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BASIC RESEARCH ARTICLE

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Investigating the frequency of intrusive memories after 24 hours using a visuospatial interference intervention: a follow-up and extension

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ABSTRACT

Background: There is a need for effective, low-cost, readily available measures for reducing trauma symptoms so that people exposed to potentially traumatic events can receive help more quickly. A previous study reported that performing an intervention including a visuospatial task shortly after a reminder of a series of unpleasant film clips seen 24 hours earlier reduced the number of intrusive memories over the following week.

Objective: This study reports a follow-up and extension of the earlier promising finding. The prediction was that participants performing the visuospatial task immediately after the reminder would report fewer intrusions compared to three other groups who 1) performed no task, and novel conditions who 2) performed the task before the reminder, and 3) performed the task 90 minutes after the reminder.

Method: A trauma-analogue method was used, where students (N = 200) watched a series of short films with unpleasant material. Over the following week, they were asked to write down any intrusive memories they experienced in a diary. On the second day they returned to the lab and saw static reminders of the films. They were then randomly allocated to condition, recorded intrusive memories over the following days and returned to the lab for final testing on Day 8.

Results: A total of 49 participants did not report any intrusions and were excluded from the analyses. Two more participants were excluded as outliers, leaving a final sample of n = 149. Despite using largely the same materials as the original study there were no significant differences in the number of intrusive memories between the four groups post intervention.

Conclusions: Possible explanations include the effect not being as robust as expected, a low number of intrusions across groups, baseline differences in attention, and minor but potentially important differences in procedure between this and the original study.

Investigando la frecuencia de los recuerdos intrusivos después de 24 horas mediante una intervención de interferencia viso-espacial: seguimiento y extensión"

Antecedentes: Existe la necesidad de medidas efectivas de bajo costo y fácilmente disponibles para reducir los síntomas del trauma, de modo que las personas expuestas a eventos potencialmente traumáticos puedan recibir ayuda más rápidamente. James y cols. (2015) reportaron que realizar una intervención que incluye una tarea viso-espacial poco después de un recordatorio consistente en una serie de clips de películas desagradables vistos 24 horas antes, redujo el número de recuerdos intrusivos durante la semana siguiente.

Objetivo: Este estudio reporta un seguimiento y extensión del prometedor hallazgo de James y cols. La predicción fue que los participantes que realizaran la tarea viso-espacial inmediatamente después del recordatorio reportarían menos intrusiones en comparación con otros tres grupos que: 1) no realizaron ninguna tarea, y en condiciones novedosas que 2) realizaron la tarea antes del recordatorio y 3) realizaron la tarea 90 minutos después del recordatorio.

Método: Se utilizó un método analógico de trauma, donde los estudiantes (N = 200) vieron una serie de cortometrajes con material desagradable. Durante la semana siguiente, se les pidió que escribieran cualquier recuerdo intrusivo que experimentaran en un diario. El segundo día regresaron al laboratorio y vieron recordatorios estáticos de las películas. Luego fueron

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关键词
创伤; 创伤模拟; 俄罗斯方块; 创伤后应激障碍; 闯入性记忆

HIGHLIGHTS

- This study followed up James et al.'s (2015) finding that playing a visuospatially demanding game reduced negative intrusive memories.
- As we did not find a similar pattern of findings the intervention may be less promising than assumed and sensitive to changes in set-up.

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Statement of relevance: Following exposure to trauma one of the symptoms that affects some people most is that of involuntary intrusive memories from the traumatic event. There is an urgent need for cost-effective readily available therapeutic remedies that reduce these. A promising result was reported by James et al. (2015) where 24 hours after experimental trauma an intervention procedure which included playing a visually demanding video game after a reminder of the traumatic memory reduced the symptom. In the present study, we used a similar method and applied the same materials in another country (Norway). The experiment conducted here failed to produce the expected positive effect of the procedure including playing the video game. It is important that novel interventions are rigorously tested before being recommended for widespread use. The present study can shed light on important aspects of the intervention procedure that might guide further development.

Supplemental data for this article can be accessed here.

asignados aleatoriamente a la condición, registraron recuerdos intrusivos durante los días siguientes y regresaron al laboratorio para la prueba final el día 8.
Resultados: Un total de 49 participantes no reportó ninguna intrusión y fueron excluidos de los análisis. Se excluyeron dos participantes adicionales como valores atípicos, dejando una muestra final de $n = 149$. A pesar de utilizar en gran parte los mismos materiales que el estudio original, no hubo diferencias significativas en el número de recuerdos intrusivos entre los cuatro grupos después de la intervención.
Conclusiones: Las posibles explicaciones incluyen que el efecto no es tan robusto como se esperaba, un número bajo de intrusiones entre los grupos, diferencias basales de atención y diferencias menores pero potencialmente importantes en el procedimiento entre éste y el estudio original.

