Can a novel imagery-competing task intervention reduce intrusive memories of trauma? A study among Icelandic women

Kristjana Þórarinsdóttir

Thesis for the degree of Philosophiae Doctor

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Getur sjónrýmdarverkefni dregið úr áfallatengdum minningum? Rannsókn meðal íslenskra kvenna

Kristjana Þórarinsdóttir

Ritgerð til doktorsgráðu

Leiðbeinandi

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Ágrip

Bakgrunnur: Áleitnar endurminningar eru kjarnaeinkenni áfallastreituröskunar (ÁSR). Þetta eru minningar sem eru óvelkomnar, ósjálfráðar og fela yfirleitt í sér einhvers konar skynjun, til dæmis sjónræna. Þær valda vanlíðan og hafa skerðandi áhrif á virkni í daglegu lífi. Þótt til sé árangursrík meðferð við ÁSR, þá krefst hún oft ítarlegrar lýsingar á áfallareynslu viðkomandi, sem eykur á vanlíðan og eykur líkur á brottfalli úr meðferðinni. Einnig krefst áfallameðferð sérhæfðrar klínískrar þjálfunar sem takmarkar aðgengi þar sem sérhæfðir meðferðaraðilar eru of fáir til að sinna öllum þeim sem þurfa á meðferð að halda. Þörf er á inngripum sem eru einföld í fyrirlögn og hægt er að veita með fjarfundarbúnaði.

Markmið: Helsta markmið þessarar doktorsritgerðar var að meta árangur af hugrænu inngripi sem ætlað er að draga úr tíðni áleitinna endurminninga. Inngripið er sjónrýmdarverkefni sem reynir á getu til skynúrvinnslu og byggist á kenningum um virkjun og endurvistun minninga. Inngripið felur í sér að virkja áfallaminningu og gera svo sjónrýmdarverkefni (Tetris með hugrænum snúningi) sem miðar að því að trufla skynúrvinnslu áleitinna endurminninga. Markmið rannsóknanna var að meta árangur inngripsins eins og það var lagað að íslensku þýði. Markmið voru einnig að kanna hvort inngripið væri raunhæf leið til þess að draga úr tíðni áleitinna endurminninga og hvort lægri tíðni hefði áhrif á einkenni ÁSR, einkenni þunglyndis og kvíða, og hvort inngripið hefði jákvæð áhrif á daglega virkni.

Aðferð: Þrjár rannsóknir voru framkvæmdar með endurteknu AB-rannsóknarsniði þar sem inngripinu var beitt gegn áleitnum endurminningum eftir áföll. Rannsókn I var með konu sem hafði einkenni ÁSR undir greiningarviðmiðum. Hún var með fjórar áleitnar endurminningar og skráði tíðni þeirra í fjórar vikur á grunnlínu og í átta vikur á inngripstímabili. Einnig skráði hún tíðni þeirra í eina viku á eftirfylgdartímabilum (eins mánaðar og þriggja mánaða). Rannsókn II var með þremur konum (tvær með áfallastreituröskun og ein með einkenni undir greiningarviðmiðum). Hver þátttakandi skráði tíðni áleitinna endurminninga í eina viku á grunnlínu, í allt að sex vikur á inngripstímabili og aftur í eina viku við eftirfylgd (eftir einn mánuð og þrjá mánuði). Inngripið var ýmist veitt augliti til auglitis eða í gegnum fjarfundarbúnað. Rannsókn III var með átta konum sem upplifðu áleitnar endurminningar. Þrjár þeirra uppfylltu greiningarviðmið fyrir ÁSR og þrjár voru með einkenni undir greiningarviðmiðum.

Inngripið var veitt augliti til auglitis í rannsókn I, að hluta til með fjarfundarbúnaði í rannsókn II og alfarið með fjarfundarbúnaði í rannsókn III. Inngripið var ýmist veitt af klínískum sálfræðingum sem sérhæfa sig í áfallameðferð eða sálfræðinemum án sérhæfðrar klínískrar þjálfunar. Þátttakendur skráðu tíðni áleitinna endurminninga í

dagbók á grunnlínu, á inngripstímabili og í eina viku við eftirfylgd eftir einn og þrjá mánuði. Í öllum rannsóknum var tíðni áleitinna endurminninga helsta útkoma. Einnig voru könnuð áhrif inngripsins á ÁSR einkenni, þunglyndis- og kvíðaeinkenni, og virkni, ásamt því að kanna fýsileika þess.

Niðurstöður: Niðurstöður sýndu að inngripið var talið fýsilegt og ásættanlegt, og það leiddi til verulegrar lækkunar í tíðni áleitinna endurminninga. Í rannsókn I lækkaði heildartíðni minninga um 52% á inngripstímabili miðað við grunnlínu, 76% við eins mánaðar eftirfylgd og 92% við þriggja mánaða eftirfylgd miðað við grunnlínu. Jafnframt hjöðnuðu einkenni áfallastreituröskunar, þunglyndis og kvíða, auk þess sem inngripið hafði jákvæð áhrif á svefn, einbeitingu og daglega virkni. Þátttakandi taldi inngripið ásættanlega leið til að draga úr tíðni áfallaminninga. Rannsókn II sýndi sambærilega lækkun á tíðni áleitinna endurminninga hjá öllum þátttakendum. Einn þátttakandi var með 38,8 minningar á viku á grunnlínu, sem lækkaði í 18,0 minningar á viku á inngripstímabili (54% lækkun) og í 8 á viku við eins mánaðar eftirfylgd (80% lækkun), en hækkun í 13 minningar á viku (67% lækkun) við þriggja mánaða eftirfylgd. Annar þátttakandi skráði 10,8 minningar á viku á grunnlínu, sem lækkaði í 4,7 á viku á inngripstímabili (57% lækkun) og í 1 á viku við eins mánaðar eftirfylgd (91% lækkun) og engar minningar við þriggja mánaða eftirfylgd. Þriðji þátttakandi skráði 33,7 minningar á viku í grunnlínu, sem lækkaði í 20,7 á viku á inngripstímabili (39% lækkun) og í 5 á viku við eins mánaðar eftirfylgd (85% lækkun), hækkun í 8 minningar á viku (76% lækkun) við þriggja mánaða eftirfylgd. Allir þátttakendur greindu frá hjöðnun einkenna ÁSR, einnig dró úr þunglyndis- og kvíðaeinkennum ásamt því að virkni jókst hjá tveimur þátttakendum. Þátttakendur töldu inngripið vera ásættanlega leið til þess að draga úr tíðni áleitinna endurminninga.

Í rannsókn III var inngripið veitt með fjarfundarbúnaði eingöngu og að hluta til af sálfræðinemendum sem ekki höfðu sérhæfða þjálfun í áfallameðferð. Allir átta þátttakendur sýndu lækkaða tíðni áleitinna endurminninga frá grunnlínu til inngripstíma, lækkunin var smávægileg hjá tveimur þátttakendum (alls 6,3%–93% lækkun). Við eins mánaðar eftirfylgd voru sex af átta þátttakendum með frekari lækkun (58%–100%) og við þrjá mánuði var lækkunin 72%–100%. Hjá flestum þátttakendum hjöðnuðu einkenni áfallastreituröskunar, þunglyndis og kvíða og virkni jókst hjá sjö af átta þátttakendum. Þátttakendur töldu inngripið í fjarfundarbúnaði og veitt að hluta af sálfræðinemendum vera mjög ásættanlega leið til þess að draga úr tíðni áleitinna endurminninga.

Ályktanir: Niðurstöður þessarar doktorsritgerðar veita vísbendingar um að sjónrýmdarverkefni sem truflar endurvist áfallaminninga geti dregið verulega úr tíðni þeirra og jafnframt dregið úr áfallaeinkennum ásamt öðrum sálrænum einkennum og aukið daglega virkni. Inngripið beinist að kjarnaeinkenni áfallastreituröskunar og er einfalt að veita óháð staðsetningu og er talið ásættanlegt af þátttakendum. Það krefst ekki ítarlegrar lýsingar á áfallareynslu og er hægt að veita án sérhæfingar í

áfallameðferð. Allt þetta dregur úr hindrunum sem einkenna hefðbundna áfallameðferð. Niðurstöður hafa einnig lýðheilsulegt gildi þar sem fjarþjónusta virðist bera svipaðan árangur. Næstu skref er að þróa inngripið áfram og að bera það saman við annað inngrip í slembiraðaðri rannsókn. Rannsóknirnar benda eindregið til þess að þetta einfalda sjónrýmdarverkefni geti dregið úr tíðni áleitinna endurminninga, og úr tíðni áfallastreitueinkenna og einkenna þunglyndis og kvíða, og aukið daglega virkni. Það getur átt þátt í að bæta aðgengi að úrræðum fyrir einstaklinga sem orðið hafa fyrir áföllum.

Lykilorð: Áleitnar endurminningar, áföll, áfallastreituröskun, sjónrýmdarverkefni

Abstract

Objective: Intrusive memories of trauma, experienced as vivid and distressing involuntary sensory memories, are the core clinical symptom of posttraumatic stress disorder (PTSD) and contribute to the enduring distress and functional impairment associated with the disorder. Although existing PTSD treatments are effective, they often require a detailed description of the trauma on the patient's behalf, causing additional distress. They also depend on specialist clinical delivery, making therapists too few to deliver therapy to all those in need. These factors limit accessibility and scalability of the interventions. There is a pressing need for brief, simple and scalable interventions that minimize treatment barriers and that can be delivered remotely.

The overarching aim of this thesis was to adapt to the Icelandic population and then evaluate a brief cognitive intervention designed to reduce the frequency of established intrusive trauma memories using an imagery-competing task after a memory retrieval, drawing from theories of memory reconsolidation. This is known as a novel imagery-competing task intervention (ICTI). Specifically, the intervention combines a memory reminder cue with a visuospatial task (playing Tetris with mental rotation) to disrupt sensory-perceptual features of intrusive memories. The objectives were to test the efficacy of the intervention in an Icelandic context. Further objectives were to evaluate whether the intervention would be a feasible way to reduce the frequency of intrusive memories and whether such reduction in frequency would have an impact on PTSD symptoms, depression and anxiety symptoms and functional impairment.

Methods: Three studies were conducted using repeated single-case AB designs in which each intrusive memory "hotspot" was targeted individually. Study I was a single-case design with a woman with subthreshold PTSD. She monitored four intrusive memories across a four-week baseline, an eight week intervention period, and one- and three-month follow-ups. Study II was a case series of three women (two with PTSD, one with subthreshold PTSD). Each participant monitored their intrusive memories for one week at baseline, up to six weeks during the intervention phase, and again for one week at the one- and three-month follow-ups. Study III was a case series with eight trauma-exposed women, three with PTSD and three with sub-threshold PTSD. The intervention was delivered face-to-face in Study I, partly remotely in Study II and entirely remotely in Study III, with guidance provided by either clinical psychologists or psychology students without specialist mental health training. Participants completed baseline, intervention, and follow-up diaries at one- and three-months. Across all studies, the primary outcome was frequency of intrusive memories recorded in daily diaries. Secondary outcomes were PTSD symptoms, depression

symptoms, anxiety symptoms, functional impairment, and acceptability and feasibility of the intervention.

Results: Across the three studies, the intervention was found to be feasible, acceptable, and consistently associated with substantial reductions in intrusive memories. Results in Study I showed a 52% reduction in the frequency of total intrusive memories during the intervention compared to baseline, increasing to a 76% reduction at the one-month follow-up and a 92% reduction at the three-month follow-up. Improvements were also observed in PTSD symptoms, depression and anxiety symptoms, sleep, concentration, and functioning. The participant rated the intervention as an acceptable way to reduce the frequency of intrusive memories. Study II also found reductions across all three participants. One participant reported 38.8 intrusions per week at baseline, which reduced to 18.0 per week during the intervention period (54% reduction). The number of intrusive memories further reduced to 8 per week at the one-month follow-up (80% reduction) and increased to 13 (67% reduction) at the three-month follow-up. The second participant reported 10.8 intrusions per week at baseline, which reduced to 4.7 per week during the intervention period (57% reduction) with a further reduction to 1 per week at the one-month follow-up (91% reduction) and to zero at the three-month follow-up. The third participant reported 33.7 intrusions per week at baseline, which reduced to 20.7 per week during the intervention period (39% reduction) and to 5 per week at the one-month follow-up (85% reduction) and increased to 8 per week (76% reduction) at the three-month follow-up. All participants reported reductions in PTSD symptoms post-intervention, with two also showing reductions in depression and anxiety symptoms. Participants rated the intervention as being acceptable.

Study III extended these findings to remote delivery and non-specialist guidance. All eight participants showed reductions in intrusive memories from baseline to the intervention period, although reductions were minimal for two participants, overall, 6.3% to 93% reduction. At the one-month follow-up, six out of eight participants showed further reductions, 58% to 100%, and by the three-month follow-up reductions were 72% to 100%. Most participants experienced improvements in PTSD, depression, and anxiety symptoms, and functioning improved for seven out of eight participants. Participants rated the digital delivery and non-specialist guidance as highly acceptable.

