Title: Chilling and Blurring Negative Memories: An Experimental Memory Training Study

Running Title: Intervening in Different Stages of Memory

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Abstract:

Aims: The present study examined the extent to which the methods of Broadening attentional scope (BAS) during acquisition, and working memory interference (WMI) during reconsolidation could influence memory formation process.

Methods: 95 participants were randomly assigned to inactive control (n=30), BAS (n=33), and WMI (n=32) groups. During watching a traumatic film, participants in the BAS group were instructed to allocate their attention to the peripheral details of the film, while participants in the WMI group performed a spatial working memory task. Memory vividness and emotionality were assessed before and after the intervention using a visual analogue scale, and valence, arousal, and dominance were measured by self-assessment manikin immediately after watching the film. Moreover, all the participants were asked to record their intrusive memory for 3 days after the experiment. Statistical software package SPSS was used for group comparisons.

Results: Our results suggested that interfering with visuospatial working memory during retrieving emotionally valanced memories could significantly reduce the level of vividness of mental images from pre to post assessments ($p=0.004$). However, in terms of emotionality, arousal, dominance and the number of intrusive memories, we found no significant differences between the three groups.

Conclusions: Participants in the WMI group outperformed in blurring the negatively valanced memory at the post assessment. In contrast with our primary assumption, broadening attentional scope didn't make any significant changes compared to the other two groups. Future studies with larger sample size and objective measurements may provide additional evidence on the efficacy of these methods, specifically in the context of clinical implication.

Keywords: Working memory interference, Emotional memory, Broadening attentional scope, Vividness

1. Introduction

Although a negative emotional event may occur once throughout life, it is stored in long-term memory and contributes to longer lasting effects on memory-related mechanisms (Yonelinas & Ritchey, 2015). By retrieving the emotionally laden memories, people may experience physiological (i.e., respiratory sinus arrhythmia, impaired autonomic modulation, and sleep quality) (Beauchaine, 2015; Chopko et al., 2021; Cohen et al., 1998; Lukowski et al., 2017; Shah et al., 2013), cognitive (i.e., impaired time estimation and learning) (Schuitevoerder et al., 2013; Vicario & Felmingham, 2018), and emotional difficulties (i.e., depressive symptoms, social anxiety, health anxiety) (Muse et al., 2010; Payne et al., 2019; Slofstra et al., 2017; Wild et al., 2007), that lead to reduced performance over time (Visser et al., 2018). To control these adverse impacts of negative memories, an increasing number of studies focused on manipulating the stages of memory and hindering the formation of emotional memories, known as memory training (Koster et al., 2021).

Memory is a cognitive process with multiple stages of encoding/acquisition, storage, and retrieval/reconsolidation (Stern & Alberini, 2013). Followed by acquiring information through sensory receptors, they could be stored in the long-term memory through a process called "consolidation" (Stern & Alberini, 2013). Each time we recall the stored memories, they become fragile and prone to change. It is suggested that this process, which is referred as reconsolidation, lasts between 1 to 6 hours (Nader et al., 2000; Rafei et al., 2021). Several studies revealed that different stages of memory could be affected by various factors including emotionally charged events (Yonelinas & Ritchey, 2015).

During the first stage of memory (acquisition/encoding), individuals allocate their attentional resources to an object and learn new information (Stern & Alberini, 2013). Affective information, particularly those with negative valance, engage attention more than the positive ones and shown to be detected more quickly and automatically by individuals (Dijksterhuis & Aarts, 2003; Gable & Harmon-Jones, 2012). This phenomenon has been known as the *treat superiority effect* or the similar one which is termed as the *weapon bias effect* (Rivera-Rodriguez et al., 2021). Therefore, individuals may ignore the peripheral information, that are more neutral, in face of the negatively valanced event (Chipchase & Chapman, 2013). Previous studies applied different methods to manipulate the acquisition stage and subsequently affect later recalls. These methods include reappraisal training (Woud et al., 2013), concrete processing training (White & Wild, 2016), cognitive interferences with visuospatial tasks (Badawi et al., 2020; Lau-Zhu et al., 2019; Tabrizi & Jansson, 2016), and verbal task (Tabrizi & Jansson, 2016). However, despite the key role of attention, there has been a limited focus on the effect of orienting and expanding attention on later recall of emotional memories, thus far.