对使用视觉空间干扰干预24 小时后闯入性记忆频率的考查:后续和扩展

背景: 需要有效的低成本, 现成的测量来减少创伤症状, 以便暴露于潜在创伤事件的人能够更快地获得帮助。詹姆斯等人 (2015) 报告说, 24 小时前看到的一系列令人不快的电影片段提示物后不久进行包括视觉空间任务在内的干预, 会减少下一周闯入性记忆次数。
目的: 本研究报告了 James 等人可观发现的后续和扩展。预测是, 在提示物后立即进行视觉空间任务的参与者报告的闯入相较于以下其他三个组更少:1) 不进行任务,2) 在提示物之前进行任务的新条件, 以及3) 在提示物后90分组进行任务。
方法: 使用创伤模拟方法, 200名学生观看一系列包含令人不快材料的短片。在接下来的一周里, 他们被要求在日记中写下他们所经历的任何闯入性记忆。第二天, 他们回到实验室, 看到了电影的静态提示物。然后他们被随机分配到条件, 在接下来的几天里记录闯入性记忆, 并在第 8 天返回实验室进行最终测试。
结果: 共有 49 名参与者没有报告任何闯入, 从分析中剔除。另外两名参与者作为异常值被剔除, 留下 最终n=149 的样本。尽管使用与原始研究大致相同的材料, 但干预后四组之间的闯入性记忆次数没有显著差异。
结论: 可能的解释包括效应不如预期的那么稳健, 闯入次数跨组都很少, 注意力的基线差异以及本研究与原始研究之间在程序上的微小但可能重要的差异。

1. Introduction

Several cognitive models of posttraumatic stress disorder (PTSD) (e.g. Brewin & Holmes, 2003; Ehlers & Clark, 2000) have identified intrusive memories of trauma as the 'hub of symptomatology' (Iyadurai et al., 2019). That is, the involuntary popping up into consciousness of negative memories are deemed to be central to the maintenance of the disorder, acting as drivers of other symptoms. Intrusive memories are by their very nature relatively difficult to bring under experimental control but an approach that has been developed is the trauma film paradigm, that James et al.'s (2016a) review shows can be an ethically acceptable and sufficiently realistic method that has allowed intrusive memories to be generated and studied in a laboratory setting. In this paradigm, participants watch a film or series of clips containing some distressing scenes and are asked to record in a diary any intrusive memories that they experience over the following days or weeks.

A line of experimental studies using emotionally negative or trauma-related stimuli has tested the idea that intrusive memories can be weakened or reduced through mechanisms of concurrent and retroactive interference. For example, it has been suggested that the performance of a working memory task, while simultaneously recalling a negative memory might alter subsequent expression of that memory (Engelhard, Van Uijen, & Van den Hout, 2010). The underlying assumption is that concurrent interference can occur when performing two tasks simultaneously that involves competition for working memory resources, thus less capacity is available to process the troubling memory, which consequently will become less vivid and less emotional. In line with this, a recent meta-analysis by Mertens, Lund, and Engelhard (2020) demonstrated that emotional memories are indeed reduced in intensity if one recalls them while simultaneously performing an unrelated yet demanding task.

It has been argued that intrusive traumatic memories can also be disrupted by retroactive interference during memory consolidation and reconsolidation. According to this perspective, retroactive interference can occur soon after presentation of trauma stimuli, that is, during an initial time-window of memory consolidation when the memory is labile. Furthermore, when a previously consolidated memory is reactivated it can become malleable, and during a time window of reconsolidation intrusive memories might be reduced or weakened. In line with these notions, a study by Holmes, James, Coode-Bate, and Deeprose (2009) showed that soon after viewing unpleasant film clips after a film, receiving a reminder cue and playing Tetris, a video-game requiring visuospatial manipulation of two-dimensional blocks, reduced the number of intrusive images from the clips, compared to participants in a 'no task' control condition. Moreover, in Experiment 1 in a paper by James et al. (2015),

participants watched the same film clips, but instead of performing the Tetris-task 30 minutes after the film clips, the task was completed the day after initial viewing. In this set up, half of the participants were given a memory-reactivation task (still images from the clips), and then played Tetris for 12 minutes. The other half, in the control condition, were given a break. Again, the group given the Tetris-task after the reminders experienced significantly fewer intrusions than the control group, thus supporting the idea that engaging in a demanding task requiring visuospatial processing can disrupt the reconsolidation of intrusive memories; note that the dual task will have engaged visuospatial processing specifically but that it will necessarily also have engaged general working memory resources. James et al. (2015) replicated these findings of the intervention procedure 24 hours after film viewing in a second experiment in the same paper.