Conclusions: The research presented in this thesis provides evidence in support of a brief imagery-competing task intervention which can substantially reduce the frequency of long-standing intrusive memories of trauma. Furthermore, it can improve associated psychological symptoms and functioning. The intervention targeting the core clinical symptom of PTSD is low-cost, scalable and acceptable. It does not require patients to describe their trauma in detail, and it can be delivered by non-specialists after training, thereby addressing key barriers in traditional effective PTSD

treatments. The studies further demonstrate the feasibility of remote digital delivery, indicating scalability and public mental health relevance. The findings support progression to a randomized controlled trial. Overall, the thesis highlights the promise of this simple and brief intervention for reducing intrusive memories and related distress, improving access to care for trauma-exposed populations.

Keywords: Intrusive memories of trauma, trauma, post-traumatic stress disorder, visuospatial task intervention

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Thinking back to the time when I started this journey, I am reminded of words spoken by my supervisor Andri S. Björnsson. He said that the PhD adventure would be difficult but that it should, however, always be joyful. I can say now that this journey was certainly sometimes difficult and not always joyful. I can however state that I could not have had a better partner, leader, supervisor and dear friend than Andri to keep me on track. I thank him for his ongoing encouragement, academic advise and of course for all the joyful times of which there have been many. After this journey ends, I know that our friendship will carry on.

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I would like to end by thanking my patients and the women taking part in this research. Trauma has been a big part of my life and delivering trauma therapy and this intervention is very dear to me. My patients and participants have taught me more than they will ever know.

Contents

List of Abbreviations

PTSD	Post-traumatic stress disorder
ICTI	Imagery-competing task intervention
DSM-5	Diagnostic and statistical manual of mental disorders, fifth edition
NICE	National Institute for Health and Care Excellence
tf-CBT	Trauma focused cognitive behavioural therapies
EMDR	Eye movement desensitization and reprocessing
CT-PTSD	Cognitive therapy for PTSD
CPT	Cognitive processing therapy
PE	Prolonged exposure
COVID-19	Coronavirus disease 2019
SAGA	Stress-And-Gene-Analysis
PCL-5	PTSD checklist for DSM-5
MINI	Mini-international neuropsychiatric interview
CAPS-5	Clinician-administered PTSD scale for DSM-5
KT	Kristjana Thorarinsdottir
JH	Johann Hardarson
MK	Marie Kanstrup
EAH	Emily Holmes
MDD	Major depressive disorder
SAD	Social anxiety disorder
PD	Panic disorder
GAD	Generalized anxiety disorder
EA	Electronic arts

GDPR	General data protection regulation
REDCap	Research electronic data capture
DSM-IV	Diagnostic and statistical manual of mental disorders, fourth edition
PHQ-9	Patient health questionnaire–9
GAD-7	Generalized anxiety disorder–7
SDS	Sheehan disability scale
M	Mean
SD	Standard deviation

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I. Thorarinsdottir, K., Holmes, E. A., Hardarson, J., Hedinsdottir, U., Kanstrup, M., Singh, L., Hauksdottir, A., Halldorsdottir, T., Gudmundsdottir, B., Valdimarsdottir, U., Thordardottir, E. B., Gamble, B., & Bjornsson, A. (2021). Reducing intrusive memories of childhood trauma using a visuospatial intervention: Case study in Iceland. *JMIR Formative Research*, *5*, e29873. https://doi.org/10.2196/29873

II. Thorarinsdottir, K., Holmes, E. A., Hardarson, J., Stephensen, E. S., Jonasdottir, M. H., Kanstrup, M., Hauksdottir, A., Halldorsdottir, T., Gudmundsdottir, B., Thordardottir, E. B., Valdimarsdottir, U., & Bjornsson, A. (2022). Using a brief mental imagery competing task to reduce the number of intrusive memories: Exploratory case series with trauma-exposed women. *JMIR Formative Research*, *6*, e37382. https://doi.org/10.2196/37382

III. Thorarinsdottir, K., Holmes, E. A., Hardarson, J., Agustsdottir, F., Kanstrup, M., Singh, L., Hauksdottir, A., Halldorsdottir, T., Gudmundsdottir, B., Thordardottir, E. B., Valdimarsdottir, U. & Bjornsson, A. (2025). Reducing intrusive trauma memories using a brief mental imagery competing task intervention: A case series of trauma exposed women in Iceland. *JMIR Formative Research*. http://dx.doi.org/10.2196/72748

Declaration of Contribution

Kristjana Thorarinsdottir (KT) designed the studies under the supervision of Andri S. Bjornsson (ASB) and Emily A. Holmes (EAH). Data collection was conducted by the Icelandic research team, led by ASB, KT and Johann Hardarson (JH) in collaboration with EAH. KT analysed the data in collaboration with ASB, JH, EAH and Beau Gamble (BG). KT wrote the manuscripts under the supervision of ASB and EAH. All co-authors read and approved the final versions of the papers for submission. All members of the doctoral committee read and accepted the doctoral thesis.

1 Introduction

1.1 Psychological trauma and post-traumatic stress disorder

Psychological trauma is an extremely common experience. Studies have shown that between 70-90% of people experience at least one psychological trauma in their lifetime (Kilpatrick et al., 2013; Kessler et al., 2017). These experiences can for example include natural disasters, accidents, and physical and sexual violence (Kessler et al., 2017; Einarsdottir et al., 2024; Thordardottir et al., 2024). A third of those who experience trauma report having endured four or more such events (Benjet et al., 2016). Trauma can have lasting effects on mental health, including post-traumatic stress disorder (PTSD). PTSD is characterized in the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) by four symptom clusters and to meet diagnostic criteria a minimum number of symptoms within each of the clusters is required. The symptom clusters are as follows: The B-cluster which contains the re-experiencing symptoms like intrusive memories, nightmares, and flashbacks. The C-cluster refers to avoidance symptoms for example avoiding thoughts or feelings related to the traumatic event. The D-cluster entails negative alterations in mood and cognition such as negative beliefs about the self, self-blame, and a persistent negative emotional state. Lastly, the E-cluster consists of changes in reactivity and arousal like hypervigilance and having trouble concentrating. For a diagnosis of PTSD, the presence of at least one symptom within the B-cluster needs to be present, one symptom in the C-cluster and two symptoms need to be present within both D- and E-clusters. The symptoms must persist for at least a month (American Psychiatric Association, 2013). PTSD is associated with high levels of distress and impaired functioning regarding social, occupational, and interpersonal activity. This could for example include having trouble engaging in everyday activities like working or attending social gatherings. PTSD also has high comorbidity with other mental disorders like major depressive disorder and social anxiety disorder and is furthermore associated with increased suicidality (American Psychiatric Association, 2013; McMillan et al., 2017; Panagioti et al., 2012; Rosen et al., 2020; van Minnen et al., 2015).

Overall, PTSD has a lifetime prevalence of 8,3% (Kilpatrick et al., 2013). Prevalence rates vary across different countries from 0.5% to 14.5%. In a recent study in the Icelandic population by Einarsdottir et al. (2024), results showed that about 80% had experienced at least one traumatic event, and lifetime prevalence was a little over 10%. The overall prevalence of probable PTSD among women was 15.9% in another

study in Iceland by Thordardottir et al. (2024). The highest prevalence of probable PTSD was among those who had experienced sexual assault (36.9%) and lowest among those who had experienced natural disasters (3.3%).

Overall, individuals are not likely to seek treatment for PTSD and treatment seeking is twice as likely in higher-income countries like Australia, France and Germany compared to lower-income countries like Peru, Colombia and Bulgaria (Koenen et al., 2017).

Many people who do not meet the full criteria still develop clinically significant PTSD symptoms. Sub-threshold PTSD has been characterized as meeting symptom criteria for two or three of the symptom clusters (B-E) (McLaughlin et al., 2015). Sub-threshold PTSD is also associated with substantial distress, impaired functioning, and comorbidity (McLaughlin et al., 2015).

1.2 Cognitive models of PTSD

According to cognitive theories, PTSD develops when trauma is processed in a way that leads to the individual experiencing a sense of current threat, even though the threat has passed. This is explained by two factors: firstly, by overly negative appraisals of the trauma like “I am not safe”; “I will never recover”. Secondly, because the traumatic memory is inadequately processed due to poor elaboration and contextualization, as well as strong perceptual priming. Problematic negative appraisals and trauma memories are maintained by behavioural and cognitive responses such as avoidance of any stimuli that serve as a trigger of the trauma (Ehlers & Clark, 2000).

1.3 The core clinical feature of PTSD

The core clinical feature of PTSD is the re-experiencing symptoms (B-cluster i.e., intrusive memories, nightmares, flashbacks, and emotional and physical distress when reminded of the trauma) (American Psychiatric Association, 2013; Kupfer & Regier, 2011). The main re-experiencing symptom of interest in the current research project is intrusive memories. Intrusive memories are unwanted and often vivid recollections of the trauma which consist of sensory impressions rather than thoughts. They can include all sensory modalities (i.e., visual, auditory, olfactory, gustatory, and tactile) but are predominantly visual. They are often experienced as if they are happening here and now rather than having taken place in the past and they evoke the same emotions (including physical reactions) that were experienced at the time of the trauma (Ehlers et al., 2004). The emotions and sensory impressions are thus re-experienced regardless of whether the individual has learned new information that contradicts the original impression or even if the individual knows it is not true (e.g., feeling of being in danger even though knowing one survived) (Ehlers et al., 2004; Holmes et al., 2005).

According to network theories, intrusive memories serve as an activation factor for the other three symptom clusters (C-E) (Bryant et al., 2017; McNally, 2012; 2017). They cause significant distress and interfere with everyday functioning, making them a key target for treatment (Bryant et al., 2017; Iyadurai et al., 2019). Furthermore, clinically targeting core symptoms like intrusive memories in PTSD can have positive effects on other symptoms in the symptom network. For example, if one feels self-disgust after trauma, targeting intrusive memories that remind the person of being disgusting might result in less emotional distress and improved functioning. The emotional distress and impaired functioning associated with the intrusive memories would be increased or maintained with ongoing re-experiencing of the memories. Therefore, targeting intrusive memories can have beneficial effects not only by reducing the memories themselves but also the impairment directly related to them, leading to improvement in the symptom network overall (McNally, 2012; 2017).

1.4 Treatment for PTSD

There are various treatment options available for PTSD that have empirical support (National Institute for Health and Care Excellence [NICE], 2018; Lewis et al., 2020a). These therapies are broadly defined as cognitive behavioural therapies with trauma focus (tf-CBT) and eye movement desensitization and reprocessing (EMDR). Trauma focused CBT treatments include for example cognitive therapy for PTSD (CT-PTSD), cognitive processing therapy (CPT) and prolonged exposure (PE). Recommendations for empirically validated therapy for PTSD usually include individualized therapy that has a duration of 8-12 sessions (NICE, 2018; Lewis et al., 2020a). There is also some evidence that group CBT with a trauma focus, and guided internet-based CBT, can be effective in reducing symptoms of PTSD (Lewis et al., 2020a).

1.5 Barriers to PTSD treatment

Although existing therapies have been empirically validated, they do involve some significant limitations. Pre-existing therapies require a high level of training for therapists. This limits the number of therapists qualified to deliver such treatment (Kantor et al., 2017; Kazlauskas, 2017). Individual therapy carries high cost, in part because of the number of therapy sessions needed. There can also be concerns about stigma which can prevent individuals from seeking out treatment in the first place (Kantor et al., 2017). Most empirically validated treatments for PTSD require patients to recall and talk about the traumatic experience in detail. Many patients are reluctant to recall and re-experience their memories of trauma and therefore often drop out of such treatments (Kantor et al., 2017). Many therapists are also reluctant to deliver trauma-focused therapies such as prolonged exposure due to fear of exacerbation of symptoms or concerns with patients' dropout (Najavits, 2015).

Dropout from PTSD treatment is indeed high, about 16% overall (ranging from 14-18%) in meta-analytic research (Lewis et al., 2020b). These numbers are thought to be even higher in real life settings, i.e., outside of clinical trials (Najavits, 2015). Only half of those who have severe PTSD receive treatment and only a minority receive specialty health care (Koenen et al., 2017). Access to empirically validated treatment for PTSD is limited in many places, especially in rural areas. New, briefer approaches that reach more people or can be delivered remotely in geographically dispersed countries via the Internet are needed (Kantor et al., 2017).

One way to overcome these treatment barriers is to develop scalable, easily accessible, and acceptable interventions that focus on one tractable symptom rather than the full diagnosis of PTSD (Singh et al., 2020). Such an intervention may lead to improvement in the symptom network overall (McNally, 2012; 2017).

1.6 Development of an imagery-competing task intervention for intrusive memories

An intervention has recently been developed that is simple and brief and aimed at reducing the number of intrusive memories after trauma. This intervention is scalable, building on principles from cognitive science (Holmes et al., 2014; 2018), and is in line with recent calls within the literature to develop new therapeutic approaches for PTSD such as those that target memory (re)consolidation (Hoge & Chard, 2018). This intervention option focuses on reducing one single symptom (i.e., intrusive memories) rather than all PTSD symptoms (Singh et al., 2020).

