Preventive efforts in the aftermath of analogue trauma: The effects of Tetris and exercise on intrusive images

Antonia Brühl[a],*, Nina Heinrichs[a], Emily E. Bernstein[b], Richard J. McNally[b]

[a] *University of Braunschweig, Department of Psychology, Institute of Clinical Psychology, Psychotherapy and Assessment, Humboldtstr. 33, 38106, Braunschweig, Germany*
[b] *Harvard University, Department of Psychology, 1230 William James Hall, 33 Kirkland Street, Cambridge, MA, 02138-2044, USA*

A B S T R A C T

Background and objectives: Efficacious interventions soon after trauma exposure to prevent posttraumatic stress disorder (PTSD) are scarce. Evidence suggests that post-trauma, reminder cues to reactivate trauma memory followed by a cognitive visuospatial task, such as Tetris, reduce later intrusive images. Furthermore, studies indicate that aerobic exercise may reduce PTSD symptoms. The present study aimed to test whether playing Tetris, without prior reminder cues, after an experimental trauma limits the development of analogue symptoms and to compare Tetris to aerobic exercise, which could plausibly alter cognitive-affective processing of the trauma as well.
Methods: Participants (N = 71) watched a distressing film and were randomly assigned to either playing Tetris, cycling, or remaining sedentary for 25 min without prior reminder cues. Intrusive images and co-occurring distress were recorded in a diary during the following week. After one week, participants completed a recognition test to assess voluntary memories of the film.
Results: Neither Tetris nor exercise, without prior memory reactivation, reduced intrusive images and associated distress nor impeded voluntary memory compared to the control condition. There were no effects of physical fitness level at baseline or voluntary exercise during the subsequent week on analogue symptoms.
Limitations: Although participants were instructed to record intrusions as they occurred in diaries, they did not receive additional reminders throughout the follow-up period.
Conclusions: Our findings suggest that neither a single bout of aerobic exercise, nor playing Tetris without prior memory reactivation, after an analogue trauma reduces stress symptoms. Potential explanations and clinical implications are discussed.

1. Introduction

Intrusive images of a trauma are sensory-based re-experiencing symptoms characteristic of posttraumatic stress disorder (PTSD; Brewin, Gregory, Lipton, & Burgess, 2010; Creamer, O'Donnell, & Pattison, 2004) that are key targets for preventive efforts. Although evidence-based treatments for PTSD are available, early interventions that prevent the development of such symptoms following trauma exposure are scarce (Roberts, Kitchiner, Kenardy, & Bisson, 2009; Sijbrandij, Kleiboer, Bisson, Barbui, & Cuijpers, 2015). One preventive approach is the use of visuospatial cognitive tasks, such as the computer game Tetris, that may inoculate against the emergence of intrusive images (Holmes, James, Kilford, & Deeprose, 2010). Following encoding of new information, memories are consolidated and malleable

over a 6-h period (Walker, Brakefield, Hobson, & Stickgold, 2003). Yet limits in cognitive capacity mean that visual trauma images may compete for resources that support concurrent cognitive visual tasks during consolidation (Holmes, Brewin, & Hennessy, 2004). Therefore, a visuospatial cognitive task performed during consolidation of a trauma memory may interfere with the latter's consolidation, thereby reducing the frequency of later intrusive images. Consistent with these hypotheses, studies have shown that individuals who played Tetris soon after watching a distressing film reported fewer intrusive images in the following week relative to subjects who performed no task (Holmes et al., 2010; Holmes, James, Coode-Bate, & Deeprose, 2009). Holmes et al. (2010) had participants watch a distressing film for 21 min before performing filler tasks for 30 min and viewing a reminder of the film (a brief memory reactivation task). Immediately thereafter, participants

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* Corresponding author.
E-mail addresses: a.bruehl@tu-bs.de (A. Brühl), nheinric@uni-bremen.de (N. Heinrichs), ebernstein@g.harvard.edu (E.E. Bernstein),
rjm@wjh.harvard.edu (R.J. McNally).