Similar patterns of results have been found in two other studies when the memory reminder and Tetris gameplay were presented 4 and 3 days after initial viewing of the videos, respectively (Hagenaars, Holmes, Klaassen, & Elzinga, 2017; Kessler et al., 2020); these studies were in collaboration with the original lead author but conducted in independent labs at two different universities. Because a reduction in such intrusions could, in turn, alleviate other symptoms related to posttraumatic stress disorder (PTSD) (Solberg, Birkeland, Blix, Hansen, & Heir, 2016), if confirmed, findings from this line of research could facilitate the development of a highly scalable and cost-effective way to alleviate PTSD symptoms in trauma-exposed individuals. Thus, the present study attempted to follow up and extend James et al.'s (2015) experiment 1 findings by using the no task condition and the reactivation+Tetris condition (where one group played Tetris 10 minutes after the memory reactivation task). In addition, the present study included two more conditions. One group played Tetris 10 minutes *prior* to the memory reactivation task. Thus this group allowed a follow-up of James, Lau-Zhu, Tickle, Horsch, & Holmes's (2016b) study testing for the possible proactive effects of playing Tetris. James et al. (2016b) in fact predicted and reported no effect of using a task prior to experimental trauma exposure on the number of intrusive memories; however, our thinking is that a preventive effect of such an intervention is potentially so important that it should be investigated again. With a fourth condition we again sought to shed light on the potential time-limits within the intervention and this group played Tetris 90 minutes *after* the memory reactivation task. The rationale for this latter condition is that the memory of the films will have been rendered malleable for several hours after reactivation (McGaugh, 2000; Wixted, 2004, 2005), so this condition will test the superficially counterintuitive prediction that visuospatial processing so long after the reminders of the unpleasant video clips could reduce the frequency of intrusive memories.

2. Method

The project protocol was approved by the ethical committee at the Department of Psychology, University of Oslo, project number 1411849. The data collection was conducted in two labs located at the Department of Psychology, University of Oslo and the Norwegian Centre for Violence and Traumatic Stress Studies.

2.1. Participants

Two hundred twenty-four male (n= 62) and female (n= 162) students aged 18–44 years (M = 23.0 years, SD = 4.43) participated in the study. They were recruited through posters, lectures and word-of-mouth at the University of Oslo, and on social media. All participants provided their written and informed consent prior to participation, before which they were notified of the distressing nature of the films. All participants were awarded a gift certificate of 500 NOK (~$50) on Day 1, regardless of whether they completed the study. In their Experiment 1, James et al. (2015) ran two groups of 26 participants each and observed the effect that the present study attempted to follow up. Based on this, we decided to increase the number of participants per group to 50, ensuring that we could observe a potentially weaker effect between groups, even if payment on Day 1 led to higher rates of attrition. There was no formal power calculation.

2.2. Materials

The self-report questionnaires were already translated into Norwegian. The other experimental materials were adapted from James et al. (2015) and translated into Norwegian, then discussed and adapted by four English-Norwegian bilinguals, one of whom is mother tongue English.

2.2.1. Trauma film

A 12-min film consisting of 11 short clips was used as an experimental analogue of viewing traumatic events in real life. The film contains footage of various events in line with criteria for trauma including witnessing serious injury and death, such as car accidents and surgical procedures, in line with criteria for trauma as specified in DSM-5. The same film has been shown to induce intrusive memories in participants in previous studies in the UK (Holmes et al., 2009; James et al., 2015). It was displayed on a high-resolution PC screen

on a desk and viewed at a comfortable distance, around 50 cm. The screen was 50 × 32 cm.

2.2.2. Memory-reactivation task

Participants were presented with 11 still images – one for each film clip – for 2 seconds each, using PowerPoint on the same screen as they saw the trauma film. The images were presented in the same order as their respective film clips, and depict the moment just before the worst part is about to occur, as these have been shown to be the ones typically yielding intrusive memories (Michael & Ehlers, 2007). This task was immediately followed by a 10-min break to allow for initiation of memory reconsolidation processes (Ågren et al., 2012; James et al., 2015). During this ten-minute break participants completed a filler task, in which they were asked to rate the pleasantness of 15 short music clips.

2.2.3. Tetris

The computer game Tetris consists of seven differently-coloured two-dimensional blocks of various geometric shapes, made up of smaller squares (e.g. a purple line, a red square). The blocks fall slowly from the top of the screen, one at a time, in a randomized order. Each time the blocks line up such as to form a horizontal line with no empty spaces, the line disappears, and the player is awarded points. The goal of the game is to complete as many lines and gain as many points as possible before the screen is completely filled up with blocks. This is achieved by rotating and moving the falling blocks using the four arrow keys on a standard QWERTY-keyboard. Blocks are rotated 90 degrees to the right with the 'up'-arrow, moved to the left and right with the left and right arrows, respectively, and are sped up by pressing the down-arrow. Participants were instructed to focus upon the block immediately succeeding the one currently in play at any given time, which is shown in the upper right-hand corner of the screen. To encourage mental rotation, they were asked to depict 'in their minds eye' how to best move and rotate this block in addition to the one currently in play. The game was at freetetris.org, (a different version to James et al., 2015 who used *Tetris* (Version 1.2.1; Blue Planet Software, 2007) set to 'Marathon' mode, see Discussion), played at level one with the sound turned off, and scores were not recorded. Participants were asked to restart the game immediately if they 'lost' before the allotted time was up.