There are several different time points during which a memory can be altered (Visser et al., 2018). According to theories of memory consolidation, trauma memories do not form immediately after trauma. Post trauma there is a window of several hours in which the memory is malleable and vulnerable to disruption (Nader, 2003; Walker et al., 2003). Perceptual sensory memories can be disrupted during memory consolidation by actively engaging in visuospatial tasks that compete with the sensory perceptual resources of the brain. This type of interference results in reduced vividness and emotionality of the traumatic memory (Andrade et al., 1997; Baddeley & Andrade, 2000; Engelhard, van Uijen & van den Hout, 2010; van den Hout & Engelhard, 2012).

One such task involves playing the computer game Tetris with mental rotation, i.e., actively rotating the blocks in one's mind while playing the game. This entails bringing an image to mind, which can be the visual content of a memory, using a memory reminder. Then playing the game with focus on trying to place the next block (game contains seven differently shaped and coloured blocks) being played by visualizing how to rotate it for the best fit, for a certain amount of time (for further information see Holmes et al., 2019, chapter 11).

Laboratory studies to date have indicated that to reduce the occurrence of intrusive memories after trauma the task must compete specifically with visuospatial resources (Holmes et al., 2010). Supporting this are mixed results for verbal tasks in reducing intrusive memories, for example the verbal computer game Pub quiz or word games. In a study conducted by Hagenaars et al. (2017), both Tetris gameplay and word games after memory reactivation resulted in fewer intrusive memories of analogue trauma, which participants were exposed to four days prior. However, in Holmes et al. (2010), a Pub quiz did not result in reduction of intrusive memories and in some cases even resulted in increased frequency of intrusions 30 minutes after experimental trauma compared to a no-task control and Tetris game play with mental rotation.

The trauma film paradigm involves exposing participants to distressing film footage in a controlled research setting. This is done to induce analogue intrusive memories. Studies utilizing this method with healthy participants have shown that in comparison to control tasks, visuospatial tasks in the form of the computer game Tetris administered during or soon after the film can reduce the frequency of intrusive memories of experimental trauma (visual scenes) in the following week (Holmes et al., 2009; 2010).

1.7 Imagery-competing task intervention to prevent intrusive memories

Studies on using Tetris gameplay with mental rotation after a hotspot recall (memory orientation cue) to prevent intrusive memories from forming have been extended from laboratory settings to real-life circumstances with promising results. In a randomized control trial conducted by Iyadurai et al. (2018) among survivors of road traffic accidents, the frequency of intrusive memories was compared between two groups. Firstly, an intervention group where the intervention comprised of a memory reminder cue followed by 20-minute Tetris gameplay with mental rotation and the latter an attention-placebo group which entailed a written activity log for 20 minutes. Both conditions were delivered in an emergency department within six hours of a motor vehicle accident. The results showed that the intervention group reported fewer intrusive memories than the control condition group. Furthermore, the frequency of intrusive memories declined more quickly for those in the intervention group compared to the control condition group. Another study among women who had an emergency caesarean section found that women in the intervention group had 48% less intrusive memories than the usual care group when the intervention was delivered within 6 hours of the traumatic event (Horsch et al., 2017). Recently, Kanstrup et al. (2021) conducted an exploratory pilot randomized controlled trial among trauma exposed patients (N = 41) in a hospital emergency department (i.e., mixed trauma sample). Participants were allocated randomly to two groups; the intervention included a reminder cue followed by Tetris gameplay with mental rotation

and the active control condition was to listen to a podcast. Both were delivered on participants' smartphone within 72 hours of arriving at the emergency department. Participants in the intervention group reported fewer intrusive memories both one week (48%) and five weeks later (90%) compared to the control group. Results of credibility and expectancy measures were very similar in both groups, and no serious adverse events were reported associated with the intervention (Kanstrup et al., 2021).

1.8 Reducing already established memories with an imagery-competing task intervention

The possibility of targeting already established trauma memories is suggested through the process of memory reconsolidation (Visser et al., 2018). Reconsolidation is the process in which a previously consolidated memory is reactivated, is malleable and re-stabilization is needed for the memory to persist (Nader et al., 2000). The memory can be altered (e.g., become less emotional) with an intervention that disrupts the reconsolidation process. However, for that to happen, the memory must first be reactivated by a reminder cue (Merlo et al., 2014). There are also some indications that a time gap of a few minutes between the memory reminder and the intervention is needed to allow the memory to become destabilized (Schiller et al., 2010). However, there are no clear indications of when the reconsolidation process begins after a reminder cue. For example, in Hagenaars et al. (2017) no time gap was used between the memory reminder cue and Tetris gameplay, which still led to a reduction in frequency of intrusions of analogue trauma. In a study conducted by James et al. (2015), a time gap of 10 minutes was used in between the memory reminder and visuospatial task. The results showed that even the frequency of established intrusive memories that are induced by experimental trauma can be reduced dramatically by disrupting reconsolidation with a competing visuospatial task. They found, furthermore, that both memory reactivation and playing Tetris with mental rotation were required for reduction of subsequent intrusions (James et al., 2015), supporting the notion that reconsolidation mechanisms are at stake (Dudai, 2004).

The acceptability of using Tetris game play with mental rotation as a visuospatial interference intervention for intrusive memories of trauma has been tested by Holmes et al. (2017) among 22 Syrian refugees. Most participants felt that this task was an acceptable way to reduce the daily frequency of intrusive memories.

Kessler et al. (2018) used an intervention that included a memory reminder cue followed by Tetris gameplay with inpatients suffering from complex PTSD (N=20). In each intervention session, one memory was targeted at a time, which included a memory reminder for a specific intrusion before playing Tetris for 25 minutes with mental rotation on a weekly basis. Thus, one session was used for each specific memory. Results showed that targeting a specific intrusion was usually followed by a

sudden drop in the frequency of that intrusive memory, often to zero, either in the week directly following the intervention or one week later. The frequency of targeted intrusive memories was reduced by 64% compared to an 11% reduction on average for non-targeted memories. Out of the 20 patients, 16 showed a 50% or more reduction in intrusion frequency for a given memory, for more than 50% of their intrusions. Eleven patients showed a 50% reduction response for every intrusive memory and only one patient did not show any reduction of the frequency of their intrusive memories. According to self-report measures on depressive, anxiety and PTSD symptoms from admission to discharge, about half of participants reported clinical improvements in their symptoms. Furthermore, there were no serious adverse events or drop-out associated with the intervention (Kessler et al., 2018).

In a single case study by Iyadurai et al. (2020) the intervention was implemented with a patient diagnosed with bipolar II disorder and comorbid PTSD symptoms, experiencing various intrusive images, for example of childhood trauma, social situations, and obsessive images. The patient recalled the imagery content and played Tetris with mental rotation for 10 minutes. The results showed that post intervention the images became less vivid and less distressing and that the frequency of intrusions went from daily occurrence to coming up once or twice per week. The patient also reported less PTSD symptoms and improvements in mood post intervention.

In Kanstrup et al. (2020) the intervention was adapted for people who were refugees and used to target already established memories of their war-related trauma (N=4). The memory reminder used here was a brief list of intrusive memories (i.e., hotspot sheet) where participants were asked to briefly describe in a few words the imagery content of their intrusions, either by writing it down themselves or telling the researcher what to write. The intervention was delivered in a community setting such as a library and memories were targeted one by one in separate intervention sessions. All four participants showed a decrease in the number of intrusive memories after the intervention and reported improved functioning. For example, one participant had a decrease from ten memories at baseline to zero after the first intervention week, and another participant reported 28 memories at baseline which reduced to 14 after the first intervention week. Participants reported improvements in for example sleep, concentration and functioning. The intervention was considered feasible and acceptable.

Singh et al. (2021) used a digitalized adaptation of the intervention with three nurses working clinically during the COVID-19 pandemic. All experienced intrusive memories from a work-related traumatic event. Participants completed the intervention once with a researcher which included 25-minute Tetris gameplay with mental rotation after a memory reminder delivered remotely. Participants reported different numbers of intrusive memories in week one (baseline), the first reported nine, the second

reported seven and the third reported four intrusive memories. After the guided intervention session, the intervention delivery was self-guided by the participants. The number of intrusive memories was greatly reduced for all participants, and they all reported the number of intrusions being zero during week five. Participants reported reductions in PTSD symptoms and improved functioning. One participant for example reported that having intrusive memories effected their empathy and interactions with patients, which highlights how reduction the reduction of intrusive memories might be beneficial to health care professionals and their patients.

The digitalized intervention and data collection were perceived as feasible and rated acceptable and all participants would recommend the intervention to a colleague. Participants regarded the digital intervention as a useful tool that could easily be used in everyday work life. They all considered the intervention to be useful in dealing with future trauma exposure (Singh et al., 2021).

The feasibility of a fully remote format delivery of the intervention was explored among 12 Icelandic women in a study by Hardarson et al. (2024) (note: this study was conducted as the next study in the series after those presented in this thesis). Intrusive memories, the intervention and how to use it were explained through short, animated videos to participants in three separate sessions (baseline session and two intervention sessions). Participants were in the first intervention session instructed to play Tetris on their computer for at least 20 minutes using mental rotation and were encouraged to use the intervention at their convenience after having an intrusive memory whether it had been targeted in session or not. Participants monitored the daily frequency of their intrusive memories over a five-week period and for one week at week one at the three-month follow-up. They also answered questionnaires at week one, one month and at three months after the first intervention session. Eight participants completed the primary outcome (total number of intrusive memories) and their intrusive memories reduced by 68% from baseline to five weeks after the second intervention session. Seven participants completed the three-month follow-up, and the number of intrusive memories had reduced by 91% compared to baseline. PTSD, depressive and anxiety symptoms were decreased at each time point from baseline to the three-month follow-up and functioning was reported to improve as well.

No adverse events related to the intervention were reported by participants and they rated the intervention to be an acceptable way to reduce intrusive memories. The findings demonstrated the feasibility of the intervention, mostly delivered by non-specialists after online training (Hardarson et. al., 2024).

In summary, results from previous research warrant further investigation of this novel and brief intervention, aimed to target intrusive memories after trauma. The intervention is simple and scalable and therefore could reach people despite geographical restraints. It does not require detailed description of traumatic events on participants' behalf. The intervention therefore has the potential to remove some

existing barriers when it comes to PTSD treatment. Targeting the core symptom of PTSD has the aim of reducing not only intrusive memories but also other symptoms in the PTDS network.

2 Aims

2.1 Primary aims

Our primary aim was to investigate whether a brief imagery competing task intervention (i.e., hotspot memory recall then Tetris gameplay with mental rotation for 25 minutes) would result in participants reporting fewer intrusive memories during the intervention phase than in the preceding baseline phase. We furthermore predicted that the reduction in the number of intrusive memories would be maintained during one-month and three-month follow-ups. We expected that targeted intrusive memories would decrease more than non-targeted ones.

2.2 Secondary aims

In addition, we explored whether having fewer intrusive memories of trauma would be associated with improvements in functional impairment and reductions in symptoms of PTSD, depression, and anxiety (secondary outcomes). We explored the feasibility of the intervention as well.

3 Materials and methods

3.1 Participants

Participants were recruited from a sub-study of the Stress and Gene Analysis (SAGA) Cohort, a population-based longitudinal study of Icelandic women (e.g., Thordardottir et al., 2024). The sub-study included two groups from the SAGA cohort: women with a probable diagnosis of PTSD (defined as a score of 33 or higher on the Posttraumatic Stress Disorder Checklist 5 (PCL-5)) and women unlikely to have PTSD (scores in the lowest fifth of the PCL-5 distribution). Eligibility for the studies was determined by using two semi-structured diagnostic tools: the Mini International Neuropsychiatric Interview (MINI) and the Clinician-Administered PTSD Scale for DSM-5 (CAPS-5). These interviews were used for all participants to confirm clinical diagnoses and to assess exclusion criteria.

Participants from the sub-study who consented to being contacted for future research were subsequently evaluated for inclusion in this research project.

The screening process involved providing a brief explanation of intrusive memories, defined as involuntary and distressing recollections that often include sensory impressions such as visual or auditory experiences, typically manifesting as images or short film-like sequences. Subsequently, the presence of this symptom was evaluated.

The inclusion criteria for the studies were as follows: (a) having experienced at least one Criterion A trauma as defined by the DSM-5 (American Psychiatric Association, 2013); (b) reporting at least one intrusive memory occurring a minimum of three times per week over the past four weeks; (c) availability to attend 3–8 sessions with the researcher; (d) willingness to monitor intrusive memories in daily life; (e) access to a smartphone; and (f) proficiency in speaking Icelandic and reading study materials in Icelandic. The exclusion criteria were the following: (a) a current diagnosis of a psychotic disorder; (b) a current manic episode; and (c) acute suicidality.

3.2 Study I

3.2.1 Participant

The participant reported clinically significant PTSD symptoms within the past month, stemming from physical violence experienced during childhood. The total symptom severity score was 22/80 on the CAPS, with the participant missing one symptom in the E cluster to meet full diagnostic criteria (reporting 5 symptoms in cluster B, 2 in cluster C, 3 in cluster D, and 1 in cluster E; see Measures). This assessment was carried out two months prior to participation in the current study as part of a sub-study within the SAGA cohort using the CAPS (see Measures). Additionally, the participant met diagnostic criteria for social anxiety disorder and obsessive-compulsive disorder based on the MINI diagnostic interview (see Measures). While the participant had previously received psychological treatment for work-related issues, she had never received trauma-focused psychological treatment. She also reported no use of psychotropic medication in the three months preceding participation.