Ever since the fragile nature of memory in the reconsolidation stage has been explored (Nader et al., 2000), the reconsolidation stage has become the focus of both experimental and clinical studies, specifically for patients who suffer from post-traumatic stress disorder. Several studies try to intervene with the reconsolidation stage to moderate the negative responses to the recalled memories. They explain that working memory tasks compete with the memory for limited resources in working memory (Andrade et al., 1997; Engelhard et al., 2011). Some studies support the effectiveness of blocking the process of reconsolidation by interfering in working memory after presenting a retrieval cue. These studies used multiple tasks including imagery/written rescripting (Rijkeboer et al., 2020), linguistic tasks (Hagenaars et al., 2017; Jongeneel et al., 2020),

visuospatial tasks (Hagenaars et al., 2017; James et al., 2015; Kessler et al., 2018), and spatial task without visual feedback (Cuperus et al., 2019). In contrast, some studies show conflicting reports regarding whether interfering with visuospatial working memory during the reconsolidation stage could dampen emotional responses in later recalls (Cuperus et al., 2016; Jansson & Dylman, 2021; Mertens et al., 2018)

Given the importance of the negative effects followed by recalling negative emotional memories, the present experimental study aimed to compare the effects of two interventions on emotional responses (vividness, emotionality, valence, arousal and dominance) to the voluntarily recalled memory of a negatively valanced event. To manipulate the scope of attention during the acquisition stage, we instructed a group of participants to broaden their attentional scope by reallocating their attention to attend to peripheral and neutral stimuli, instead of the central and negative ones (Gable & Harmon-Jones, 2012). For the other group, we used a visuospatial interference intervention to intervene with the stage of reconsolidation (Cuperus et al., 2019). We assumed that compared to the inactive control group, using these two methods (broadening attentional scope and working memory interference) could significantly reduce the emotional responses after recalling the negative event. To examine the lasting effects of the interventions on the involuntarily retrievals, we followed up the participants over a 3-days period using a diary method that requires participants to record the number of intrusive memories related to the traumatic film they had watched during the experimental session (Hagenaars et al., 2017; James et al., 2015; Kessler et al., 2018).

2. Material and methods

2.1 Participants

100 students enrolled in this study through advertising in online academic networks and distributing posters around the campuses of University of Tehran and Islamic Azad University. Inclusion criteria were being 20 to 30 years of age, self-report of having normal vision and hearing, and being a native Farsi speaker. All the recruited participants signed an informed consent showing that they understand the purpose and procedures required for the study. The participants were randomly allocated into three groups, including Broadening attentional scope (BAS) (n= 34), working memory interference (WMI) (n= 33), and the inactive control group (n= 33). Five participants (n=5) were dropped out after allocation: two participants intentionally terminated the study due to the sensitive content of the film, two participants did not attend the second session, and one participant did not focus on the film and asked irrelevant questions while watching the film. Finally, data of 95 participants were entered into our final analysis. This study is approved by Iran National Committee for Ethics in Biomedical Research (IR.UT.PSYEDU.REC.1398.032).

2.2 Procedure

Participants were invited to come to our lab for two experimental sessions. They were also compensated for the time they spent in the study. The present experimental study was designed in two sessions of watching a traumatic film (session 1), reactivating the memory and performing assessments (session 2). Participants were also asked to keep a daily intrusive memory diary for the following 3 days (after session 2) and were collected via a 5-min phone interview by the first author (FA). Memory vividness and emotionality were assessed at two time points in session 2, while self-assessment manikin was administered only at the end of session 2. All assessments were

taken by a research team member who was a trained clinical psychologist (FA). Figure 1 depicts the procedure of the study.