2.2.4. Intrusion diary

A pen-and-paper diary was used in which participants were asked to note all intrusive memories of the film in the week separating the first (Day 1) and last (Day 8) session. The intrusion diary was a Norwegian translation of the one used by James et al. (2015). Participants were asked to note each time they experienced an intrusive memory from the film, designating whether the given memory was verbal or image-based (or a combination of both). As in James et al. (2015) participants were instructed not to write down memories that they had recalled deliberately that they should distinguish between thoughts and actual image-based memories, and to write down the content of intrusions immediately. Subsequently, it was checked that diary entries did in fact match with actual video clips, however unlike in James et al. (2015) the percentage match was not calculated. The dependent variable 'number of intrusions' was identified by counting each participants' number of intrusions reported between day 2 and 8. The total number of intrusions for the whole week was calculated as a sum score.

2.2.5. Intrusion-provocation task

Participants viewed 11 blurred images from the film presented in a random fixed order, using PowerPoint. Each picture was presented for 2 seconds on the same screen as the one on previous visits to the lab. Immediately after the last image they were instructed to close their eyes and make a cross on a sheet of paper each time they experienced an intrusive memory from the film over the following 2 minutes. The total number of crosses yielded the IPT intrusion score.

2.2.6. Verbal and visual recognition memory tests

Participants' memory for the films was tested by means of true/false judgements to 32 propositions about the film clips (16 true), and 22 images, 11 of which were taken from the film clips. The same materials were used as in James et al. (2015) so that the 11 previously seen images were not the same as those used in the intrusion-provocation task.

2.2.7. Film discomfort

Participants were asked to rate the level of discomfort they felt related to the trauma film on a 10-point scale ('Not at all' to 'Extremely'. The instructions given were 'Please indicate how unpleasant the film you just saw was'.

2.2.8. Attention to film

Participants were asked to rate how much attention they had given the film, also on a 10-point scale ('Not at all' to 'Full attention'. The instructions given were 'Please indicate how much attention you gave the film you just saw'.

2.2.9. Tetris difficulty

Participants were asked to rate how difficult they thought playing Tetris was on a visual analogue scale. The analogue scale was 15 cm long, where 0

millimetre indicated easy, and 150 mm indicated very difficult. Answers were recorded in millimetres.

2.2.10. Mood

Before and after the film participants were asked to rate their current level of various mood states (sad, hopeless, depressed, fearful, horrified, anxious) on a visual analogue scale from 'not at all' to 'extremely'. Answers were recorded in millimetres.

2.2.11. Belief in the effectiveness of Tetris

On day 8, participants were asked to what extent they believed that playing Tetris would reduce or increase the number of intrusive memories. Answers were recorded on a 20-point scale where −10 indicated a belief that Tetris would decrease intrusions a lot, through 0 indicating a belief that Tetris would have no effect, to +10 indicating a belief that Tetris would increase intrusions a lot.

2.2.12. Self-report questionnaires

Trait anxiety was measured with the Norwegian version of the Beck Anxiety Inventory (BAI) (Beck, Epstein, Brown, & Steer, 1988). A sum score was computed for all items, which could range from 0 to 63.

Depressive symptomatology was measured with the Norwegian version of the Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996). A sum score was computed for all participants, ranging from 0 to 63.

Prior trauma history was assessed with the Norwegian version of the Traumatic Experiences Checklist (TEC; Nijenhuis, Van der Hart, & Kruger, 2002). The TEC is a self-report questionnaire inquiring about 29 types of potential trauma. The total score ranges from 0 to 29. These measures are ones often used in our labs but differ from those used in James et al. (2015).

Finally, the Impact of Event Scale-Revised (IES-R; Weiss & Marmar, 1997) was used to assess the subjective distress caused by the trauma film. The IES-R is a self-report, 22-item scale, comprised of 3 subscales representative of the major symptom clusters of post-traumatic (intrusion, avoidance, and hyperarousal). Each item is scored on a 5-point Likert scale; 0 = not at all, 1 = a little bit, 2 = moderately, 3 = quite a bit, 4 = extremely, with a total sum score ranging from 0 to 88. As in James et al. (2015), the questions were adapted to refer specifically to distress caused by the film.

2.3. Procedure

Participants took part in three laboratory sessions, which occurred on Day 1, Day 2 and Day 8, all three sessions taking place at the same time of day (±2 hours).

Day 1 was identical for all participants regardless of experimental group. On this day, participants were first asked to complete the BAI, BDI, and TEC. This was followed by 3 min of Tetris practice, after which they were asked to rate how hard they found the game on an analogue scale from 'not at all difficult' to 'very difficult'. Next, participants viewed the trauma film, alone in a dark room with the door closed. The experimenter instructed the participants to picture that they were there, as a bystander, seeing the events unfold right in front of their eyes. These instructions were given to ensure that participants paid full attention to the film. Before and after the film they were also asked to rate their current level of mood states, as described above. The diary was explained, and they were asked to return it in 24 hours. Finally, in a change from James et al. (2015), the participants were reimbursed with a gift certificate at this point.