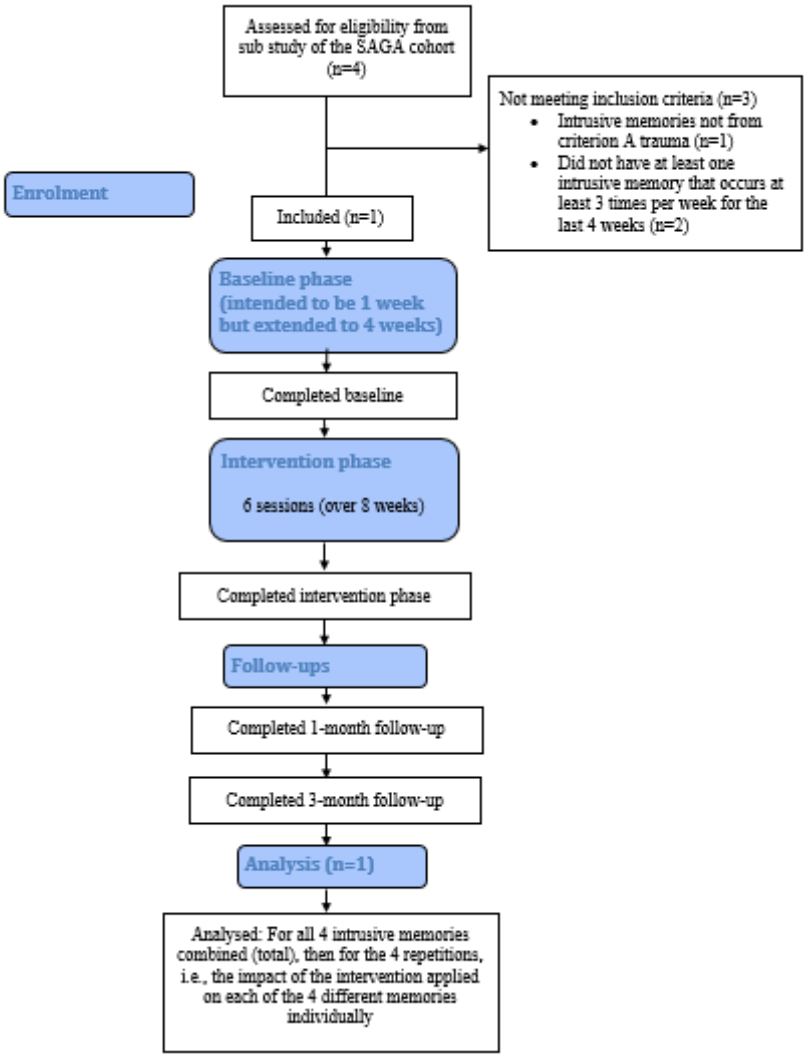

Figure 1. Adapted CONSORT participant flow diagram for Study I.

3.2.2 Procedure

The frequency of each intrusive memory was recorded daily in a diary by the participant over several time periods: a 4-week preintervention phase, the 8-week intervention phase, and one week each at the one-month and three-month follow-ups. During the preintervention phase, the participant documented intrusive memories daily to establish a baseline level of intrusions.

Although this phase was initially intended to last one week, it was extended to four weeks due to scheduling delays. Similarly, the intervention phase, originally planned

for six weeks, was extended to eight weeks for the same reason. Despite these adjustments, the participant continued to monitor the frequency of intrusive memories throughout the extended periods, and all data were included in the analyses. At both follow-up intervals, the participant resumed the daily diary for one week.

The intervention targeted four distinct intrusive memories sequentially across six sessions guided by a clinical psychologist with expertise in trauma-focused CBT. At the beginning of each intervention session the participant was asked which intrusive memory she would like to target, the daily diary was considered here (which memory was the most frequent or distressing). The study design implemented an AB design repeated four times, corresponding to the intervention for each memory. In addition to the guided sessions, the participant had the option to independently administer the intervention for previously targeted memories after the first session.

3.2.3 Training

Researchers delivering the intervention in Study I and Study II were clinical psychologists who have specialised training in delivering trauma therapy (Kristjana Thorarinsdottir (KT) and Johann Hardarson (JH)). They underwent training from experts and received clinical supervision, promoting adequate intervention delivery and protocol adherence. Training included two in-vivo workshops for three days and then approximately six months later for two days delivered by the clinical researcher with expertise in developing the intervention (Emily Holmes (EAH)) and delivered together with a clinical psychologist with expertise delivering the intervention in other settings (Marie Kanstrup (MK)). Theoretical background and practical aspects of the intervention (e.g., how to explain and capture the primary outcome measure) were covered in the workshops as well as roleplaying with the trainers until adequate performance was reached. During data collection, researchers received continued supervision, adherence checks and support regarding any adaptations necessary from a clinical supervisor via telephone after sessions with the participant, and in weekly supervision meetings (led by EAH). The researchers also participated in remote group training meetings twice a month with other researchers using the intervention.

3.3 Study II

3.3.1 Participants

Five women that met the inclusion criteria were selected (see Figure 2 CONSORT diagram). The participants are identified as P1, P2, P3, P4, and P5. The initial two recruits, P1 and P2, did not complete the intervention sessions due to timing issues related to medical and family matters. Although baseline data were collected from them, they were later excluded from the data analyses. Following their withdrawal, a question was added during recruitment to assess whether participants anticipated

any obstacles to their participation. According to the MINI, P1 did not meet the diagnostic criteria for any psychological disorders, while P2 met the criteria for bipolar disorder and reported subthreshold PTSD symptoms.

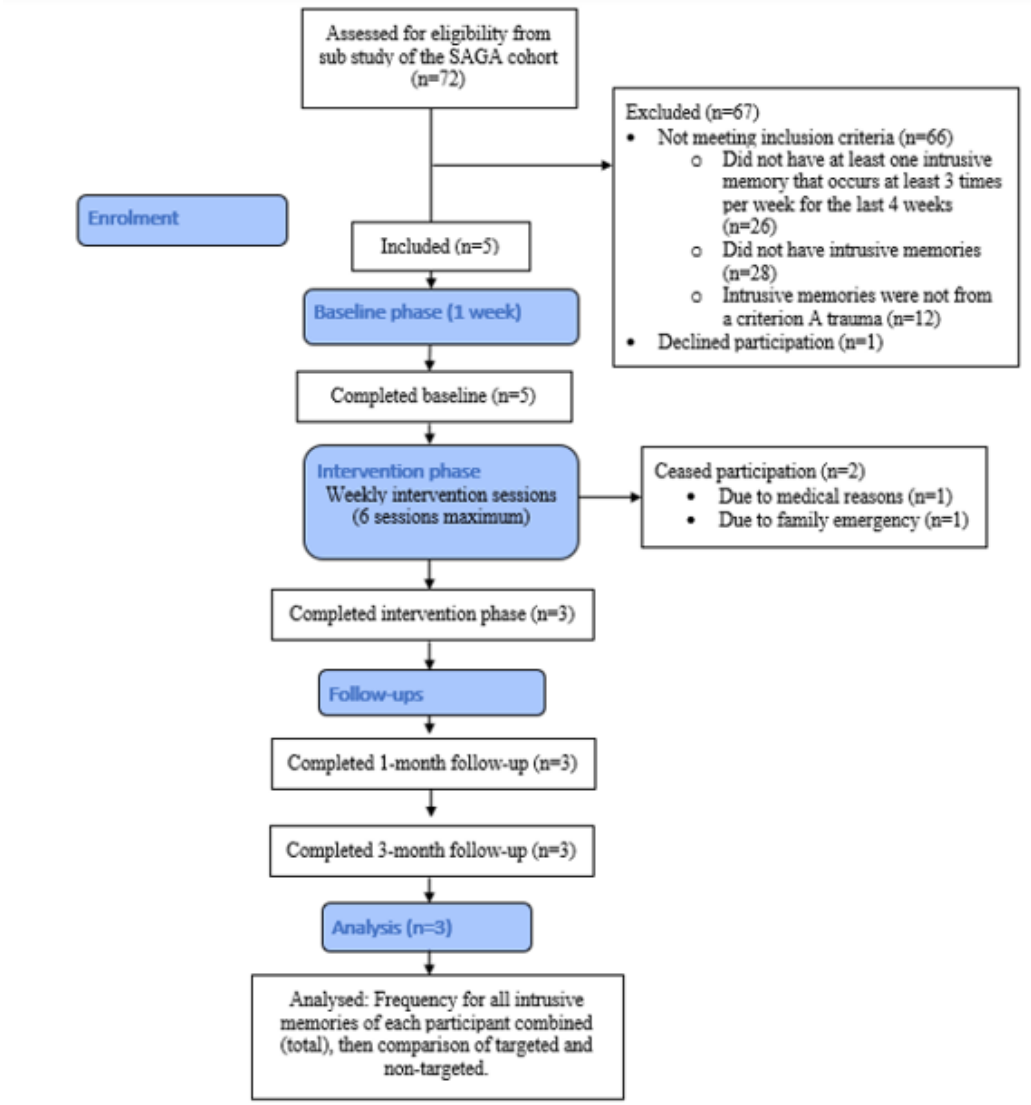

Figure 2. Adapted CONSORT participant flow diagram for Study II.

Three participants completed the study. Among them, two participants had PTSD along with other comorbid conditions, and one exhibited subthreshold PTSD. Specifically, P3, a woman in her forties met the criteria for both PTSD and major depressive disorder (MDD). P4, a woman in her sixties, did not meet any formal diagnostic criteria but reported subthreshold PTSD symptoms. Lastly, P5, a woman in her fifties was diagnosed with MDD, social anxiety disorder (SAD), and PTSD.

Regarding their intrusive memories, P3 reported having 10 different intrusive memories from childhood physical violence, P4 reported 3 intrusive memories from childhood sexual abuse, and P5 reported 6 intrusive memories from childhood sexual abuse (see procedure and training in Study I).

3.4 Study III

3.4.1 Participants

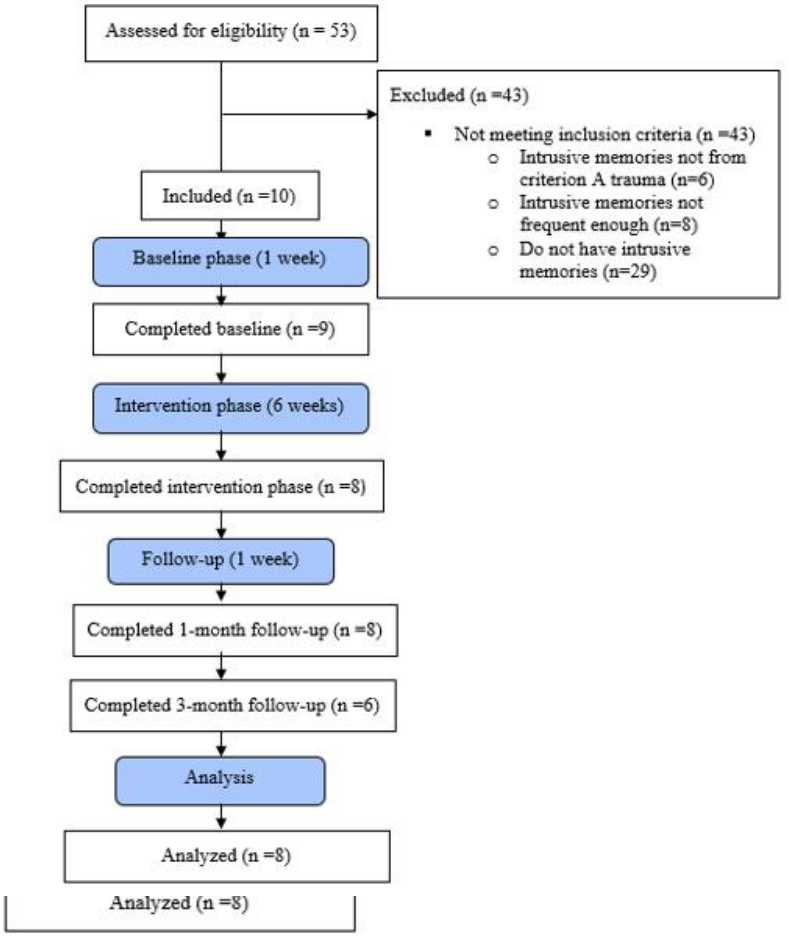

Figure 3. Adapted CONSORT participant flow diagram for Study III.

Ten participants were initially recruited, ranging in age from 22 to 65 years (M=43.2, SD=15.67). Participants will hereafter be referred to as P1, P2, P3, etc. Two participants (P6 and P8) did not complete the intervention sessions due to non-suitability of the study timing in their lives (P6 did not complete baseline measures

but baseline data were collected from P8). Both P6 and P8 were excluded from data analyses.

