, D., & Baddeley, A. (1997). Eye-movements and visual imagery: A working memory approach to the treatment of post-traumatic stress disorder. *British Journal of Clinical Psychology*, *36*, 209–223. doi:10.1111/j.20448260.1997.tb01408.x

Baddeley, A. (1998). Working memory. *Comptes Rendus de l'Académie Des Sciences – SeriesIII - Sciences de La Vie*, *321*, 167–173. doi:10.1016/s0764-4469(97)89817-4

Baddeley, A. D., & Andrade, J. (2000). Working memory and the vividness of imagery. *Journal of Experimental Psychology: General*, *129*, 126–145. doi:10.1037/0096-3445.129.1.126

Baddeley, A. D., & Hitch, G. (1974). Working Memory. *Psychology of Learning and Motivation*, *8*, 47–89. doi:10.1016/s0079-7421(08)60452-1

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

Bisson, J., & Andrew, M. (2007). Psychological treatment of post-traumatic stress disorder (PTSD). *Cochrane Database of Systematic Reviews*, (3), 1-87. New York, NY: Wiley & Sons. doi:10.1002/14651858.cd003388.pub3

Bourne, C., Frasquilho, F., Roth, A. D., & Holmes, E. A. (2010). Is it mere distraction? Peri-traumatic verbal tasks can increase analogue flashbacks but reduce voluntary memory performance. *Journal of Behavior Therapy and Experimental Psychiatry, 41*, 316–324. doi:10.1016/j.jbtep.2010.03.001

Bradley, R., Greene, J., Russ, E., Dutra, L., & Westen, D. (2005). A Multidimensional Meta-Analysis of Psychotherapy for PTSD. *American Journal of Psychiatry*, *162*, 214–227. doi:10.1176/appi.ajp.162.2.214

De Jongh, A., Ernst, R., Marques, L., & Hornsveld, H. (2013). The impact of eye movements and tones on disturbing memories involving PTSD and other mental disorders. *Journal of Behavior Therapy and Experimental Psychiatry*, *44*, 477–483. doi:10.1016/j.jbtep.2013.07.002

Dienes, Z. (2011). Bayesian Versus Orthodox Statistics: Which Side Are You On? *Perspectives on Psychological Science*, *6*, 274–290. doi:10.1177/1745691611406920

Ehlers, A., & Steil, R. (1995). Maintenance of Intrusive Memories in Posttraumatic Stress Disorder: A Cognitive Approach. *Behavioural and Cognitive Psychotherapy*, *23*, 217-249. doi:10.1017/s135246580001585x

Ehlers, A., Hackmann, A., Steil, R., Clohessy, S., Wenninger, K., & Winter, H. (2002). The nature of intrusive memories after trauma: the warning signal hypothesis. *Behaviour Research and Therapy*, *40*, 995–1002. doi:10.1016/s0005-7967(01)00077-8

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

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

Jeffreys, H. (1961). *Theory of Probability*, (3). Oxford, UK: Oxford University Press.

Kemps, E., & Tiggemann, M. (2007). Reducing the vividness and emotional impact of distressing autobiographical memories: The importance of modality-specific interference. *Memory*, *15,* 412–422. doi:10.1080/09658210701262017

Kristjánsdóttir, K., & Lee, C. W. (2011). A Comparison of Visual Versus Auditory Concurrent Tasks on Reducing the Distress and Vividness of Aversive Autobiographical Memories. *Journal of EMDR Practice and Research*, *5,* 34–41. doi:10.1891/1933-3196.5.2.34

Lee, C. W., & Cuijpers, P. (2013). A meta-analysis of the contribution of eye movements in processing emotional memories. *Journal of Behavior Therapy and Experimental Psychiatry*, *44,* 231–239. doi:10.1016/j.jbtep.2012.11.001

Lilley, S. A., Andrade, J., Turpin, G., Sabin-Farrell, R., & Holmes, E. A. (2009). Visuospatial working memory interference with recollections of trauma. *British Journal of Clinical Psychology*, *48,* 309–321. doi:10.1348/014466508x398943

Maxfield, L., Melnyk, W. T., & Hayman, G. C. A. (2008). A Working Memory Explanation for the Effects of Eye Movements in EMDR. *Journal of EMDR Practice and Research*, *2*, 247–261. doi:10.1891/1933-3196.2.4.247

Mulder, J., Hoijtink, H., & Leeuw, C. de. (2012). BIEMS: AFortran90 Program for Calculating Bayes Factors for Inequality and Equality Constrained Models. *Journal of Statistical Software*, *46*, 1-39. doi:10.18637/jss.v046.i02

Prakash, J., Saha, A., Das, R. C., Srivastava, K., & Shashikumar, R. (2016). Post traumatic stress disorder. *Medical Journal Armed Forces India*, *72*, 189–191. doi:10.1016/j.mjafi.2015.04.004

Sadock, B. J., Sadock, V. A., & Ruiz, P. (2014). *Kaplan and Sadock's synopsis of psychiatry: Behavioral sciences/clinical psychiatry* (11th ed.). Philadelphia, PA: Lippincott Williams & Wilkins.