The experimental sessions were as follows:

Session 1: Participants signed a written informed consent and filled out a demographic form about their age, gender, education level, history of diseases (e.g., cardiovascular or multiple sclerosis), cigarette smoking and drug and alcohol consumption, and phone number (for follow-up contact). To control for possible problems in terms of attention and impulsivity at baseline, we used the Integrated Visual and Auditory Continuous Performance Test (IVA/CPT). Followed by the baseline screening, all participants watched a traumatic film including distressing scenes. Before watching the film, the BAS group was instructed to attend to the neutral and peripheral details of the film (e.g., the place, the color of costumes that actors worn), since they would be asked to recall them later. The other two groups (control and WMI) were asked to merely watch the film, without any prior instruction. After watching the film, each participant was asked to describe the most distressing scene. A static picture of the selected scene was provided then, to be used as a personalized retrieval cue in the next session (session 2). The first experimental session took about 30 minutes and participants left the lab for the next 24 hours.

Session 2: 24 hours after the first session, participants returned to the lab and were asked to imagine the most distressing scene from the film for 10 seconds with closed eyes. They scored the vividness and emotionality of this mental image on two 200 mm visual scales from 1 to 10. After that, each participant was presented with their retrieval cue. Participants in the WMI group were asked to carry out a spatial working memory task during this time, while the other two groups had to merely retrieve the memory using the retrieval cue (Cuperus et al., 2019). The spatial memory task used for this study was the manikin matchsticks shapes (e.g., house, airplane). Following the retrieval phase, all participants performed a 3-minute filler task (simple verbal questions e.g., "spell your first school name backward.") in order to eliminate the residual visual details of the previous retrieval. At the end of this session, memory vividness and emotionality were assessed again and participants also rated their subjective emotional responses (valence, dominance, and arousal) via pictorial test of self-assessment manikin. The second experimental session took about 15 minutes to complete, and participants left the lab after they were explained about the intrusive memory diary for 3 days follow-up.

Follow-up: During a 3-days follow-up after the second experimental session, participants were asked to keep the diary of the film-related intrusive memories and to report the number of their experiences on a telephone interview carried out by one of our research team members.