Eight women completed the study. Three of them met criteria for PTSD (P2, P7 and P9) and three had subthreshold symptoms of PTSD (P1, P3 and P10). P1 reported subthreshold PTSD symptoms and met criteria for agoraphobia without a history of panic disorder (PD). P2 met criteria for PTSD, general anxiety disorder (GAD) and PD with agoraphobia. P3 reported subthreshold PTSD symptoms and met criteria for SAD. P4 met criteria for MDD and SAD. P5 met criteria for PD without agoraphobia. P7 met criteria for PTSD, P9 met criteria for PTSD and SAD, GAD and MDD. P10 reported subthreshold PTSD symptoms and met criteria for SAD (see Measures).

P1, a woman in her sixties; reported having 3 different intrusive memories from a single event involving an accident in adulthood. P2, a woman in her forties, reported having 8 different intrusive memories from a single event involving an accident that took place in her adulthood. P3, a woman in her fifties, had 6 different intrusive memories from a single event involving an accident that happened in her childhood. P4, a woman in her thirties, reported having 5 different intrusive memories involving physical violence in adulthood. P5, a woman in her fifties, and P7, a woman in her thirties, both reported having 7 different intrusive memories involving physical violence and sexual abuse in childhood, but one of P7´s memories was from an accident in adulthood. P9 and P10, both women in their thirties, reported having 3 different intrusive memories involving sexual abuse and physical violence taking place during their childhood.

3.4.2 Training

All individuals delivering the intervention underwent training, feedback and continued clinical supervision from researchers/clinical psychologists (EAH and MK, with expert experience in this intervention) to promote adequate intervention delivery and protocol adherence. In addition to previous training for the clinical psychologists (N=2) (see Study I), who delivered the intervention in Study I and Study II, the students, master´s level student and three bachelor's degree graduates participated in training workshops remotely via online video sessions. The students delivered the intervention for three participants for Study III (P7, P9 and P10), intervention delivery was otherwise conducted by the clinical psychologists who have specialised training in delivering trauma therapy (KT and JH). All workshops included topics such as theoretical background, practical aspects (including how to explain and use the primary outcome measure) as well as roleplaying with trainers, with individual feedback provided until adequate performance was reached. All individuals delivering the intervention received ongoing clinical supervision and support after each session via telephone from a clinical supervisor (KT) and in weekly group supervision meetings (EAH and MK).

3.5 Design

Single-case designs represent a critical step in evaluating the efficacy of novel interventions and refining intervention protocols (Krasny-Pacini & Evans, 2018; Vohra & Punja, 2019). These designs enable researchers to examine individual variability and symptom trajectories over time (Senn, 2018). In line with moving toward individualized, patient-centred care, N-of-1 trials are becoming increasingly important (Bradbury et al., 2020). Traditionally, the replication of AB (or ABAB) designs is considered necessary to establish the effects of an intervention (Krasny-Pacini & Evans, 2018). However, Kanstrup et al. (2021) argued that a traditional ABAB design may not be optimal in all such cases. When examining this intervention in their study, effects of the intervention persisted after a single session and did not exhibit rebound, which made it impossible to withdraw and reintroduce the intervention as required by a classic ABAB design.

Instead, Kanstrup et al. (2021) recommended a multiple-baseline AB design, like the approach described by Kessler et al. (2018). This design involves targeting different intrusive memories consecutively, with separate intervention sessions for each memory. This allows for a focused assessment of the intervention's effect on each memory over time. The present study adopted this methodological approach. However, the design is referred to as a repeated AB design to avoid confusion with other case-series frameworks, such as those involving multiple randomized baselines.

In this design, intrusive memories were targeted one at a time across different sessions (Kessler et al., 2018). A critical component of the procedure is that the participant distinguishes between the contents of their various intrusive memories—for example, (a) red curtain, (b) man's face, (c) blood on the floor, (d) closed door (note: examples are fictitious to preserve anonymity) and tracks the frequency of each intrusion over time. The repeated AB design allows for variation in the length of baseline ('A,' pre-intervention monitoring only) and intervention ('B') phases across memories, depending on when each specific memory was targeted. Each baseline phase serves as a control period, enabling comparison of intrusion frequency before and after being targeted with the intervention.

3.6 Baseline session

During the first session, the participant completed baseline questionnaires (focusing on secondary outcomes) and the researcher explained the concept of intrusive memories (mostly visual, like images or film clips) that are involuntary and distressing. The participant then briefly described each of her intrusive memories using just a few words to convey their visual content. The researcher recorded these brief descriptions on a clearly visible "hotspots" sheet. Importantly, the participant did not engage in detailed discussions about the trauma or the memories. Each intrusive

memory was labelled with a symbol (e.g., the first memory was marked “A”, the second “B”, etc.), and the participant was instructed on how to monitor their daily frequency using a diary as the primary outcome measure. In the diary, she noted the corresponding symbol for each memory within specific time frames, with the diary structured to cover seven days, each divided into four time periods (see Measures).

3.7 Intervention sessions

In each intervention session (maximum 6 sessions), participants chose one intrusive memory to target and (guided by the researcher) completed the intervention procedure. The memory chosen could be the most distressing or frequent, or for some other reason the one that the participant wished to target at that time. The intervention consisted of a brief memory reminder, i.e., briefly thinking about the intrusive memory to bring the image to mind without it becoming emotionally overwhelming; this approach is different from the memory reminder used by Kessler et al. (2018) or Kanstrup et al. (2021). Participants were asked: “What would be the best way for you to bring the memory to mind without it becoming emotionally overwhelming?”

After the memory reminder procedure, participants were trained in playing Tetris with mental rotation. They then played Tetris using mental rotation for 25 minutes (see Holmes et al., 2019, chapter 11). For in-person meetings the Tetris gameplay was delivered with Nintendo DS, set to “Marathon” mode and ghost piece off, on a 10.1-inch screen. When intervention sessions took place remotely the Tetris gameplay was done on the participants´ computer with share screen on so the researcher could monitor the gameplay, especially regarding mental rotation. Participants were invited to self-administer the intervention for memories already targeted in session using a mobile version of Tetris created by Electronic Arts (EA mobile Montreal Team, 2014). For this they were instructed to play in the same way as in-session when the intrusion came to mind involuntarily. Only one intrusion was targeted per session; when the next intrusion was targeted, participants (not researchers) selected the memory to target. In the last intervention session, participants again completed secondary outcome measures.

For Study I all sessions were completed face to face. During data collection for Study II Covid-19 hit (the University of Iceland closed March 19th, 2020), researchers switched to remote (rather than in person) delivery. This was done through Kara Connect, which is a GDPR compliant online platform, certified by the Icelandic Directorate of Health. Thus, for Study II the last intervention session for P3 was done remotely, intervention sessions two and onwards were remote for P4 and all sessions were remotely delivered for P5. Tetris was played online (https://tetris.com/) on the participants’ computers (ghost piece off and sound set to 0%) with share screen on so the researcher could monitor participants gameplay via Kara Connect, which increased the likelihood of instruction adherence, especially regarding using mental

rotation. In Study III all sessions were delivered remotely in the same way as in Study II.

3.8 Follow-up

At the one-month and three-month follow-ups, participants recorded the number of intrusions in the diary daily for one week and completed secondary outcomes measures. Data were recorded on a laptop into the REDCap database (Research Electronic Data Capture; www.project-redcap.org), an encrypted, electronic software and stored on a secure server (Harris et. al., 2009).

4 Measures

4.1 Eligibility assessments (part of the SAGA cohort sub-study)

***The Clinician Administered PTSD Scale (CAPS-5*)** is a 30 item semi-structured interview used to assess symptoms of PTSD from an index trauma and symptom severity in the past month, according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) (American Psychiatric Association, 2013). Each item is scored on a 5-point Likert scale (0=mild/subthreshold; 4=extreme/incapacitating) with a threshold symptom rating of 2 (i.e., moderate) for a possible diagnosis. Frequency and severity for each symptom was scored separately on a 5-point Likert scale (0 = mild/subthreshold; 4=extreme/incapacitating) with a threshold symptom rating of 2 (i.e., moderate) for a possible diagnosis. The CAPS-5 has excellent internal consistency (Cronbach's alpha =.88) and test-retest reliability (.83) along with good convergent validity (.83) (Weathers et al., 2018) making it a useful tool for diagnosing PTSD.

The Mini International Neuropsychiatric Interview (MINI) is a structured diagnostic interview that assesses Axis I psychiatric disorders according to the DSM-IV. The MINI has been shown to have good sensitivity and specificity for most diagnoses (Lecrubier et al., 1997). Inter-rater and test-retest reliability has been shown to be good, with kappas in the high to very high range (κs=.79–1.00) (Sheehan et al., 1997). The Icelandic translation (Sigurðsson, 2008) shows good convergent validity with self-report measures of anxiety and depression.

4.2 Primary outcome measure

***Intrusive memory diary*.** The diary was adapted from previous experimental and clinical studies (see e.g., James et al., 2015; Iyadurai et al., 2018; Kanstrup et al., 2021). It included a daily record of four times per day (morning, afternoon, evening

and night) for one week. The diary instructions included a definition of intrusive memories as being distressing and involuntary mental images (such as visual images or a film in the mind's eye). Participants were instructed not to record voluntary thoughts or verbal thoughts without sensory content. Participants monitored the occurrence of their intrusive memories in a daily diary for one-week pre-intervention; for maximum of six weeks during the intervention phase and then again for one week during one-month and three-month follow-ups. When indicating having an intrusion, participants used the symbol corresponding to that specific memory, and therefore it was possible to examine change in frequency (here calculated as the number per week) for each memory individually. The primary outcome was the change in the number of intrusive memories from baseline to the intervention phase and to longer-term follow-ups.

4.3 Secondary outcome measures

PTSD symptoms in the past month were evaluated with the Posttraumatic Stress Disorder Checklist 5 (PCL-5), a self-report scale with 20-items. Each symptom is rated on a 5-point Likert scale (0=not at all; 4=extremely), higher scores indicating greater severity. PCL-5 evaluates the severity of PTSD symptoms corresponding to the DSM-5 criteria for PTSD and has strong internal and test-retest reliability, along with good convergent and discriminant validity (Blevins et al., 2015). Criteria of clinical significance are not available for the PCL-5, however a score of 24 or below post-treatment can be interpreted as clinically significant change (Wortmann et al., 2016).

Depressive symptoms in the past two weeks were evaluated with the Patient Health Questionnaire-9 (PHQ-9), a self-report measure with 9-items rated on a 4-point Likert scale (0=not at all; 3=nearly every day) (Kroenke et al. 2001). The PHQ-9 evaluates depressive symptoms and their severity and has good internal reliability and good test-retest reliability (Kroenke et al., 2001). A 5-point change in the total score is considered clinically significant (Kroenke, 2012).

Anxiety symptoms in the past two weeks were evaluated with the Generalized Anxiety Disorder-7 scale (GAD-7), a self-report questionnaire in which each item is rated on a 4-point Likert scale (0=not at all; 3=nearly every day). The GAD-7 assesses symptoms of general anxiety disorder and their severity. It has been shown to have good internal reliability and good test-retest reliability (Spitzer et al., 2006). In general, the GAD-7 has been useful in screening for anxiety disorders (Kroenke et al., 2007). A 4-point change on the GAD-7 is considered clinically significant (Toussaint et al., 2020).

Functional impairment in the previous week was evaluated with the Sheehan Disability Scale (SDS), a self-report measure with three domains ((1) work/school, (2) social, and (3) family life) assessing functional impairment on an 11-point scale (0=not at all; 10=extremely) (Leon et al., 1997). A 3-point change on the SDS scale

has been considered a measure of response to treatment (Coles et al., 2014). Instructions in the current study asked the participant to assess impairment associated with intrusive memories. The scale has been found to have good internal and test-retest reliability along with good construct validity (Leon et al., 1997). The Icelandic version of the SDS has been shown to have good internal consistency in clinical groups (α=.84) (Bjornsson et al., 2020).

Self-guided adherence for using the gameplay part of the intervention in daily life was assessed with the item "How often did you manage to play Tetris after you experienced an intrusive memory?" (11-point scale; 0=not at all; 10=every time).

Feasibility and acceptability ratings of the intervention were assessed with two self-rated items, "Would you recommend playing Tetris to a friend?" and "Do you consider gameplay to be an acceptable way to reduce the daily frequency of intrusive memories?" The scores ranged from 0 to 10 where higher scores referred to greater acceptability. The following two open-ended questions were included: 1. "How did you feel about playing Tetris after you had an intrusive memory?" 2. "Did you find the intervention helpful? If yes, how?"

The impact of intrusive memories on concentration, sleep and stress in the past week was evaluated with six self-rated items: Two items assessing general concentration difficulties and difficulties due to intrusive memories (11-point scale; higher scores indicating more difficulties), one item assessing disruption on concentration in minutes in the past week, two items assessing the effect of intrusive memories on sleep (11-point scale; higher scores indicating more sleep disturbance), and one item assessing the effect of intrusive memories on stress levels (0=not at all; 10=affected very much).