On day 2, participants were allocated to four groups in the order in which they were recruited to the lab: A reactivation + Tetris-group (n = 50) (similar to James et al., 2015), a Tetris + reactivation group (n= 50) (similar to James et al., 2016b), a reactivation + 1.5-h break + Tetris group (n = 50) (a novel condition), and a no-task control group (n = 50) (similar to James et al., 2015). The ratio of women to men was the same across all groups.

The reactivation + Tetris-group was first given the memory-reactivation task and then asked to play Tetris for 12 minutes.

The no-task control group completed only the music filler task followed by a 12-min break (i.e. the same length of time as for Tetris in the other groups). Participants were told that they could think about anything they liked.

Participants allocated to the reactivation + break + Tetris-group waited for 1 h and 30 minutes after the reactivation before playing Tetris. They did not have to wait in the laboratory but were asked to refrain from drinking beverages that could affect their subsequent Tetris performance (e.g. coffee, alcohol) and from playing games on their computer or mobile phone. Similarly, they were told that they could think about anything they liked. There was no check on what they did during their break time.

The Tetris + reactivation group played Tetris for 12 minutes immediately after arriving at the laboratory, and then performed the memory reactivation task in reverse order (i.e. the 10-min music-filler task first, followed by the trauma film images).

On Day 8 participants returned with the diary, and completed the Intrusion Provocation Task, verbal and visual recognition memory tests to assess their memory for the film, and the IES-R. They were also asked to indicate how accurately they believed they had completed the diary on a 10-point scale from 'Incorrectly' to 'Extremely correctly', and to what extent they

believed that playing Tetris would reduce or increase the number of intrusive memories of the type recorded in the diary, as described above. Finally, participants were debriefed, and thanked for their participation.

2.4. Statistical analyses

In the present study, participants were allocated to four experimental groups; No task, Tetris play 10 minutes after memory reactivation, Tetris play 1.5 hours after memory reactivation, and Tetris play 10 minutes *prior* to memory reactivation. With these four groups, the following hypotheses and analytical plan were developed for the number of intrusions in the diary days 2–8.

Hypotheses between groups

Compared to the No Task group:

Tetris play 10 minutes after memory reactivation reduces the frequency of image-based intrusions (James et al., 2015).

Tetris play 1.5 hours after memory reactivation reduces the frequency of image-based intrusions.

Tetris play *prior* to reactivation shows no effect (James et al., 2016b).

2.5 Analytical plan

1) First, exclude participants that did not experience any image-based intrusions during the first 24 hours, and 2) exclude outliers with number of intrusions >3 SD's from the mean of the whole sample day 2–8. Then, 3) describe sample characteristics using cross-tabulations and summary statistics. Finally, 4) perform an overall independent analysis of variance (ANOVA) including all groups, with the mean number of image-based intrusions as a dependent variable, followed by three hypothesis-driven independent sample t-tests comparing groups pairwise.

A fifth step (a Hurdle analysis modelled with negative binomial distribution) was added due to the fact that 49 (24.5%) of participants reported zero intrusions on day 2–8 (i.e. data were zero-inflated) and that the data were overdispersed. We note that we followed a slightly different analytical plan to James et al. (2015).

3. Results

A total of 24 participants dropped out of the study (6 simply failed to turn up on Day 2 or 8, 13 withdrew for various reasons including illness and being delayed, 1 person fainted during the film, and 3 were released by the experimenter due to the lab being unavailable, internet problems and for not playing Tetris, and for one participant the reason is not recorded; of these 6 were men, 17 were women, 10 didn't turn up on Day 2 and 13 didn't turn up on Day 8, and 3 were from the No Task group, 9 from the Reactivation + Tetris group, 5 from the Tetris + Reactivation group and 6 from the Reactivation + 90 minutes + Tetris group), leaving 200 participants with a complete dataset. Moreover, the exclusion of participants that did not report any image-based intrusions for the first 24 hours resulted in the reduction of 49 cases. In addition, two cases who reported a number of intrusions that was 5 *SD's* higher than the mean of the whole sample (mean 35.85 or higher, their actual numbers of intrusions were 36 and 73) on day 2–8 were excluded, leaving 149 valid cases for analysis as shown in Table 1. The demographics of the excluded participants were not significantly different from the included participants (see Supplementary Materials). There were no significant differences between the groups for age, gender, BDI, BAI and TEC after initial allocation to the experimental conditions as shown in Table 1.

3.1. Analysis of variance (ANOVA)

An overall analysis of variance (ANOVA) with the independent variable of 'group allocation' ('No task', 'Reactivation + Tetris after 10 min.', 'Reactivation + Tetris after 1.5 hours.', and 'Tetris + reactivation') and the dependent variable of 'number of intrusive, image-based memories day 2–8', was conducted. The between groups comparison did not show a significant effect of group allocation [$F(3,145) = 0.13$, $p = .94$]. Means and standard deviations are presented in Table 1.