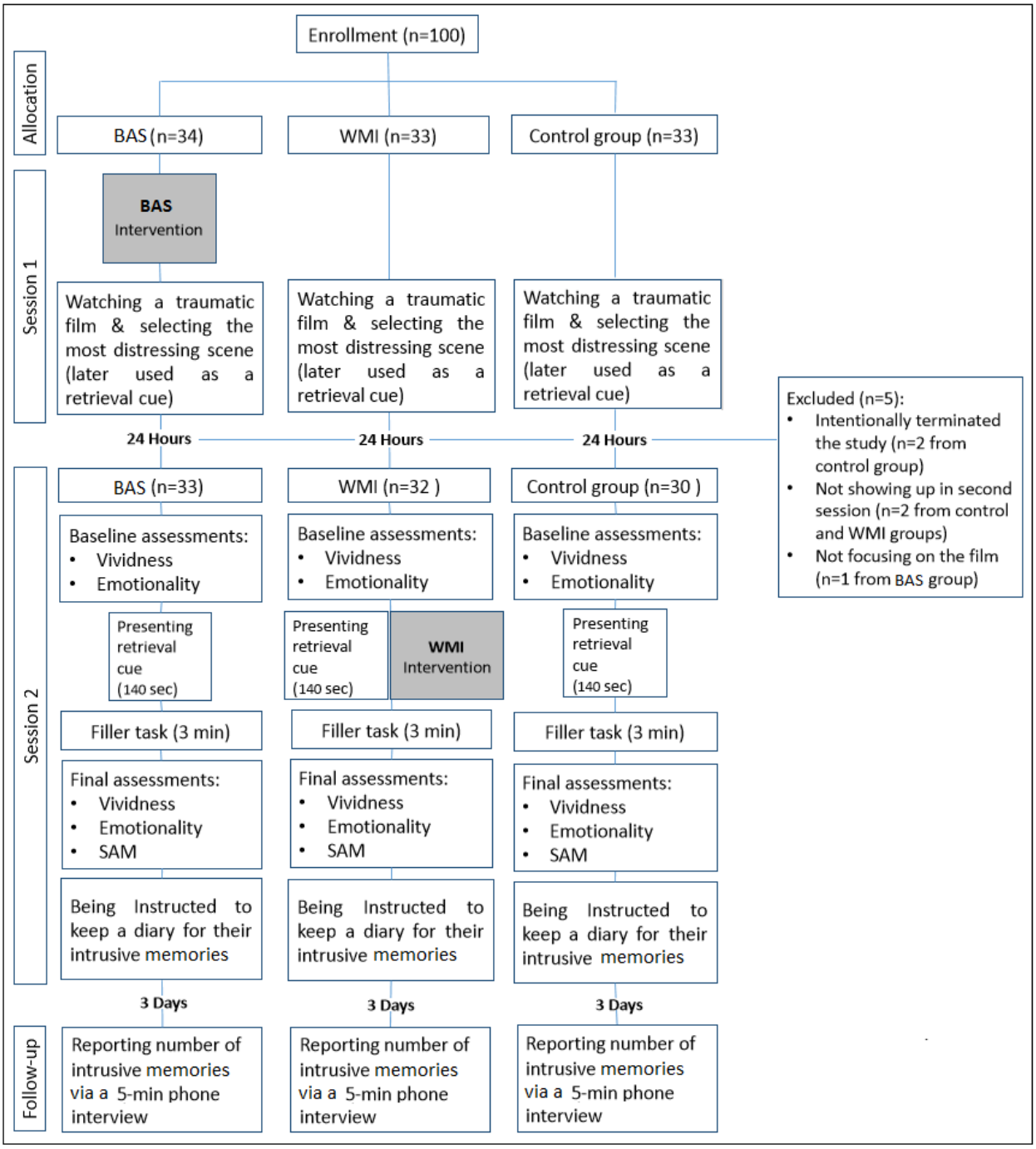

Figure 1. The procedure was conducted over a course of 3 sessions. In order to manipulate the acquisition phase, BAS intervention performed in session 1 right before watching the traumatic film. WMI intervention performed in session 2 while retrieval cue is presented. BAS= Broadening Attentional Scope, WMI= Working Memory Interference, SAM= Self-assessment Manikin

2.3 Materials

2.3.1 Demographics form: Age, gender, education level, history of diseases, illicit drug/ alcohol/ cigarette consumption, and phone number were collected using a demographic form.

2.3.2 Integrated Visual Auditory (IVA-2) test: IVA is a kind of Continuous performance test, measuring several factors involved in cognitive performance including attention and response control. To take this test, participants should click the mouse when they see or hear the number "1" and withhold a response when they see or hear the number "2" (Niazmand-Aghdam et al., 2021). To control for the potential of disproportionate effects of cognitive problems, we used the Persian version of the IVA-2 test to measure sustained visual attention and full-scale response control at baseline.

2.3.3 Traumatic film: A Persian film was trimmed and 5 minutes of it was used for the present experiment. Based on the traumatic film paradigm (James et al., 2016), we selected an episode including surgery and injury, taking place at a hospital including cool hues. Participants watched this film on a 13-inch MacBook Air in session 1.

2.3.4 Retrieval cue: Similar to the study by Cuperus et al. (2019), each participant described the most distressing scene just immediately after they watched the film in the first session. A static picture of this scene was provided to be used as a personalized retrieval cue in session 2. The selected static picture appeared four times on the screen and presented for 25 seconds on a black screen (with time intervals of 10 seconds). The static pictures and the black screens were presented automatically on a 13-inch MacBook Air for 140 sec in total.

2.3.5 Visual analogue scale (VAS): Two 200 mm VAS, ranging from 0 (not at all) to 10 (completely), were used to measure memory vividness ("*How much do you think that your created mental image of the film was clear and vivid*?") and emotionality ("*How much do you think that your created mental image of the film was negative*") before and after the interventions in session 2.

2.3.6 Self-assessment manikin (SAM): At the end of the second session, participants were asked to score their emotional experience by rating on three pictorial scales regarding to the retrieved memory related to the traumatic film. Each scale was presented by a manikin depicting different levels of valence (from 1= most unpleasant to 9= most pleasant), arousal (from 1= lowest to 9= highest), and dominance (from 1= lowest to 9= highest) (Bradley & Lang, 1994). No verbal explanation about the subscales was given by assessor (FA).