Salyards, C. J. (2005). *Non-visual flashbacks: In vivo versus imaginal exposure*. Marquette University, ProQuest Dissertations Publishing (Publication No. 3184685). Retrieved from http://epublications.marquette.edu/dissertations/AAI3184685

Seidler, G. H., & Wagner, F. E. (2006). Comparing the efficacy of EMDR and trauma-focused cognitive-behavioral therapy in the treatment of PTSD: a meta-analytic study. *Psychological Medicine*, *36*, 1515-1522. doi:10.1017/s0033291706007963

Shapiro, F. (1989). Eye movement desensitization: A new treatment for post-traumatic stress disorder. *Journal of Behavior Therapy and Experimental Psychiatry*, *20*, 211–217. doi:10.1016/0005-7916(89)90025-6

Shapiro, F. (1996). Eye movement desensitization and reprocessing (EMDR): Evaluation of controlled PTSD research. *Journal of Behavior Therapy and Experimental Psychiatry*, *27*, 209–218. doi:10.1016/s0005-7916(96)00029-8

Shapiro, F., & Maxfield, L. (2002). Eye movement desensitization and reprocessing (EMDR): Information processing in the treatment of trauma. *Journal of Clinical Psychology*, *58*, 933–946. doi:10.1002/jclp.10068

Stuart, A. D. P., Holmes, E. A., & Brewin, C. R. (2006). The influence of a visuospatial grounding task on intrusive images of a traumatic film. *Behaviour Research and Therapy*, *44*, 611–619. doi:10.1016/j.brat.2005.04.004

Tabrizi, F., & Jansson, B. (2016). Reducing involuntary memory by interfering consolidation of stressful auditory information: A pilot study. *Journal of Behavior Therapy and Experimental Psychiatry, 50*, 238–244. doi:10.1016/j.jbtep.2015.09.003

Van de Schoot, R., Kaplan, D., Denissen, J., Asendorpf, J. B., Neyer, F. J., & van Aken, M. A. G. (2014). A Gentle Introduction to Bayesian Analysis: Applications to Developmental Research. *Child Development*, *85*, 842–860. doi:10.1111/cdev.12169

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

Van den Hout, M. A., Engelhard, I. M., Rijkeboer, M. M., Koekebakker, J., Hornsveld, H., Leer, A., & Akse, N. (2011). EMDR: Eye movements superior to beeps in taxing working memory and reducing vividness of recollections. *Behaviour Research and Therapy*, *49*, 92–98. doi:10.1016/j.brat.2010.11.003

Van den Hout, M., Kindt, M., Muris, P., & Salemink, E. (2001). Vreemde oogbewegingen maken herinneringen minder levendig en minder emotioneel. *Directieve Therapie, 21*, 121–127. doi:10.1007/bf03060262

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

Vandierendonck Gino De Vooght Koen, A. (1998). Interfering with the Central Executive by Means of a Random Interval Repetition Task. *The Quarterly Journal of Experimental Psychology Section A*, *51*, 197–218. doi:10.1080/713755748

Van Veen, S. C., Engelhard, I. M., & van den Hout, M. A. (2016). The effects of eye movements on emotional memories: using an objective measure of cognitive load. *European Journal of Psychotraumatology*, *7*, 1-11, 30122. doi:10.3402/ejpt.v7.30122

Yehuda, R. (2002). Post-Traumatic Stress Disorder. *New England Journal of Medicine*, *346*, 108–114. doi:10.1056/nejmra012941

World Health Organization (2013). *WHO releases guidance on mental health care after trauma*. Retrieved from http://www.who.int/mediacentre/news/releases/2013/trauma_mental_health_20130806/e

Appendices

Appendix A

The conditions used during the experiment

The experiment consisted of 16 conditions. The order of the conditions was balanced, wherein six participants were randomly assigned to one of each condition (*see table A)*.