3.2. Independent-sample T-tests for between group differences

Independent-sample t-tests were conducted to compare intrusion frequency (number of image-based intrusions reported between day 2 and 8) in the four experimental groups. Contrary to our hypotheses, there was not a significant difference in the number of intrusions between the 'No task' ($M = 2.86$, $SD = 3.60$) and 'Reactivation + Tetris after 10 minutes' ($M = 2.79$, $SD = 3.83$) groups; $t(68) = .087$, $p = .931$. Neither was there a significant difference in the number of intrusions between 'No task' ($M = 2.86$, $SD = 3.60$) and 'Reactivation + Tetris after 1.5 hours' ($M = 3.18$, $SD = 3.23$) groups; $t(75) = -.399$, $p = .691$. Finally, in line with our hypothesis, there was not a significant difference in the number of intrusions between the 'No task' ($M = 2.86$, $SD = 3.60$) and 'Tetris + reactivation' ($M = 2.72$, $SD = 3.36$) groups; $t(74) = .184$, $p = .855$. These results suggest that playing Tetris after memory reactivation does not have a lowering effect on intrusion frequency in this trauma-analogue experimental design.

Table 1. Number of intrusions and procedure-related measures, plus demographic and clinical scores, by condition (M±SD).

	No task controls ($n \approx 37$)	Reactivation + Tetris after 10 minutes ($n \approx 33$)	Reactivation + Tetris after 1.5 hours ($n \approx 40$)	Tetris + Reactivation ($n \approx 39$)
Age (*M±SD*)	21.59 ± 3.5	23.0 ± 3.58	23.3 ± 3.76	23.67 ± 5.54
Gender (female)	75.7%	75.8%	72.5%	74.4%
Intrusions first 24 hours (*M±SD*)	3.65 ± 3.42	2.97 ± 1.43	3.82 ± 3.57	3.15 ± 2.0
Number of intrusions, day 2–8 (*M±SD*)	2.86 ± 3.60	2.79 ± 3.83	3.18 ± 3.23	2.72 ± 3.36
TEC tot (*M±SD*)	3.38 ± 2.62	4.36 ± 3.57	3.60 ± 3.31	4.51 ± 4.12
BAI (*M±SD*)	6.51 ± 4.78	6.58 ± 7.79	5.25 ± 3.43	6.74 ± 8.08
BDI-2 (*M±SD*)	8.67 ± 8.49	7.53 ± 8.90	7.70 ± 7.68	6.85 ± 8.85
IES total (*M±SD*)*	13.86 ± 9.38	13.48 ± 10.08	11.65 ± 8.45	18.49 ± 12.83
-IES intrusions (*M±SD*)	6.59 ± 3.66	6.85 ± 3.83	6.58 ± 4.23	8.46 ± 5.77
-IES avoidance (*M±SD*)*	5.54 ± 4.77	4.73 ± 4.80	4.03 ± 3.93	7.05 ± 4.90
-IES hyperarousal (*M±SD*)*	1.73 ± 2.48	1.91 ± 2.82	1.05 ± 1.66	2.97 ± 4.31
Attention to film (*M±SD*)*	8.92 ± 1.09	9.48 ± 0.87	9.47 ± 0.72	9.44 ± 0.68
Visual recognition test (*M±SD*)	15.17 ± 1.77	14.7 ± 2.2	15.55 ± 1.93	15.05 ± 1.92
Verbal recognition test (*M±SD*)	19.95 ± 3.48	19.82 ± 3.48	20.41 ± 2.47	20.44 ± 3.0
Diary accuracy (*M±SD*)	8.0 ± 1.13	8.21 ± 0.99	8.4 ± 1.13	8.65 ± 0.98
Task difficulty (*M±SD*)	25.5 ± 24.9	23.6 ± 19.6	24.6 ± 24.2	35.6 ± 29.5
Intrusion Provocation Task (*M±SD*)	5.1 ± 3.5	4.6 ± 3.2	5.3 ± 2.9	4.9 ± 4.0
Belief in Tetris effectiveness (*M±SD*)*	−1.49 ± 3.0	−3.39 ± 2.7	−.85 ± 4.0	−.69 ± 3.5
Mood before movie (*M±SD*)	36.9 ± 38.8	28.5 ± 30.5	30.3 ± 37.4	33.4 ± 50.6
Mood after movie (*M±SD*)*	126.4 ± 79.2	128.3 ± 77.8	75.9 ± 64.7	122.1 ± 89.6
Film discomfort (*M±SD*)	7.19 ± 1.6	6.79 ± 1.93	6.08 ± 2.1	6.85 ± 2.4

TEC = Traumatic Experiences Checklist; BAI = Beck Anxiety Inventory; BDI-2 = Beck Depression Inventory-II; IES = Impact of Event Scale.
Difference between study arms tested with ANOVA and t-test: *$p < 0.01$. For IES total: difference between groups 3 and 4. For Attention to film: group 1 differed from all other groups. For Belief in Tetris effectiveness:group 2 differed from all others. For Mood after movie: group 3 differed from all others. For IES avoidance:group 4 differed from group 2 and 3. For IES hyperarousal: group 3 and 4 differed.