2.3.7 Intrusive memory diary: We used the diary method (Vredeveldt et al., 2018) to record the number of film-related intrusive memories that participants may experience in a 3 days follow-up. At the end of session 2, they were explained about intrusive memories and then, were asked to keep a paper-based diary to record once they experience them, either voluntarily or involuntarily. Participants were told that they would receive a phone call after 3 days to report the total number of their intrusions.

2.4 Analyses

One-way between-subjects analysis of variance (ANOVA), Chi-squared, and Kruskal-Wallis tests were firstly performed on all screening and baseline variables to check the probable differences between the three groups. We then used GLM repeated measures ANOVA (RM-ANOVA) and pairwise comparisons adjusted by the Bonferroni correction to investigate the effects of interventions on vividness and emotionality. The model included the main effect for the time and group as well as time × group interaction effect. To explore within-group changes, three paired sample t-tests were conducted. To compare SAM scores and the number of intrusive memories (during follow-up), we used Kruskal-Wallis nonparametric tests. All analyses were conducted using IBM SPSS 24.0 and statistical significance was assumed for a p-value < 0.05.

3. Results

95 participants (65 females, 35 males, mean age= 23.58 ± 2.53 years) were randomized into three groups in terms of inactive control (n= 30), BAS (n= 33), and WMI (n= 32). The groups were same in terms of screening variables including age (F= 2.91, p > 0.05), gender (χ2= 0.083, p > 0.05), visual sustained attention (F= 0.547, p > 0.05), and full-scale response control (F= 0.226, p > 0.05). Comparison of vividness and emotionality at baseline also showed no differences between the study groups (χ2= 0.546, p > 0.05; χ2= 0.355, p > 0.05, respectively). The screening and baseline variables are described in Table 1.

Table 1 Descriptive data of participants in screening and baseline variables (n=95)

	Control (n= 30) Mean (SD)/ n (%)	BAS (n= 33) Mean (SD)/n (%)	WMI (n= 32) Mean (SD)/n (%)	Between-conditions comparison F/ χ2 (*p*)
Age	23.07 (2.67)	23.21 (2.64)	24.44 (2.09)	2.91 (0.06)**
Gender (female)	21 (70.00%)	22 (66.7%)	22 (68.8%)	0.083 (0.95)*
Visual sustained attention	89.67 (28.38)	90.67 (24.68)	95.56 (17.95)	0.547 (0.58)**
Full scale response control	98.60 (16.31)	96.06 (14.86)	98.19 (17.47)	0.226 (0.79)**
Baseline vividness	7.30 (1.55)	6.94 (2.13)	7.38 (1.07)	0.546 (0.76)***
Baseline emotionality	6.23 (2.31)	6.45 (2.70)	6.22 (2.60)	0.355 (0.84)***

BAS= Broadening attentional scope, WMI= Working Memory Interference
*. Chi-squared test
**. One-Way ANOVA test
***. Kruskal-Wallis test

Results of GLM repeated-measures ANOVA test for emotionality scores indicate that the main effect of group (Mean Square= 4.42, df = 2, F= 0.43 p= 0.65, η2= 0.009, Observed Power = 0.12), main effect of time (Mean Square = 2.70, df = 1, F= 1.69, p= 0.20, η2= 0.02, Observed Power = 0.25) and the effect of time × group interaction (Mean Square = 1.11, df = 2, F= 0.69, p= 0.50, η2= 0.015, Observed Power = 0.16) were not significant. In case of vividness scores, the GLM repeated-measures ANOVA test showed that the main effect of group (Mean Square = 2.40, df = 2, F= 0.52 p= 0.59, η2= 0.011, Observed Power = 0.13) and the main effect of time was not statistically significant (Mean Square= 4.12, df = 1, F= 2.72 p= 0.10, η2= 0.029, Observed Power = 0.37), while the effect of time × group interaction is statistically significant (Mean Square = 6.24, df = 2, F= 4.12 p= 0.019, η2= 0.082, Observed Power = 0.72). Figure 2 shows estimated marginal means of emotionality and vividness scores in the two times and different conditions graphically.