either played Tetris, a verbal-conceptual task, or sat quietly for 10 min. Results showed that Tetris decreased the frequency of intrusive images from the film, whereas the verbal task increased them. The authors concluded that verbal tasks do not compete for resources requisite for consolidating visual images. James et al. (2015) expanded these findings by showing that 24 h after watching a trauma film, playing Tetris following a memory reactivation cue reduced intrusive memories in the following week. Therefore, playing Tetris may disrupt not only the initial consolidation, but also the reconsolidation of trauma images. To initiate reconsolidation after 24 h, James et al. (2015) reactivated the trauma memories by presenting reminder cues in form of film stills from the trauma film and showed that both a prior memory reactivation and playing Tetris were required to reduce intrusive images. These findings suggest that during reconsolidation processes, explicit memory reactivation may play an important role in this paradigm. Although Tetris certainly constitutes an innovative intervention, replication studies from outside the Holmes research group are scarce. Given that there is no effective comparator intervention directly delivered post-trauma (Roberts et al., 2009), prior studies have only compared Tetris to a no-task control or other cognitive tasks. Therefore, we aimed to partially replicate and extend previous findings (Holmes et al., 2010) by comparing Tetris to a physical intervention. The duration of these activities was extended and the 30-min post-film interval and the memory reactivation task were omitted.

Aerobic exercise can help people weather physical and emotional stress (Bernstein & McNally, 2016; Salmon, 2001; Zschucke, Renneberg, Dimeo, Wüstenberg, & Ströhle, 2015). Moreover, it diminishes PTSD symptoms (Asmundson et al., 2013; Rosenbaum, Tiedemann, Sherrington, Curtis, & Ward, 2014) perhaps by mitigating physiological arousal (Blumenthal et al., 1988; Glynn, Christenfeld, & Gerin, 2002; Kishida & Elavsky, 2015) or decreasing vulnerability to adverse effects of rumination (Bernstein & McNally, 2017; Puterman et al., 2011). Additionally, neurochemical changes following exercise, such as an elevated brain-derived neurotrophic factor (BDNF), that are crucial for memory consolidation may facilitate fear extinction (Powers et al., 2015).

Taken together, Tetris and aerobic exercise constitute accessible approaches that may reduce the likelihood of developing PTSD. Therefore, the *primary aim* of our experiment was to partially replicate a version of Holmes et al.'s (2010; Experiment 1) and test whether participants who play Tetris after seeing a distressing film (without reminder cues), compared to a no-activity control group, report fewer intrusive images over the following week. Furthermore, we expected that Tetris would have no effect on voluntary memory of the film. The *secondary aim* was to investigate if engaging in a single bout of aerobic exercise would also curb the development of analogue intrusive symptoms. Given the protective effects of exercise for mood (Mata, Hogan, Joormann, Waugh, & Gotlib, 2013), we predicted that exercise should reduce the frequency of intrusive images, and lessen their distressing impact, thanks to enhancing emotion regulation processes. However, in line with previous findings, acute exercise may enhance general memory consolidation and thus also improve deliberate recall of voluntary memories (Roig, Nordbrandt, Geertsen, & Nielsen, 2013). Similarly, we expected participants with higher fitness levels and more regular exercise habits to have better voluntary memory, but fewer involuntary or intrusive images and less accompanying distress, than less fit or inactive participants.

2. Method

2.1. Participants

Seventy-one participants (30 women, 41 men, M_{age} = 31.27, SD = 12.06), including university affiliates and community members, completed the study. We advertised the study as an investigation of how exercise, intrusive memories, and distress are related and noted

that participants may cycle or engage in a less physically active task. Eligible participants were at least 18 years old and denied current or past mental health treatment. Further exclusion criteria were possibility of pregnancy, medical contraindications to exercise (Physical Activity Readiness Questionnaire; Adams, 1999), or a score above the cut-off (> 24) on the Exercise Addiction Inventory: Short Form (EAI; Szabo & Griffiths, 2004). The study protocol was approved by Harvard University's Committee on the Use of Human Subjects.