3.3. Hurdle regression model

Due to the fact that 49 (24.5%) of participants reported zero intrusions on day 2–8 (i.e. the data were zero-inflated), and that the data were overdispersed (i.e. the variance was greater than the mean), we conducted a Hurdle analysis modelled with a negative binomial distribution. This analysis supported the findings from the ANOVA and the 3 t-tests, with no group differences found in either part of the two-part Hurdle model (see supplementary material for details).

4. Discussion

The present study fails to find the same pattern of findings as those reported in Experiment 1 by James et al. (2015). In the present study, playing a visually demanding video game after a memory reactivation task did *not* reduce the number of intrusive image-based memories related to a trauma film previously viewed compared to a control condition. Possible interpretations of the results are discussed, including a consideration of some differences between studies. The procedural differences between this study and James et al. (2015) do not permit a test of replication but do permit us to reflect on the Tetris paradigm and possible future directions. Moreover, it is also possible that the study was somewhat underpowered, notwithstanding the fact that the current study had a final *N* per group of between 33 and 40, and James et al. had $N = 26$.

4.1. Low intrusion frequency

In the present study, participants reported fewer intrusions in the control condition compared to the James et al. (2015) study (mean = 2.86 compared to >5). Moreover, many reported zero intrusions (49/200) in the baseline phase prior to allocation to condition, requiring removal from the final analysis. This step does not appear to have been necessary to apply in previous studies, and even after the removals of the 'zero intrusions', the control group mean is still lower than the control group means in studies by Asselbergs et al. (2018), Badawi, Berle, Rogers, and Steel (2020) and Kessler et al. (2020). While Asselbergs et al. (2018) and Badawi et al. (2020) are both studies where the intervention was given at an earlier time frame than the current one, the control group should be comparable. A possible explanation for this is that the films were shown on a PC which is smaller than the screen used by James et al. (2015) (100 cm × 133 cm), and although the film was the same as James et al. used, it was a copy and the visual and audio quality was reduced, perhaps thereby also reducing the film's

impact. Moreover, because the film clips were largely aimed at a British audience, the film possibly did not feel self-relevant to participants in Norway. This possible lack of self-relevance to participants in the present study may have led to fewer intrusions and a lack of cognitive processing. Furthermore, with a low number of intrusions, the intervention had little to work with, i.e. it might be that we prescribed an intervention where there was nothing to cure. In future studies, a pilot phase to test whether films generate intrusions in a given new population may be useful (cf. Badawi et al., 2020). On the other hand, using the trauma film paradigm, Hagenaars, Van Minnen, Holmes, Brewin, and Hoogduin (2008) obtained an effect of visuospatial processing with lower mean numbers of intrusions than here, as did Krans, Näring, and Becker (2009) with comparable mean numbers. However, in those studies the tasks were immediate, whereas here there was a longer time interval between experimental trauma exposure and invention (24 hours) which means effects may require a more robust number of intrusions as their frequency naturally decays over the first few days.

4.2. Tetris game was different

As noted by Asselbergs et al. (2018), their null finding with a bespoke aeroplane game they created might also be due to the fact that the beneficial effect of Tetris is related to its unique features. In a similar vein, the present study also used a game from a different provider and a slightly more basic version of 'Tetris' than that used by both James et al. (2015) and Badawi et al. (2020). These differences included blander colours on the blocks, a basic gaming interface, only one (not three) block visible in the right upper corner, no 'combo' or 'Tetris' 'reward' and a more restricted movement of the blocks. Furthermore 'marathon mode' (where the dropping speed of the tetrominoes increases when participants reach higher levels) was not used – in marathon mode the game is adaptive to the players' performance. In the freeware version used here, no mode had to be chosen, rather the game simply started at Level 1 and got quicker after the completion of 10 rows. Overall, this may have made the game less engaging and possibly less taxing of working memory resources, including visuospatial aspects, compared to the game used in the original studies. The free (rather than the original brand) version may be less absorbing and compelling to play with few rewards, and without marathon mode the task is less adaptive to the players skills level, further with fewer blocks visible there is less change to practice mental rotation. Further research would be needed to compare the cognitive task properties.

4.3. Payment at the beginning

Due to restrictions set by the ethics committee, the participants in the present study were paid for their participation during their first visit to the lab. This may have led to a reduced adherence to the instructions given, less attention to experienced intrusions and willingness to write them down in their diary after they left the lab, compared to participants in the James et al. (2015) study. Taken together, this might have made small group differences disappear if the diaries were filled in with less care because one had already received payment, although the scores for self-reported diary compliance are indistinguishable from those reported by James et al. (2015); this study's four groups ranged in mean out of 10 from 8,0 to 8,7 and James et al.'s groups scored 8,2 & 8,3. It is nevertheless possible that payment during the first lab session increased attrition, contributing in part to the reduction in overall number per condition to 38 instead of 50.