To explore within-group differences, pairwise comparisons with the adjustment by Bonferroni show that there were no significant differences in vividness scores within the control group (Mean Difference [T2-T1] = - 0.067, p = .82), and the BAS group (Mean Difference [T2-T1] = 0.182, p= .56). But within the WMI group a significant change was found (Mean Difference [T2-T1]= -1.00, p= .004). Table 2 shows the time, group, and interaction effects of interventions on vividness and emotionality scores.

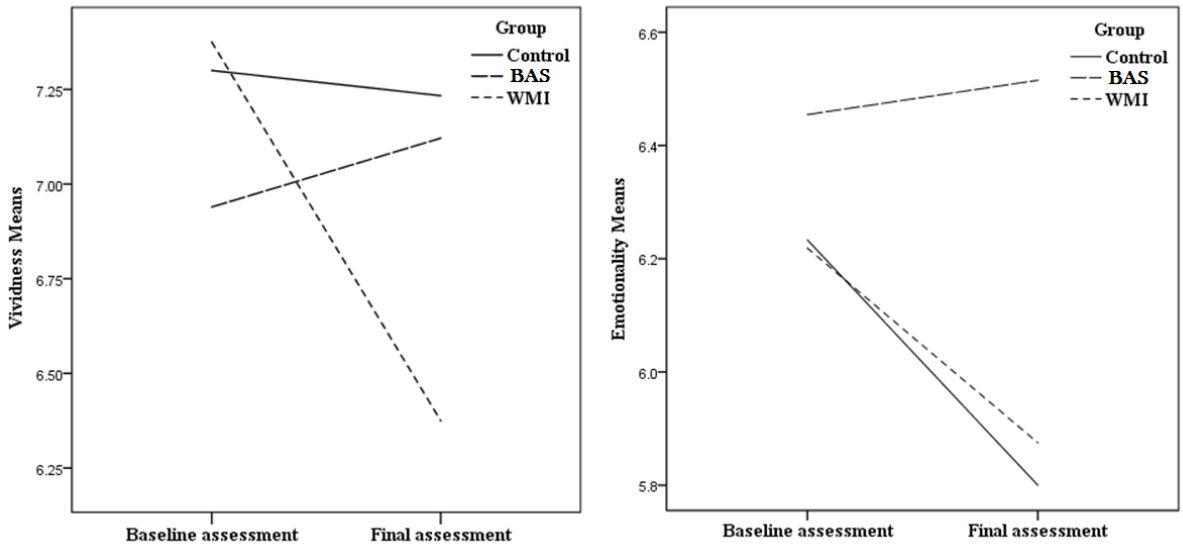

Figure 2 Estimated marginal means of emotionality and vividness scores (BAS= Broadening Attentional Scope, WMI= Working Memory Interference).

Moreover, the results of Kruskal–Wallis test indicated no significant differences between groups in terms of valence (χ2= 2.56, p= 0.28). However, in case of the arousal (χ2= 5.20, p= 0.074), dominance subscale (χ2= 5.14, p= 0.076), and the number of intrusive memories (χ2= 5.35, p= 0.069) a marginally significant (p-values between .05 and .10) difference between groups was found.

The U Mann-Whitney test showed that the BAS group (Mean Rank = 36.03) experienced significantly higher levels of arousal compared to the control (Mean Rank = 27.03) and WMI group (Mean Rank = 28.27). Regarding dominance subscale, BAS group (Mean Rank = 27.52) experienced significantly lower levels of dominance compared to the control group (Mean Rank = 36.93). In terms of intrusive memories, BAS group (Mean Rank = 36.15) reported significantly higher number of intrusive memories to the control (Mean Rank = 27.43) and WMI group (Mean Rank = 28.22). To perform a Bonferroni correction, we divided the critical p value by the number of comparisons being made and used as the adjusted significance level (0.05/3 ≈ 0.016). These results did not remain significant after the Bonferroni correction (Figure 3).