Ratings of general impact of intrusive memories were obtained with two items rating the intensity and vividness of the intrusions, rated on an 11-point scale (0=not at all; 10=very distressing/vivid).

Intrusion diary adherence was assessed with one item: "How accurately did you fill out the diary?" (0=not at all; 10=very accurately).

Impact of intrusive memories on daily functioning was evaluated with one open-ended question: "How have the intrusive memories affected your ability to function in your daily life in the past week?" and one self-rated question: "Have the intrusive memories affected your ability to function in your daily life?" (11-point scale, a higher score indicates greater impact).

4.4 Data analysis

4.4.1 Change in the total number of intrusive memories

The primary outcome was the change in the number of intrusive memories per week from the baseline phase to the intervention phase and to follow-ups (one-month and three-month). Primary outcome was examined in terms of *total* number of intrusions per week for each participant. The number of all intrusions occurring in the baseline phase for each participant was summed up as well as for the intervention phase and each of the follow-up weeks. These periods had different time lengths and therefore the mean number *per week* was calculated to make the measure comparable across phases. Missing data was dealt with by excluding these timepoints from the calculations (see Results section). For example, one participant had a baseline period of 14 days, but data were present for 6.5 days, thus the total number of intrusions per week was calculated as 10 intrusions/6.5 × 7=10.77 intrusive memories per week during baseline.

When examining change over time, percentage reduction in total intrusions per week was calculated from the baseline phase to intervention phase to other time periods as follows [1 - (mean number per week during intervention phase/mean number per week during baseline)] * 100). For example, for the same participant there were 4.7 intrusions per week in the intervention phase, this was calculated as [1-(4.7/10.77)]×100=56.4% reduction in the intervention phase compared to baseline.

4.4.2 Change in the number of targeted intrusive memories relative to non-targeted memories.

Next, we examined the data per intrusive memory. Specifically, we examined the number per week of targeted memories in comparison to non-targeted ones. This was done by calculating the number in the same way as described above for targeted memories (i.e., each of the targeted memories has different baseline and intervention periods). However, baseline and intervention periods were established for non-targeted memories since they were not targeted with the intervention. The baseline for each non-targeted memory was one week (i.e., before any memory was targeted) and the intervention phase was determined as the period from when any of the memory was targeted with the intervention.

4.4.3 Other symptoms and functioning

A descriptive approach was used to investigate whether clinically significant changes were observed in overall symptoms of posttraumatic stress, depression, anxiety and functional impairment.

4.5 Ethical statement

The studies were approved by the National Bioethics Committee in Iceland (No: VSNb2017110046/03.01). Participants provided their written and informed consent. All sessions followed a written protocol. No adverse events related to the intervention were reported by participants. However, given the early stage of this research an arrangement was made with an independent clinical psychologist who specializes in trauma for an interview free of charge to the participant, and to be referred to a licensed clinical psychologist for treatment if needed. None of the participants made use of these services.

4.6 Open science statement

In Study I we followed the preregistration for Study II which was preregistered on ClinicalTrials.gov (NCT04209283) on 2019-12-04. Study III was also preregistered on ClinicalTrials.gov (NCT04342416) on 2020-11-03.

5 Results

5.1 Study I

The participant reported four different intrusive memories that were predominantly visual, each associated with a single traumatic event that had occurred around forty years before participation. These memories were each monitored over time, with each one being targeted at a different timepoints during the intervention phase (see Figure 4).

One intrusive memory (Memory A) was targeted three times, as it was reported by the participant to be the most distressing and frequent. Each of the remaining memories were targeted once. The participant seemed to have a clear understanding of the instructions and successfully completed all intervention sessions and associated procedures. Intrusive memory diary data were missing for days 8–12 and 21–22 during the baseline phase, and for days 40–41, 49, 57–63, and 71 during the intervention phase. The diary was fully completed during the follow-up periods. Most missing entries occurred when there was a delay between sessions with rescheduling of sessions, when the participant had completed a weekly diary but had not yet received the next one. No attempts were made to recover data for missing days. Overall, the diary was completed for 81 of the 99 study days, corresponding to an 82% completion rate. No data was missing for any of the secondary outcome measures.

5.2 Primary outcome

5.2.1 Total number of intrusive memories

Across the 4-week baseline phase, the total number of intrusive memories remained relatively stable, averaging 12.6 per week (summed across all four memories). This frequency decreased to 6.1 per week during the eight-week intervention phase (a 52% reduction from baseline), to 3.0 per week at the one-month follow-up (a 76% reduction), and to 1.0 per week at the three-month follow-up (a 92% reduction; see Table 1). Figure 4 shows the total number of intrusive memories per day across all phases of the study. Visual inspection indicates a reduction in intrusions following the second intervention session. The frequency of intrusive memories remained relatively stable between sessions 2 (day 43) and 5 (day 73), followed by a further decrease that was maintained at the one-month follow-up and continued to decline at the three-month follow-up

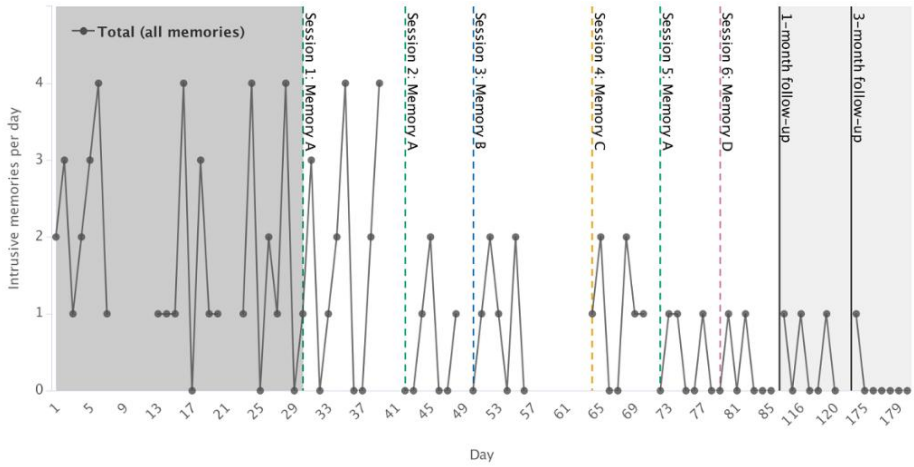

Figure 4. Graph for visual inspection of primary outcome data. Total number of intrusive memories on Y-axis as total per day. Days since enrolment are shown on the X-axis, which includes baseline (grey), intervention (white), and follow-up periods (light grey). Dashed coloured vertical lines show when each intervention session was administered and which specific memory (Memory A, B, C or D) was targeted (e.g. Session 1; Memory A in green). Memories are labelled in order of when they were targeted (e.g., 'Memory A' was targeted in the first intervention session). Solid black vertical lines show the one-month and three-month follow-ups. Gaps in the time series in baseline and intervention periods reflect missing data. (For individual intrusive memory data, see Figure 5).

5.2.2 Change in the number of each of the four specific intrusive memories

Figure 5 displays the frequency of each intrusive memory across all study phases (baseline, intervention, one-month follow-up, and three-month follow-up). All four intrusive memories showed a reduction in weekly frequency following the

intervention. The frequency of memory A decreased by 46%, memory B by 86%, memory C by 58% and the frequency of memory D decreased by 26% when compared to their specific baseline periods. At the three-month follow-up, the frequency of three out of the four intrusive memories had gone down to zero (see also Table 1).

Memory A was targeted in intervention sessions one, two, and five at the participant's request, as it was perceived as the most distressing. Visual inspection of Figure 5 indicates a decrease in frequency during the week following session one, with a further reduction observed after session two. This reduction appeared stable across both follow-up assessments. However, an increase in frequency was observed between days 65 and 73, prompting Memory A to be targeted again in session five. During that session, the participant reported having encountered an individual who had been present during the original traumatic event, which appeared to trigger the intrusive memory.

Memory B was targeted in session three, after which its frequency declined markedly in the subsequent week and remained low across follow-ups. A reduction in frequency for Memory C was observed in the week following session one (when Memory A was targeted), and this lower frequency was maintained at both follow-ups. In contrast, Memory D showed relatively little change in frequency throughout the intervention phase (targeted in session six), though a reduction was evident at the three-month follow-up.

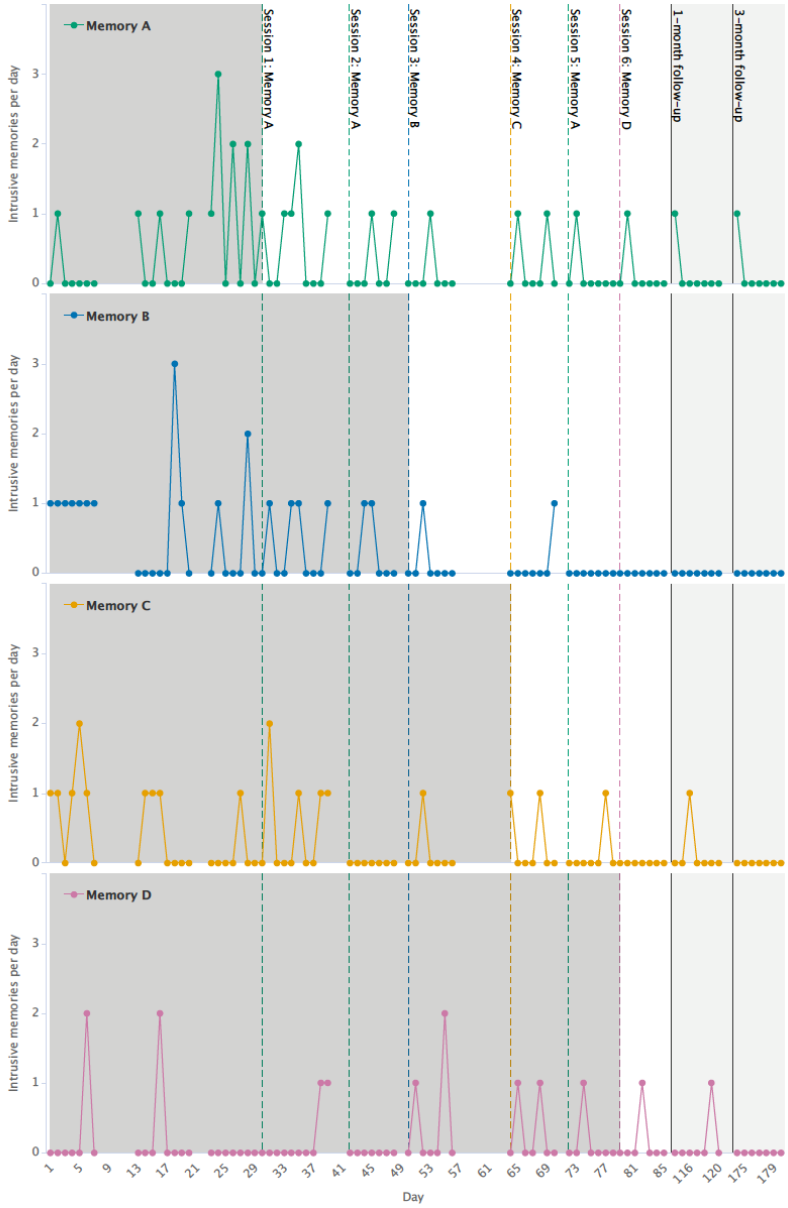

Figure 5. Graph for visual inspection of the number of intrusive memories (on Y-axis as number per day) for each of the four specific intrusive memories reported by the participant (memories A, B, C and D). Days since enrolment are shown on the X-axis, which includes baseline (grey), intervention (white), and follow-up periods (light grey). Different baseline and intervention lengths for each memory reflect that this is a repeated AB design. Dashed coloured vertical lines show when each intervention session was administered and which specific memory was targeted (e.g. Session one; Memory A in green). Memories are labelled in order of when they were targeted (e.g., 'Memory A' was targeted in the first intervention session). Solid black vertical lines show the one-month and three-month follow-ups. Gaps in the time series in baseline and intervention periods reflect missing data.

Table 1. Number of intrusive memories per week at baseline, intervention, one-month follow-up, and three-month follow-up, and relative reduction (in %) from baseline, for total intrusions and for each memory separately.

Intrusions	Baseline (A)	Intervention (B)	% reduction	1-month follow-up	% reduction	3-month follow-up	% reduction
Total	12.6	6.1	52	3.0	76	1.0	92
Memory A	3.8	2.0	46	1.0	74	1.0	74
Memory B	3.6	0.5	86	0	100	0	100
Memory C	2.4	1.0	59	1.0	59	0	100
Memory D	1.4	1.0	26	1.0	28	0	100

Note. Total intrusions does not equate to the sum of the intrusions for each memory here. This is because the length of baseline and intervention phases differ across each memory and the total. See Data analysis for more detail on how these numbers were calculated.