4.4. Randomization process

Another minor difference is the method of allocation to the four groups (computer randomization in James et al., versus researcher allocation in sequential fixed order). In order to be able to inform the participants at point of recruitment how long the lab visits would take, and because one of the conditions included a longer interval than the others, participants were assigned to condition when they were recruited (strictly following a constant sequence of the four conditions). This means that the research assistant was not blind pre-allocation to condition which could in theory have influenced expectancies, although generally one would expect any such effect to skew the data in the direction of the predictions.

4.5. Some significant differences between groups on baseline measures

Participants in the control condition reported paying significantly less attention to the film clips, compared to the other groups. Less attention to the film would be expected to lead to a smaller number of intrusions. This might also partially explain why they reported intrusion frequencies similar to the two intervention groups, and a lower number of intrusions compared to James et al.'s control group.

While before viewing the film there were no differences between groups on mood, afterwards the participants that were subsequently allocated to play Tetris 90 minutes after reactivation had lower mood on the composite VAS score.

On the total IES score and on the hyperarousal subscale, the group that played Tetris before

reactivation scored higher than the Reactivation + 90 minutes group. On the avoidance subscale, the Reactivation + 90 minutes group scored higher than the 'Tetris before reactivation' and the 'Reactivation before Tetris' groups. There were no differences on the intrusion subscale, which is presumably of most relevance here. Participants were assigned to condition in the order in which they were recruited (rather than by a formal randomization) which was not the same order in which they came to the lab, so that there is no obvious explanation for the differences in terms of systematic or cyclical factors.

4.6. Difference in sample populations

A majority of the sample was recruited from the University of Oslo, were younger than James et al.'s (2015) participants and had higher BDI-II scores. It is well-known that one must exercise caution in extrapolating from such a university sample to the general population.

4.7. Feedback and training

In the planning of the current study, one of the original study authors (EAH) discussed the theoretical knowledge about procedures and shared a written protocol, while E. James met to discuss procedures. Future research should determine if, why and to what extent training with feedback, and pilot cases are necessary, and consider formalizing procedures. For instance, unlike here, the Badawi et al. (2020) study included a pilot phase with feedback and training from the primary researchers, and modification of the film used, prior to commencing their test of replication experiment (see the section in their paper 'Commentary on replication'), and the experimenters in Hagenaars et al. (2017) and Kessler et al. (2020) had received more training through study visits, though this was not formalized. Overall, making procedures more detailed to facilitate the transfer between labs – and developing improved training and piloting protocols – would be a useful goal.

4.8. Belief in the utility of playing Tetris

One finding from the present study that suggests a possible account is that participants in the standard 'Reactivation and Tetris' group had a significantly higher belief in the utility of their condition for reducing intrusions. If this is a general finding then expectancy effects may be playing a role in the Tetris effect reported in other studies, though we note that any such effect did not operate here as intrusions were not reduced in line with expectations, possibly suggesting expectation alone is unlikely to be a key driver in other studies.

5. Conclusion

We conclude that any effect of a procedure delivered 1 day after viewing a trauma film is simply absent, or at least smaller than reported in earlier studies. That is, the results of the present study did not confirm the beneficial effects on image-based intrusions during a supposed memory reconsolidation timeframe, unlike earlier studies (Hagenaars et al., 2017; James et al., 2015; Kessler et al., 2020). It is not clear if deviations from the original protocol (e.g. different Tetris game), or differences at baseline (e.g. attention paid to film, randomization) or that receiving comparatively less training and supervision from the original authors or alongside the absence of pilot testing may in part account for the lack of effect. As this study was not a test of replication, and may be underpowered, it is not possible to draw stronger conclusions at this point.

The reporting of null findings is important and helps avoid publication bias (cf. Chalkia, Van Oudenhove, & Beckers, 2020; Schroyens, Sigwald, Van den Noortgate, Beckers, & Luyten, 2021, in the context of the literature on fear and reconsolidation in humans). In so doing it is also important is to spell out minor but potentially important differences in procedure between this and the original study, as we have done here. Future studies should carefully investigate which conditions may produce a reduction in intrusive memories and which conditions do not.

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Author contributions

Solberg, Blix and Brennen developed the study concept, based on the work of James et al. (2015). Skumlien, together with Solberg and Brennen, collected and entered the data. Solberg and Nissen analysed the data and interpreted it with Blix, Holmes and Brennen. Skumlien drafted the Methods section and Brennen and Solberg the rest of the manuscript. All authors provided critical revisions and approved the final version of the manuscript for submission.

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Data availability statement

The data that support the findings of this study are openly available at 10.17605/OSF.IO/68VX5

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