Table 2 Comparison of dependent variables between three groups (Control, BAS and WMI)

	T1			T2			Time F (*p*)	Group F (*p*)	Interaction F (*p*)
	Control (n= 30) Mean (SD)	BAS (n= 33) Mean (SD)	WMI (n= 32) Mean (SD)	Control (n= 30) Mean (SD)	BAS (n= 33) Mean (SD)	WMI (n= 32) Mean (SD)			
Vividness	7.30 (1.55)	6.94 (2.13)	7.38 (1.07)	7.23 (1.90)	7.12 (1.98)	6.38 (1.62)	2.72 (0.10)*	0.52 (0.59)*	4.12 (0.019)*
Emotionality	6.23 (2.31)	6.45 (2.74)	6.22 (2.59)	5.80 (2.09)	6.52 (2.42)	5.88 (2.29)	1.69 (0.20)*	0.43 (0.65)*	0.69 (0.50)*
SAM-valence	-	-	-	3.90 (1.12)	3.42 (1.45)	3.63 (1.38)	-	2.56 (0.28)**	-
SAM-arousal	-	-	-	3.87 (1.45)	4.67 (1.79)	3.88 (1.70)	-	5.20 (0.074)**	-
SAM-dominance	-	-	-	6.17 (1.84)	5.03 (2.16)	5.97 (1.85)	-	5.14 (0.076)**	-
Intrusive memories	-	-	-	2.27 (2.29)	5.21 (7.25)	3.09 (5.70)	-	5.35 (0.069)**	-

BAS= Expanding Attentional Span, WMI= Working Memory Interference, SAM= Self-assessment Manikin
T1=Baseline assessment, T2=Final assessment
*. GLM repeated-measures ANOVA test
**. Kruskal-Wallis test

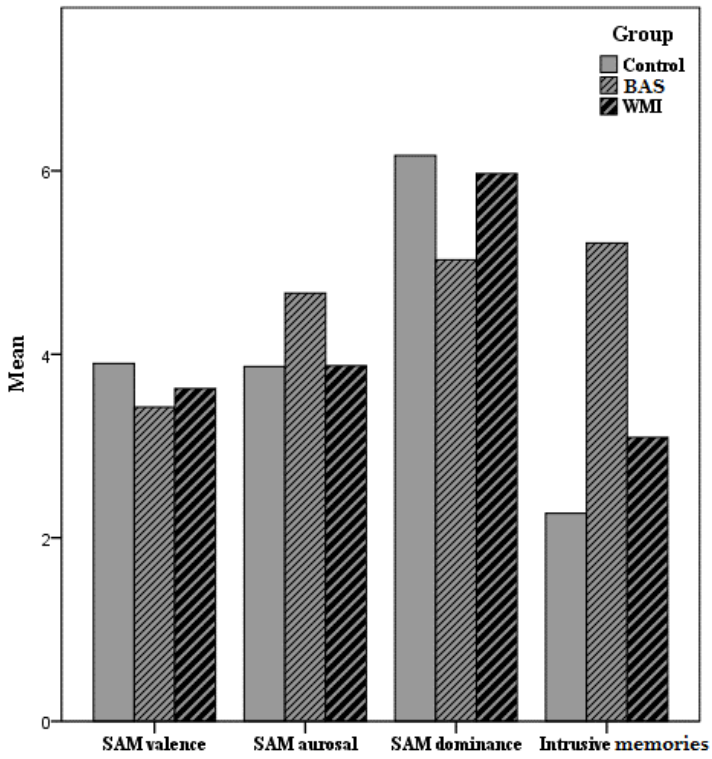

Figure 3: The mean of the dependent variables by groups

4. Discussion

In the present study, we used BAS and WMI methods to intervene in the acquisition and retrieval stages of memory formation and explored their impacts on later voluntary and involuntary retrievals. Voluntarily retrieved memories were assessed by their vividness and emotionality, and also the subjective experience in valence, arousal, and dominance subscales of SAM. Involuntary retrievals were measured by the number of intrusive memories (mental images) over three days after the experimental sessions. The results of our study showed that compared to BAS, WMI is efficient in blurring the negatively valanced memories through reducing vividness, while no change has been found in terms of emotionality, SAM subscales, and the number of intrusions.