Table A. *The conditions used during the experiment*

Condition	Practice Trial	Baseline Trial	Memory recall Trial (1)	Memory recall Trial (2)
1	VA	AV	VVA	AAV
2	VA	AV	VVA	AVA
3	VA	AV	VAV	AAV
4	VA	AV	VAV	AVA
5	VA	AV	AAV	VVA
6	VA	AV	AVA	VVA
7	VA	AV	AAV	VAV
8	VA	AV	AVA	VVA
9	VA	VA	VVA	AAV
10	VA	VA	VVA	AVA
11	VA	VA	VAV	AAV
12	VA	VA	VAV	AVA
13	VA	VA	AAV	VVA
14	VA	VA	AAV	VAV
15	VA	VA	AVA	VVA
16	VA	VA	AVA	VAV

Note. AV = Auditory dual task afterwards visual dual task, VA = Visual dual task afterwards auditory dual task, VVA = Visual memory recall and then visual dual task afterwards auditory dual task, VAV = Visual memory recall and then auditory dual task afterwards visual dual task, AAV = Auditory memory recall and then auditory dual task afterwards visual dual task, AVA = Auditory memory recall and then visual dual task afterwards auditory dual task.

Appendix B

The visual stimuli used during the visual dual task

The visual stimuli “Circle” used during the visual dual task. The circle was shown for 500 ms and the inter-stimulus interval (ISI) for the visual dual task ranged between 400 and 1000 milliseconds (*see figure B*).

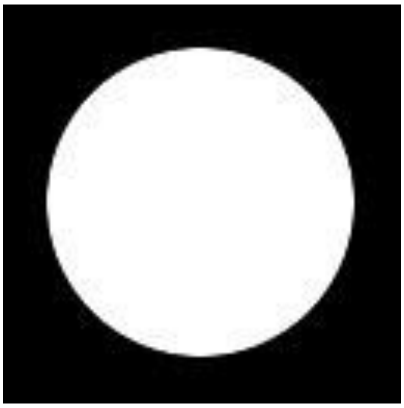

Figure B. The visual stimuli used during the visual dual task.

Appendix C

The auditory stimuli used during the auditory dual task

The auditory stimuli "Tone" (200-Hz) was present for 50 ms and the ISI for the auditory dual task ranged between 850 and 1450 milliseconds (*see figure C*).

Figure C. An illustration of the auditory stimuli used during the auditory dual task.

Appendix D

Practice and baseline trail

The practice trial consisted of the visual dual task with a series of 8 circles and the auditory dual task with a series of 8 tones (participants were assigned to sequence 1 during the practice trial; *see figure D*). This was followed by the baseline trial consisting of the visual dual task with a series of 48 circles and the auditory dual task with a series of 48 tones. The participants were randomly assigned (during the baseline trial) to start with either the visual or auditory dual task. For example, a participant was randomly assigned (during the baseline trial) to either sequence 1 or sequence 2 (*see figure D)*.