5.3 Secondary outcomes

5.3.1 PTSD, depressive, anxiety symptoms and general functioning

Initial PTSD symptom levels were high at baseline (a PCL-5 score of 51) but were reduced by more than half post-intervention (see Table 2). At the three-month follow-up, the reduction was clearly clinically significant, with a PCL-5 score of only 5 (Wortman et al., 2016). Symptoms of depression, which were moderate at baseline (PHQ-9 score in the 10-14 range), decreased to the mild range (PHQ-9 score in the 5-9 range) post-intervention, indicating a clinically significant improvement (Kroenke, 2012). Depression symptoms further improved to the minimal range (PHQ-9 score of 0-4) at the three-month follow-up. At baseline, the participant reported mild anxiety symptoms (GAD-7 score in the range of 5-10) and did not show a clinically significant change until the three-month follow-up, at which point anxiety levels were reduced to the minimal range (GAD-7 score of 0-4) (Toussaint et al., 2020). Functional impairment, as assessed by the Sheehan Disability Scale, also improved in a clinically significant manner over time, decreasing from a baseline score of 15 to 0 at the three-month follow-up (Coles et al., 2014).

Table 2. Self-report measures for secondary outcomes (post-traumatic stress, depressive, anxiety symptoms and general functioning) and impact of intrusive memories on concentration, sleep, stress, and daily functioning.

Item	Baseline interview	Postintervention	1-month follow-up	3-month follow-up
PCL-5[a]	51	35	30	6
PHQ-9[b]	13	7	8	2
GAD-7[c]	9	7	7	2
SES[d]	15	15	5	0
Concentration[e]	5	3	3	1
General concentration[f]	7	3	5	3
Duration of disruption[g]	4	2	2	1
Sleep[h]	5	3	2	0
Nightmares[i]	4	6	2	0
Stress[j]	5	3	3	1
Daily functioning[k]	5	1	3	0

Note. [a]The Posttraumatic Stress Disorder Checklist; scores ranging from 0–80; [b]The Patient Health Questionnaire-9; scores ranging from 0–27; [c]The Generalized Anxiety Disorder scale; scores ranging from 0–21; [d]The Sheehan Disability Scale; scores ranging from 0 (unimpaired) to 30 (highly impaired). [e]In the past week, how much did your intrusive memories disrupt your concentration? 0=not at all disruptive; 10=extremely disruptive; [f]In the past week, how much difficulty did you have concentrating generally? 0=no concentration at all; 10=extremely accurately; [g]When you had an intrusive memory, how long did it disrupt your concentration (in minutes), in the past week? 0(<1 min); 5(>60 min); [h]Did your intrusive memories interfere with sleep during the night in the past week? 0=not at all; 0=interfered very much; [i]Did you experience any nightmares that interfered with your sleep during the night in the past week? 0=did not experience any nightmares; 10=experienced a lot of nightmares; [j]In the past week, did your intrusive memories affect how stressed you felt? 0=not at all; 10=affected very much; [k]Have the intrusive memories affected your ability to function in your daily life? 0=not at all; 10=affected very much.

5.3.2 Impact of intrusive memories on concentration, sleep, stress, and daily functioning

Table 2 also includes the participant's ratings of the impact of intrusive memories on concentration, sleep, and stress. Notably, the impact of intrusive memories on concentration decreased from five at baseline to one at the three-month follow-up. The estimated duration of concentration disruption per intrusion was reduced from four (30–60 minutes) at baseline to one (1–5 minutes) at follow-up. Similarly, the impact of intrusions on sleep declined from five at baseline to zero at the three-month follow-up. Their impact on stress decreased from five at baseline to one at the three-month follow-up. The degree to which intrusive memories affected the participant's ability to function in daily life was also markedly reduced, from five at baseline to one post-intervention, and to zero at the three-month follow-up.

At baseline, when responding to an open-ended question about how intrusive memories influenced her daily functioning, the participant stated: "*I don't sleep very well, and that leads to fatigue which interferes with my daily functioning*." During the final intervention session, she answered the same question: "*It took some energy to try not to think about them, but they bother me very little anymore*." *At the one-month follow-up, she reported: "I can't concentrate when I have an intrusive memory, but the memories don't really bother me anymore even though I have been in quarantine. Usually when I am not busy that has meant more memories."* She also wrote: "*I have not needed to play Tetris, but it's nice to know that I can if I have an intrusive memory*." At the three-month follow-up, she stated: "*They have not been bothering me in the past weeks. It is a little uncomfortable that they may come, but they bother me very little*."

5.3.3 Feasibility and acceptability

The participant rated the likelihood that she would recommend the intervention to a friend as 10/10, indicating that she would "certainly recommend it." She also rated the acceptability of using gameplay as a method to reduce intrusive memories as 10/10, reflecting that she found it "very acceptable." When asked how she felt about playing Tetris after experiencing an intrusive memory, she described the intervention as "*very good*." In response to whether she found the intervention helpful, she stated: "*Yes, I forgot time and place, and the memory went away immediately*."

5.4 Study II

5.4.1 Total number of intrusive memories

The total number of intrusive memories per day across all study phases (baseline, intervention, and one-month follow-up) for each participant is presented in Figure 6. As the same diary measure was used at the three-month follow-up, these data are also included in Figure 6. Diary compliance was generally good across outcome

phases, with most missing data occurring during the baseline phase. During the baseline phase, the number of intrusive memories per day fluctuated for all participants.

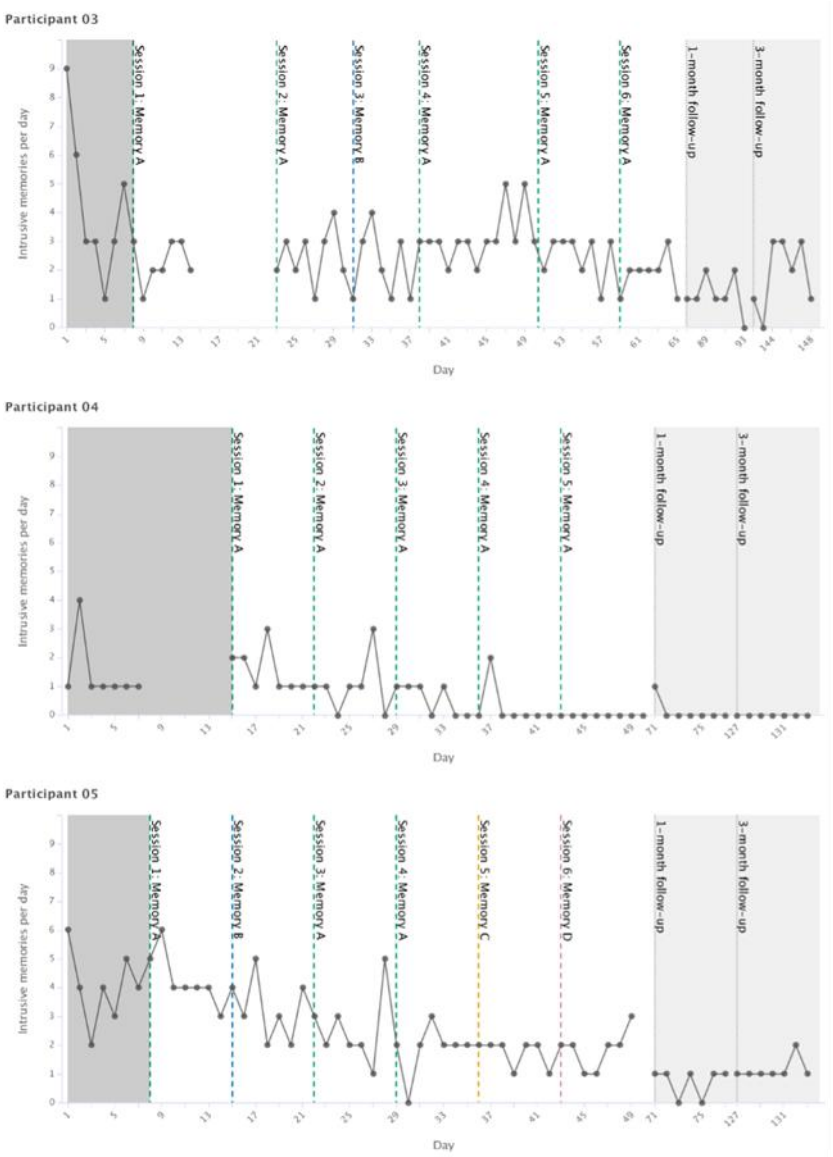

Figure 6. Graphs for visual inspection of primary outcome data for each participant (on the y axis as total number of intrusive memories per day, i.e. for all distinct memories combined). Days since study start are indicated on the x-axis, which shows baseline (in grey), intervention (in white), and follow-up periods (in light grey). Dashed vertical lines indicate when each of the intervention sessions was administered, and which distinct traumatic memory was targeted (each with a different colour line). Intrusive memories are labelled in the order of when they were each targeted (e.g., 'Memory A' targeted in the first intervention session). Dotted vertical lines indicate one-month and three-month follow-up periods. Gaps in the time series, for example in baseline, represent missing data.

A visual inspection of Figure 6 provides further detail for each participant. For participant 3 (P3), the number of intrusions decreased following the first intervention session relative to baseline, with some fluctuations throughout the intervention period (days 8–65). The frequency of intrusions declined further at the one-month follow-up but was not maintained at the three-month follow-up. For participant 4 (P4), despite some missing data during baseline, the number of intrusions remained relatively stable until the fourth intervention session targeting the same memory (day 36), when a marked decrease to zero occurred. This reduction was maintained through the final intervention session, as well as at both the one-month and three-month follow-ups. For participant 5 (P5), a slight reduction in intrusion frequency was observed after the second intervention session, followed by fluctuations until session five (day 36), when the reduction became more stable. Intrusion frequency decreased further at the one-month follow-up and was slightly increased during the three-month follow-up (see Figure 6).

Table 3. Number of intrusive memories per week in the baseline phase, postintervention phase, at one-month and three-month follow-ups from baseline phase for each participant, whereby memories that were targeted with the intervention are marked with an asterisk (*)

	Intrusions	Baseline (A)	Post-intervention (B)	1-month follow-up	3-month follow-up
P3	Memory 1 (A)*	14	11.2	6	3
	Memory 2(B)*	8.8	6.4	2	10
	Memory 3 (C)	6	0.3	0	0
	Memory 4 (D)	1	0	0	0
	Memory 6 (F)	3	0	0	0
	Memory 7 (G)	1	0	0	0
	Memory 8 (H)	3	0.1	0	0
	Memory 9 (I)	0	0	0	0
	Memory 10 (J)	2	0	0	0
	Total	38.8	18.0	8	13
	Total targeted(*)	22.8	17.6	8	13
	Total non-targeted	16	0.4	0	0

P4	Memory 1 (A)*	8.6	3.9	1	0
	Memory 2 (B)	1.1	0.8	0	0
	Memory 3 (C)	1.1	0	0	0
	Total	10.8	4.7	1	0
	Total targeted*	8.6	3.9	1	0
	Total non-targeted	2.2	0.8	0	0
P5	Memory 1 (A)*	10.6	6.5	0	2
	Memory 2 (B)*	7	2.8	0	2
	Memory 3 (C)*	2.6	4.2	0	4
	Memory 4 (D)*	2.0	5.6	5	0
	Memory 5 (E)	11.6	0.5	0	0
	Memory 6 (F)	0	1	0	0
	Total	33.7	20.7	5	8
	Total non-targeted	11.6	1.5	0	0

Note. Total intrusions does not equate to the sum of intrusions for each memory here, since the length of baseline and intervention phases differ across each memory and the total. See Data analysis for further details. Specific intrusive memories that were targeted with the intervention are marked with an asterisk (*).

P3 reported an average of 38.8 intrusive memories per week (summed across ten distinct memories) during baseline. This number decreased to 18.0 per week during the intervention phase, representing a 54% reduction from baseline, the frequency declined further to eight per week at the one-month follow-up (an 80% reduction) and was 13 per week at the three-month follow-up (67% reduction from baseline). P4 reported 10.8 intrusions per week at baseline (across three memories), which decreased to 4.7 per week during the intervention phase (a 57% reduction) and further declined to one per week at the one-month follow-up (a 91% reduction). The number of intrusive memories was zero per week at the three-month follow-up (100% reduction). P5 reported 33.7 intrusive memories per week during baseline (across six distinct memories), which decreased to 20.7 per week during the intervention phase (a 39% reduction). This number continued to decline, reaching five intrusions per week at the one-month follow-up (an 85% reduction from baseline) and P5 reported

eight intrusive memories per week at the three-month follow-up (76% reduction from baseline).

5.4.2 Change in the number of targeted intrusive memories relative to non-targeted memories

Table 3 presents the number of targeted and non-targeted intrusive memories per week across all study phases (baseline, post-intervention, one-month, and three-month follow-ups). The mean number of targeted memories was 7.6 (SD 4.3) per week during the baseline phase, which decreased to 5.8 (SD 2.7) per week during the intervention phase. The mean number of non-targeted memories decreased from 2.5 (SD 3.3) per week during baseline to 0.2 (SD 0.4) per week during the intervention phase. The number of targeted intrusions continued to decline at the one-month follow-up, reaching a mean of 2.0 (SD 2.5) per week, while non-targeted memories were reduced to zero. During the three-month follow-up, the mean frequency of targeted intrusions was 3.0 (SD 3.4) per week, and non-targeted intrusions remained at zero.