Our results showed that memory vividness during retrieval was reduced as a consequence of working memory interference. As previous studies explained (Andrade et al., 1997; Engelhard et al., 2011) a working memory task (building shapes with matches with no visual feedback) would compete with the memory for limited resources in working memory, leading to a blurred and less vivid image of the emotional memory. Insignificant differences in terms of memory emotionality and the number of intrusive memories reported in the current study could be explained by the study of Leer et al. (2014). They suggested that eight periods of 24-sec interventions are required to affect both memory emotionality and vividness. Therefore, the duration of our task might not be sufficient to produce such an effect on emotionality. Another explanation could be that there is a linear relationship between the difficulty of the task and degrading negative emotional memories (Littel & van Schie, 2019). Hence, it is plausible that our task has been not demanding enough to reduce emotionality or intrusions. Unlike lots of studies, (Cuperus et al., 2019; Hout et al., 2010; Jongeneel et al., 2020; Matthijssen et al., 2019) similar manner of vividness and emotionality was not found in this study as a result of using WMI. This dissociation between emotionality and vividness has been reported by a few studies (Cuperus et al., 2016; Jansson & Dylman, 2021; Mertens et al., 2018). Jansson & Dylman, (2021) discussed that factors like "physical context, type of material to be processed and/or emotional states at the time" may be involved in the difference of emotionality and vividness, but further research is required to provide more details that are helpful in describing the underlying processes and factors.

Unlike our expectation, BAS resulted in an increased level of arousal and the number of intrusive memories compared to the control and WMI groups, as well as a reduced effect level of dominance compared to the control group. As, these results were marginally meaningful before the Bonferroni correction, it worth discussing few points with much caution. These results are likely due to the content of the selected traumatic film in our experiment. As the film contained a limited variety of contextual details, it is plausible that the peripheral and the central aspects of the trauma are similar to each other in terms of their variation across hue and saturation and hence, participants could not efficiently distribute their attention to acquire novel information while inspecting the scene. So, we can conclude that in absence of various neutral or either positive valence details, asking participants to broaden their attention to capture the peripheral details could not only provide any chance for acquiring new information to alleviate their emotional state, but also could heighten their arousal and dampen their emotional dominance. Besides the features of the film, another plausible explanation for the unwanted results could be assigned to the stress condition caused by testing expectations experienced by participants while they were encoding the information (Marks et al., 2018; Schultebraucks et al., 2019). They knew that they would be asked to recall the details of the film, so they might have sharpened their attention which could lead to an increase in arousal.

Our study has several limitations worth noting. First, we used self-report measures of emotionality, vividness, valence, arousal, dominance, and intrusive memories which may be moderated by incorrect subjective judgment. Future studies could thus improve their reliability by applying objective measures (i.e., skin conductance response, heart rate, blood pressure) in combination with subjective ones. Second, some of our participants were recruited from the university where our lab was located, therefore they might make mistakes while recording intrusive memories, since they might have multiple exposures with experiment place several times during the follow-up period. Thus, it is suggested to control unwanted retrieval cues as much as possible, by using an unfamiliar or isolated experimental setup. Finally, we could detect possible changes in the scores of arousal, valence and dominance, if we assessed these variables before the interventions.

Despite these limitations, a strength of the present study is considering BAS as a novel method to reallocate attention during acquisition and examining its effect on later retrievals. To our knowledge, the present study is among the first experiments, in which interventions in two different stages of memory were compared. Our findings indicate that WMI in later stages of memory formation outperformed BAS in the initial stages in terms of blurring the emotionally valanced memory. Future studies with objective measurements could add more evidence on the efficacy of these methods, specifically in the context of clinical implication for patients who suffer from traumatic memories.

Data availability and material: The full dataset is available in https://osf.io/nu9ke/?view_only=fd408fcb2c9342608f9c0e27be0e5da2

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Conflict of interest: The authors report no conflict of interest.

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