2.2. Procedure

Participants completed two laboratory sessions, occurring seven days apart. During session 1, after providing written informed consent, participants completed the Depression Anxiety Stress Scales short form (DASS-21; Lovibond & Lovibond, 1995) to assess mood and anxiety symptoms, and the George Non-Exercise Test (GNET; George, Stone, & Burkett, 1997) to assess exercise habits and fitness level. Participants' maximal oxygen consumption (VO_2max) was estimated by using their GNET responses, height, and weight. All participants then watched a distressing film for 21 min, including footage of car accidents and surgeries (as used in Holmes et al., 2010). Afterwards, participants rated how closely they had attended to the film and their perceived distress on scales from 0 (*not at all*) to 10 (*extremely*). Unlike previous studies (Holmes et al., 2010), we excluded the 30-min delay period after the film, implemented in previous studies to approximate the average waiting time in an emergency department in the United States (Holmes et al., 2009). Given the apparent absence of additional rationales for this delay, we omitted a delay between the film and experimental tasks. The length of this interval period has varied across studies, with intervals of 30 min (Holmes et al., 2009; Holmes et al., 2010, Exp. 1) to 4 h (Holmes et al., 2010, Exp. 2) to estimate waiting times for emergency assistance, and 24 h for targeting reconsolidation processes (James et al., 2015). In order to reactivate the trauma film memories after these interval periods, previous studies further presented reminder cues in form of film stills immediately before participants played Tetris (e.g. Holmes et al., 2010; James et al., 2015). Given that we omitted this interval period, we assumed that trauma film memories were still sufficiently activated when playing Tetris (approximately 2 min after watching the film). Therefore, we omitted any reactivation task as well, constituting a considerable change to previous investigations of this paradigm. Instead, participants were immediately randomly assigned to one of three subsequent 25-min activities: playing Tetris (Blue Planet Software, 2016; n = 24); completing a bout of aerobic exercise (n = 24); or remaining sedentary as a no-activity control (n = 23). In the Tetris group, participants had a 2-min practice trial and then played Tetris for 25 min on a computer. Participants were instructed to work out in their mind's eye where best to place and rotate upcoming and currently falling blocks to complete the most rows. Participants in the exercise group cycled at a moderate intensity. They had 5 min of warm up and then cycled at 60–70% of their estimated maximum heart rate (208 – (0.7 x age)) for the remaining time. All participants recorded the occurrence of initial intrusive images related to film during the activity as an index of cognitive task difficulty. Afterwards, participants rated their mood, enjoyment and perceived difficulty of the activity, and activity compliance on scales from 0 (*not at all*) to 10 (*extremely*).

Participants were provided with a pen and paper diary in which to record their intrusive images, associated distress (rated 0 (*not at all*) to 10 (*extremely distressing*)), and engagement in exercise (duration, type, intensity) during the following week. Intrusive images were described as spontaneously occurring "mental images" of scenes from the film. Exercise habits were coded in line with the GNET. Finally, participants rated how accurately they completed the diary on a scale from 0 (*not at all*) to 10 (*extremely*).

During session 2, participants turned in their diary, their compliance was verified, and they completed a verbal recognition memory task (Holmes et al., 2010). This task consisted of 30 written statements

describing the film to which participants responded by checking 'true' or 'false' on the list of statements. For capturing state-level affect, we asked participants to rate six emotions on scales from 0 to 100 during session one (baseline, post-film, post-task) and at one-week follow-up.

2.3. Statistical analysis

Based on previous studies ($d = 0.91$, Holmes et al., 2009; $d = 0.70$, Holmes et al., 2010), we anticipated an effect size of $d = 0.80$. Detecting this effect in an analysis of variance (ANOVA) requires a sample size of $N = 72$ to ensure 85% power ($\alpha = 0.05$). Total sample size was $N = 75$. However, we excluded three outliers whose responses were more than three times the interquartile range above the third quartile ($n = 1$ exercise group, $n = 2$ no-activity group). We tested for normality by examining skewness, kurtosis, and the results of Sharpio-Wilks tests. For the outcome variables, z-values were calculated to test whether skewness and kurtosis significantly differed from zero. Non-parametric tests were used when assumptions for parametric analyses were violated.

We used Kruskal-Wallis tests and Mann-Whitney U tests to evaluate group differences in baseline measures, film-induced distress, attention to the film, initial intrusive images, activity enjoyment, activity difficulty, activity compliance, and diary accuracy. As a manipulation check, repeated measures ANOVAs assessed mood deterioration during film viewing. For investigating the effects of condition on frequency of intrusive images, associated distress, and voluntary memory, we conducted ANOVAs with planned comparisons. Effect size Hedge's g was computed for each comparison. Potential confounding effects of participant's fitness level at baseline and voluntary exercise during the week on outcomes were examined by employing single regression analyses.