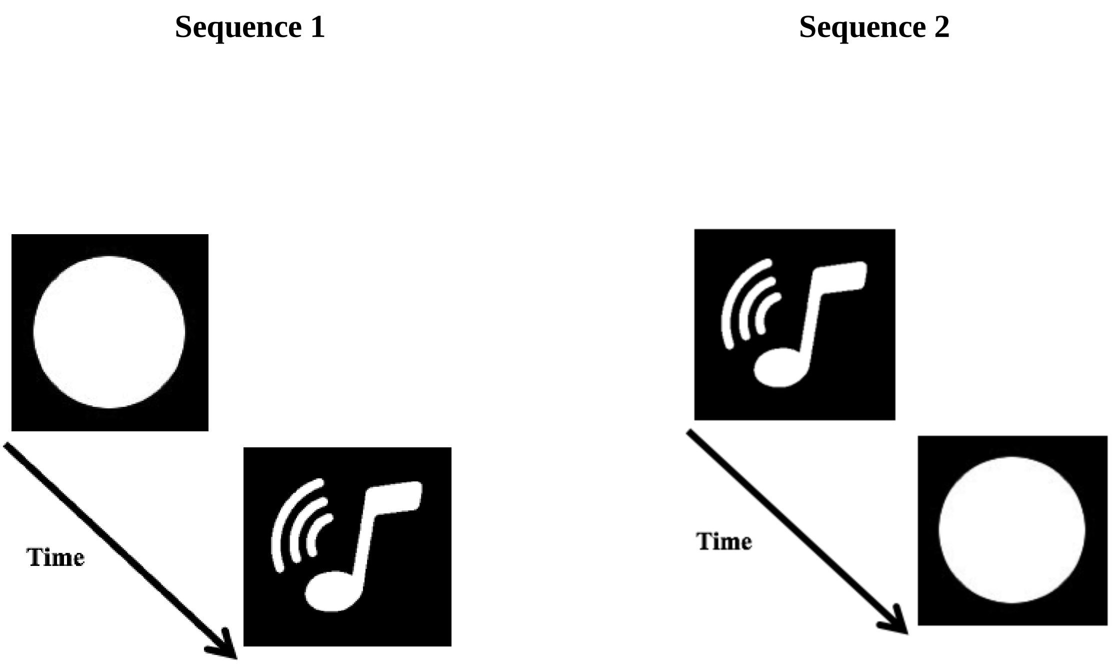

Figure D. The sequence of the dual task in the practice and baseline trial. Sequence 1 started with the visual dual task and afterwards the auditory dual task. Sequence 2 started with the auditory dual task and afterwards the visual dual task.

Appendix E

Auditory and visual memory recall trail

After recalling the auditory (or visual) memory, participants were randomly assigned to the visual and auditory trial, consisting of a visual dual task with a series of 48 circles and an auditory dual task consisting of 48 tones. Participants were reminded (by the title that was provided) at the beginning of each trial to focus on the specific fragment whilst performing the auditory or visual dual task. The participants were randomly assigned to begin with either the visual trial, followed by the auditory trial or vice versa. For example, a participant (in condition 1; *see table A*) started with the visual memory recall and performed sequence 1, afterwards the participant recalled an auditory memory and performed sequence 2 (*see figure E).*

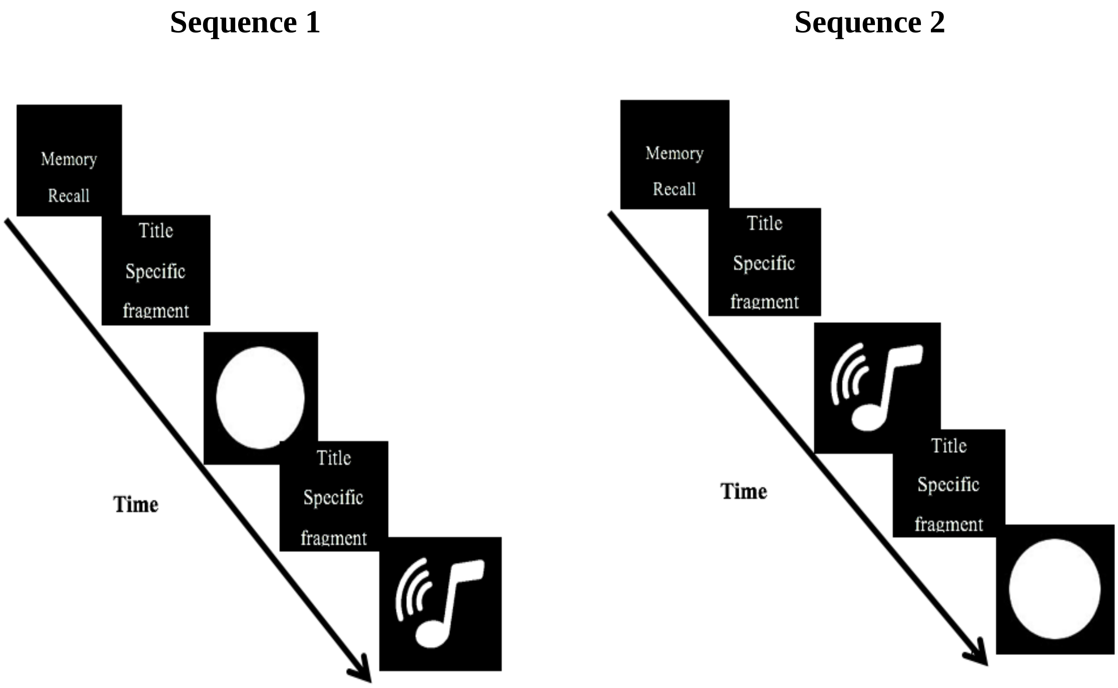

Figure E. The sequence of the dual task per memory recall condition. Sequence 1 started with the memory recall (visual or auditory), visual dual task and afterwards the auditory dual task. Sequence 2 started with the memory recall (visual or auditory), the auditory dual task and afterwards the visual dual task.