3. Results

Age and baseline characteristics are presented in Table 1. Groups did not differ in their demographic characteristics, DASS scores, film-induced distress, attention to the film, activity enjoyment and difficulty, or diary accuracy. The manipulation check of the paradigm revealed that participants experienced significant mood deterioration from pre- to post-film assessment. Across groups, positive affect decreased significantly with time ($F(2,67) = 158.46$, $p < .001$), while negative affect increased significantly post-film, $F(2,68) = 73.54$, $p < .001$. No group effects or interaction effects (time x group) emerged for positive or negative affect ($ps > .05$). Significant differences among groups emerged for participants' age ($X^2(2, N = 71) = 6.07$, $p = .048$), fitness level ($X^2(2, N = 71) = 9.00$, $p = .011$), and initial intrusive images recorded during the activity, $X^2(2, N = 70) = 14.883$, $p = .001$. Post hoc analyses revealed that the Tetris group, which performed the most cognitively demanding task, experienced fewer initial intrusions than

Table 1
Means and statistics for age and baseline assessments among experimental conditions.

Measure	Tetris		Exercise		No-task		Kruskal-Wallis	
	M	SD	M	SD	M	SD	X^2 (2, N = 71)	P
Age	27.40	9.14	35.83	14.76	30.91	10.26	6.068	.048
DASS Stress	10.92	3.31	10.08	3.12	10.13	2.82	0.955	.620
DASS Anxiety	9.08	1.91	9.04	2.69	8.65	1.75	0.912	.634
DASS Depression	9.63	3.35	8.46	1.62	8.91	2.04	1.532	.465
Fitness level	45.99	8.39	37.64	9.93	42.92	9.96	9.001	.011

Note. M = Mean. *SD* = Standard deviation. *p* = significance (2-tailed). DASS Stress = Stress subscale of the DASS-21 (Lovibond & Lovibond, 1995). DASS Anxiety = Anxiety subscale of the DASS-21 (Lovibond & Lovibond, 1995). DASS Depression = Depression subscale of the DASS-21 (Lovibond & Lovibond, 1995). Fitness level = VO_2max.
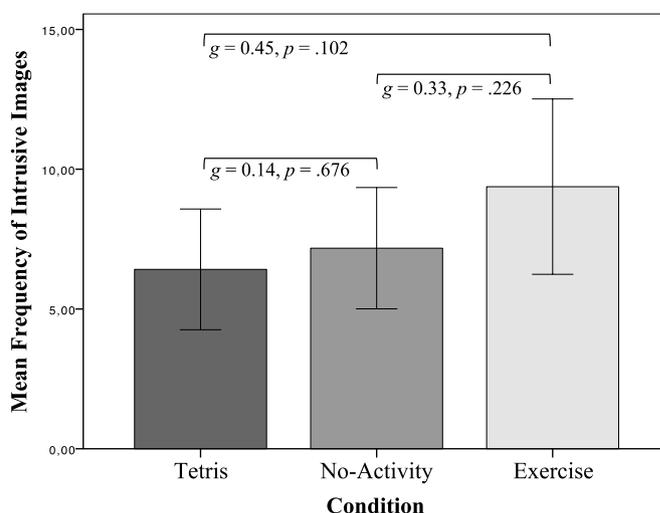

Fig. 1. Mean values and standard errors representing frequency of intrusive images recorded in the diary over one week for the three experimental conditions. Effect size Hedge's g and significance are presented for each planned comparison.

did the groups that exercised ($p = .009$) or remained sedentary ($p < .001$). The exercise group reported higher activity compliance than the Tetris group, $U = 161.00$, $N_1 = 24$, $N_2 = 24$, $p = .003$. However, activity compliance did not differ between the Tetris and the no-activity group.

Contrary to our expectations, there were no significant group differences in the frequency of intrusive images ($F(2,68) = 1.48$, $p = .235$, $\eta_p^2 = 0.042$; Fig. 1), associated distress ($F(2,61) = 1.61$, $p = .208$, $\eta_p^2 = 0.050$; Fig. 2), or voluntary memory at the follow-up visit ($F (2, 65) = 0.85$, $p = .432$, $\eta_p^2 = 0.025$; Fig. 3). There were also no significant effects of the condition on outcomes after controlling for the effect of participants' age. Effects on distress associated with intrusive images remained non-significant after controlling for frequency of intrusive images. Regressions revealed no significant main or interaction effects of fitness level and condition or voluntary exercise during the week and condition on intrusive images, distress, or voluntary memory. Results remained non-significant when we controlled for fitness level in the latter analyses.
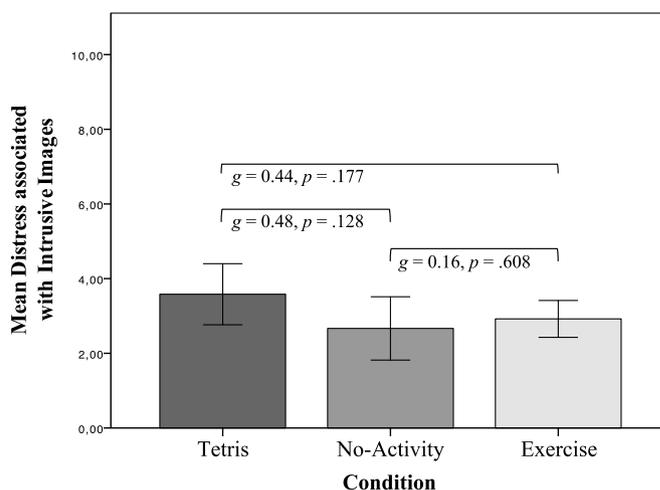

Fig. 2. Mean values and standard errors representing distress associated with intrusive images (on a scale from 0 to 10) recorded in the diary over one week for the three experimental conditions. Data are only available for participants that had at least one intrusive image. Effect size Hedge's g and significance are presented for each planned comparison.
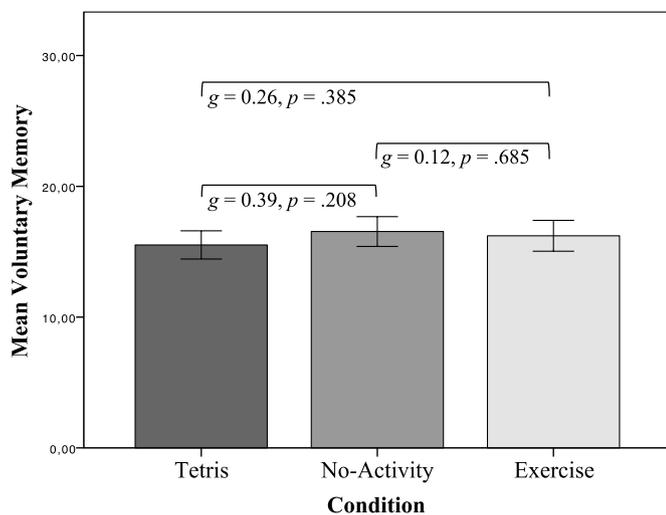
Fig. 3. Mean values and standard errors representing voluntary memory assessed with the recognition task (scores on a scale from 0 to 30) one week after watching the trauma film for the three experimental conditions. Effect size Hedge's *g* and significance are presented for each planned comparison.

4. Discussion

Consistent with prior studies, Tetris did not affect voluntary memory for the trauma-film (Holmes et al., 2010). However, contrary to expectations, we found no effect of Tetris on the frequency of intrusive images in the following week. These null findings may implicate potential boundary conditions to the effectiveness of the Tetris procedure. Unlike Holmes et al. (2010), we did not include a 30-min delay after the film followed by trauma-film reminder cues. Most previous studies used reminder cues during reconsolidation to reactivate memories. For example, James et al. (2015) compared four groups (reactivation task plus Tetris, Tetris only, reactivation task only, and no-task control) and showed that 24 h after watching a trauma film, participants who completed a memory reactivation task followed by playing Tetris reported significantly fewer intrusive images than did a no-task group. Moreover, neither playing Tetris only nor completing the reactivation task alone reduced intrusive images. Therefore, during reconsolidation process, both a memory reactivation of the trauma film and playing Tetris may be essential to reduce intrusive images. However, preliminary findings suggest that reminder cues may also play a crucial role during consolidation. Consistent with our findings, studies show that Tetris before or after a trauma-film without reminder cues does not reduce intrusive images (James, Lau-Zhu, Tickle, Horsch, & Holmes, 2016; Lau-Zhu, 2017). The intense and dynamic visual scenes from a trauma-film constitute complex memories and even in the laboratory, participants are exposed to some distractions during consolidation. Therefore, reminder cues during this period may help participants focus on the memories targeted by the interference procedure (Iyadurai et al., 2017). Studies with complex real-world trauma scenes showed that playing Tetris reduces intrusive images in car accident survivors (Iyadurai et al., 2017) and in mothers, who experienced traumatic childbirths (Horsch et al., 2017). Iyadurai et al. (2017) employed reminder cues in the hospital to reorient participants to the accident. In contrast, reminder cues were omitted in the traumatic child birth study (Horsch et al., 2017), because mothers played Tetris in the same hospital in which the trauma had occurred (i.e. surrounded by natural reminder cues). Our results support that reminder cues may be critical for the effectiveness of the Tetris procedure.

Neither engaging in a single bout of aerobic exercise after watching the film nor voluntary exercise reduced the frequency of intrusive images, associated distress, or voluntary memory. Thus, curbing the development of intrusive images after a trauma may not be a

mechanism of exercise's apparent preventive effect against the development PTSD.

But null results could also be attributed to the timing of the physical activity and emotion ratings. For example, immediately pairing a distressing trauma-film with aerobic exercise, both of which increase arousal, could be counterproductive. Indeed, previous studies indicate that PTSD symptoms are mediated by elevated psychophysiological arousal in the acute phase post-trauma (Shalev et al., 1998). Longitudinal data support this theory by showing that car accident survivors with higher resting heart rates at hospital discharge were more likely to develop PTSD (Bryant, Harvey, Guthrie, & Moulds, 2000, Bryant, Harvey, Guthrie, & Moulds, 2003). Besides the arousal per se, individual differences in cognitive processing may have moderated our effects. For example, the appraisal of the arousal may vary as a function of dispositional characteristics, such as anxiety sensitivity, or of the context in which the arousal occurs (e.g., at home or trauma site). Furthermore, previous findings on the effects of acute exercise directly after a learning session on memory are inconsistent (Hötting, Schickert, Kaiser, Röder, & Schmidt-Kassow, 2016; Segal, Cotman, & Cahill, 2012). Exercise prior to learning or after a delay may be more effective than immediately after learning (Frith, Sng, & Loprinzi, 2017; Labban & Etnier, 2011). Additionally, in the present study participants only rated initial distress in response to an intrusive image. Yet exercise need not blunt initial emotional responses to stressors, but rather hasten emotional recovery from stressors (e.g., Bernstein & McNally, 2016, 2017). Accordingly, group differences might have emerged had we assessed persistent distress.

5. Limitations and conclusion

Our study has limitations. First, participants tracked intrusions via a self-report diary rather than via smartphones which reduce the likelihood of forgetting intrusions. Second, we did not assess participants' playing visuospatial games during the week, which could have impacted intrusions. Third, we averaged the power found in previous studies, possibly overestimating the effect of Tetris. Future replications of the experiment with larger sample sizes are warranted. Finally, only the effects of single, 25-min sessions of cycling and Tetris immediately after the film were examined and it remains unclear if effects would differ for other durations, intensities, and modalities of both conditions.

Overall, our findings suggest that playing Tetris without employing a memory reactivation task or engaging in a single bout of aerobic exercise directly after an experimental trauma do not reduce analogue posttraumatic symptoms. Findings also showed that neither Tetris nor exercise diminishes voluntary memories of the trauma-film. Some other prevention approaches, such as certain drugs (e.g., propranolol; Liao & Sandberg, 2008) and cognitive suppression techniques (Anderson & Levy, 2009) do have potentially deleterious effects on voluntary memory recall. In line with Holmes et al. (2010), we emphasize that early interventions should only affect symptoms and associated impairments, but leave voluntary memory about the trauma intact for clinical as well as practical reasons (e.g., for court testimony).

Declaration of conflicting interests

The authors declare that they had no conflict of interest that relate to the research described in this publication.

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