5.4.3 PTSD, depressive, anxiety symptoms and general functioning

Table 4 shows scores for secondary measures across phases for each participant. There was a clear reduction in posttraumatic stress symptoms (PCL-5) from baseline to post-intervention, with scores continuing to decline during follow-up for all three participants who completed the intervention, indicating clinically meaningful improvement (Wortman et al., 2016). Symptoms of depression (PHQ-9) and anxiety (GAD-7) followed a similar pattern for two of the three participants (P3 and P5), showing reductions both post-intervention and at follow-up. Functional impairment, as assessed by the Sheehan Disability Scale, also decreased for the same two participants from baseline to post-intervention and at the one-month follow-up, although P3's score showed an increase at the three-month follow-up. It should be noted that P4's scores on all these measures were low at baseline, limiting measurable improvement (see Table 4).

Table 4. Self-report measures of secondary outcomes (post-traumatic stress, depressive, anxiety symptoms and general functioning) and impact of intrusive memories on concentration, sleep, stress and daily functioning for each participant.

Item		Baseline interview	Post-intervention	1-month follow-up	3-month follow-up
PCL-5[a]	P3	54	35	20	35
	P4	26	14	6	11
	P5	64	49	51	31

	P3	13	8	6	9
PHQ-9[b]	P4	5	3	3	2
	P5	19	11	14	11
	P3	14	7	6	10
GAD-7[c]	P4	2	3	5	1
	P5	18	9	17	4
	P3	20	16	13	21
SDS[d]	P4	4	3	0	0
	P5	21	16	8	7
Concentration disruption related to intrusive memories[e]	P3	7	5	3	5
	P4	2	2	1	0
	P5	7	4	4	3
	P3	7	6	5	6
General concentration[f]	P4	2	2	2	0
	P5	7	4	3	-
	P3	4	4	3	4
Duration of disruption[g]	P4	2	1	2	1
	P5	4	4	2	2
	P3	4	4	3	4
Sleep[h]	P4	1	1	1	0
	P5	10	8	7	5
	P3	7	2	2	4
Nightmares[i]	P4	0	1	1	0
	P5	10	8	8	5
Stress[j]	P3	6	2	0	2

	P4	1	1	2	0
	P5	7	3	3	3
Daily functioning[k]	P3	7	5	2	5
	P4	0	0	0	0
	P5	7	0	2	0

Note. [a]The Posttraumatic Stress Disorder Checklist; scores ranging from 0–80; [b]The Patient Health Questionnaire-9; scores ranging from 0–27; [c]The Generalized Anxiety Disorder scale; scores ranging from 0–21; [d]The Sheehan Disability Scale; scores ranging from 0 (unimpaired) to 30 (highly impaired). [e]In the past week, how much did your intrusive memories disrupt your concentration? 0=not at all disruptive; 10=extremely disruptive; [f]In the past week, how much difficulty did you have concentrating generally? 0=no concentration at all; 10=extremely accurately; [g]When you had an intrusive memory, how long did it disrupt your concentration (in minutes), in the past week? 0(<1 min); 5(>60 min); [h]Did your intrusive memories interfere with sleep during the night in the past week? 0=not at all; 0=interfered very much; [i]Did you experience any nightmares that interfered with your sleep during the night in the past week? 0=did not experience any nightmares; 10=experienced a lot of nightmares; [j]In the past week, did your intrusive memories affect how stressed you felt? 0=not at all; 10=affected very much; [k]Have the intrusive memories affected your ability to function in your daily life? 0=not at all; 10=affected very much.

5.4.4 Impact of intrusive memories on concentration, sleep, stress and daily functioning

Ratings of the impact that intrusive memories had on concentration, stress, and sleep are presented in Table 4. P5 reported improved concentration following intrusive memories over the course of the intervention and follow-up periods. At baseline, when P5 experienced an intrusive memory, her concentration was disrupted for an average of 10–30 minutes; by the follow-up phase, this disruption had decreased to one to five minutes. P3 reported a slight improvement in concentration specifically in relation to intrusive memories, although her general concentration did not change. Ratings of concentration disruption from intrusive memories were low at baseline for P4 and remained stable post-intervention. The impact of intrusive memories on sleep did not change for P3 or P4, whereas P5 showed some improvement. Nightmares were reduced for both P3 and P5, while they were almost non-existent for P4. Stress levels associated with intrusions decreased during the intervention and follow-up periods for both P3 and P5.

The reported impact of intrusive memories on participants' ability to function in daily life showed improvement over the intervention and follow-up periods, except for P4, who scored zero at baseline. At baseline, participants were asked to describe how their intrusive memories affected their daily functioning. P3 stated: "*When I have this overwhelming feeling, I find it difficult to be around other people; the worst thing is how it affects my ability to stay present for my daughters*." P4 said: "*I have anger inside me; I constantly think back to how no one noticed what was done to me*." P5

reported: "*I get very stressed and anxious; it takes a lot of energy to get out of the emotion…*"

During the final intervention session, P3 reported, "*The intrusions disrupt my concentration*," while P5 stated, "*I experience distress and nightmares*." At the one-month follow-up, P3 explained, "*When I am under a lot of stress, they disturb me more*," and P5 reported, "*The images no longer have colour, cause less disruption, and are less frequent*." At the three-month follow-up, P3 said, "*I am under a lot of stress and dealing with a certain communication problem which triggers my PTSD and the intrusions*," but added, "*I can now comprehend that this is only a memory, and I don't feel as distressed.*" P5 stated, "*They mostly impact my anxiety*," and added, "*I am not a person that easily believes in things, but this intervention works*." For all phases following baseline, P4 consistently reported, "*The memories have no impact anymore.*"

5.4.5 Feasibility and acceptability of using a computer game-play intervention

Participants were asked to rate the likelihood that they would recommend the intervention to a friend. P3 gave a rating of nine, and P5 rated it as eight, both indicating that they were highly likely to recommend the intervention to others. In contrast, P4 provided a rating of three, suggesting that she was unlikely to recommend it. Participants were also asked to evaluate whether they considered gameplay to be an acceptable approach to reducing intrusive memories. P3 and P5 each rated this item as eight, reflecting high acceptability, whereas P4 again rated it as three, indicating low acceptability.

When asked to describe how they felt about playing Tetris following an intrusion, participants provided varied responses. P3 explained, "*It reduced the emotion, sometimes I was able to concentrate and think my way through it. Sometimes I experienced a kind of peace within*." P4 described a similar sense of cognitive engagement, stating, "*I played so there was no room for other thoughts*." P5 noted, *"Sometimes it's difficult to play for 25 minutes, but I played as many times as I could, for 5 to 25 minutes*."

Participants were asked whether they found the intervention helpful. P3 reported, "*When I was able to plan while playing the game, my brain could not interrupt me. The emotion that causes distress fades.*" P4 stated, "*Yes, I could not think about anything else whilst playing*," and P5 described a noticeable somatic calming effect: "*I felt a physical calmness, like the pit in my stomach was shrinking*."

Participants self-administered the intervention during the intervention phase. P2 rated Tetris gameplay usage after having an intrusive memory ranging from one to four, P4 ratings ranged from zero to seven and P5 rated her Tetris usage ranging from six to eight. P5 used the intervention independently from the intervention phase to the one-

month follow-up (rating six) and rated Tetris gameplay after an intrusive memory as two at the three-month follow-up.

5.5 Study III

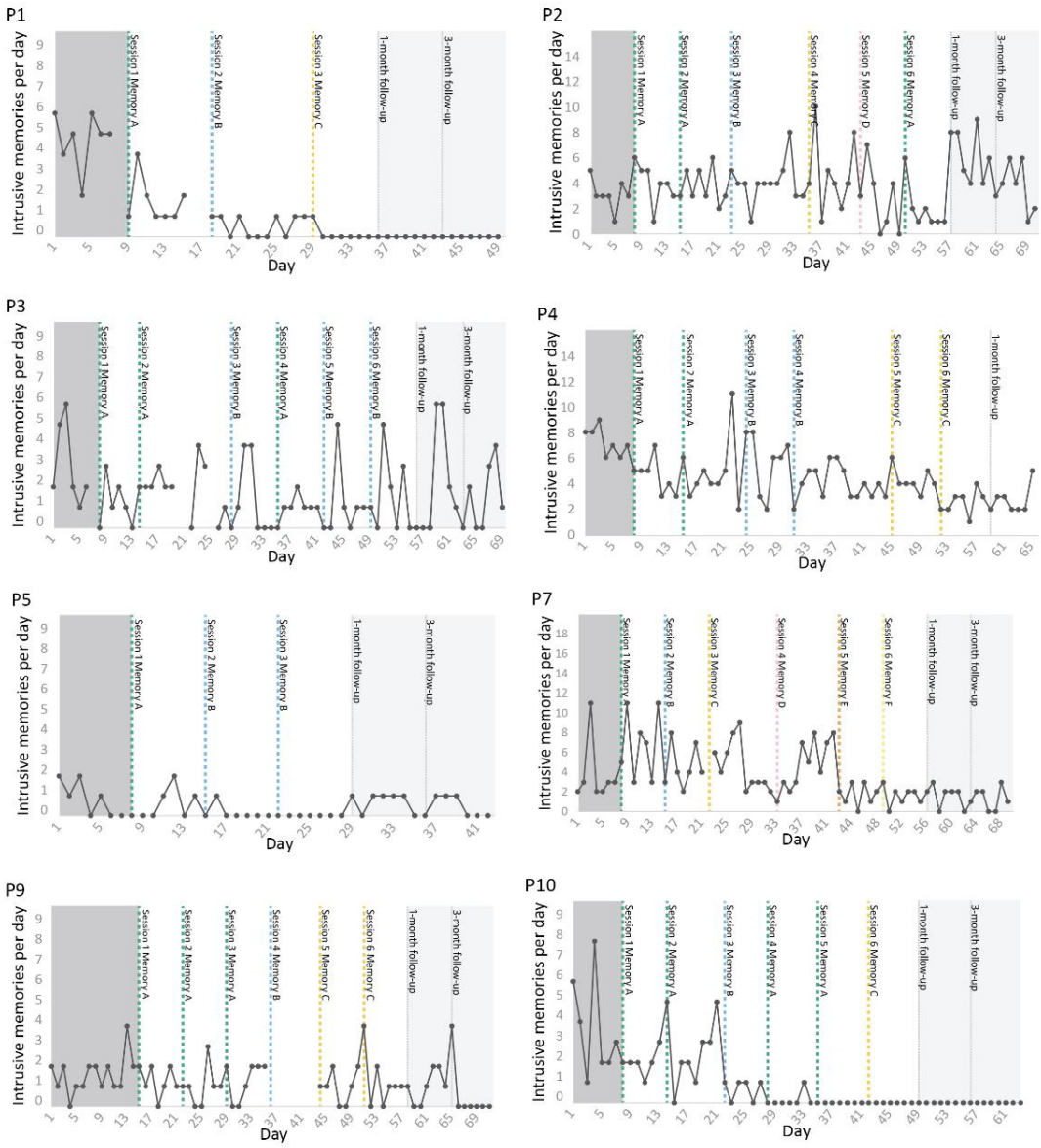

Figure 7. Total number of intrusive memories per day for each participant across phases; baseline, intervention, and follow-ups. Graphs for visual inspection of primary outcome data for each participant (on the y axis as total number of intrusive memories per day, i.e., for all distinct memories combined). Days since study start are shown on the x-axis, which includes baseline (grey), intervention (white), and follow-up periods (light grey). Dashed vertical lines show when each intervention session was administered, and which specific traumatic memory

was targeted (each with different coulor dash line). Memories are labelled in order of when they were targeted (e.g., 'Memory A' was targeted in the first intervention session). Dotted vertical lines show the one-month and three-month follow-up periods. Gaps in the time series represent missing data.

5.5.1 Change in the total number of intrusive memories

Figure 7 presents the total frequency of all intrusive memories for each participant across all study phases (baseline, intervention, one-month, and three-month follow-up). Each figure illustrates the number of intrusive memories reported during the week following the baseline session (leading up to the first intervention), as well as during the week following each subsequent intervention session.

Visual inspection for participant 1 (P1) shows that the total frequency of intrusive memories decreased following the first intervention session and continued to decline throughout the intervention phase. The frequency went down to zero at both follow-up assessments. For participant 2 (P2), the frequency of intrusive memories fluctuated during the intervention phase and increased again at follow-up. Participant 3 (P3) demonstrated a marked reduction in intrusion frequency after the first intervention session, followed by an increase after the second session. The frequency then declined again after the third session, rose slightly during the remainder of the intervention phase, increased at the one-month follow-up, and decreased once more by the three-month follow-up.

For participant 4 (P4), visual inspection indicates that intrusion frequency decreased after the first intervention session and remained relatively stable, with minor fluctuations throughout the intervention phase. This reduction was maintained at the one-month follow-up. Participant 5 (P5) showed a decline in intrusion frequency after the second intervention session, with continued reduction across the intervention phase, although this improvement was not maintained at follow-up. Participant 7 (P7) exhibited fluctuations in intrusion frequency until after the fifth intervention session, at which point a clear reduction occurred and was sustained throughout the follow-up period. For participant 9 (P9), the number of intrusive memories varied across baseline and intervention phases but showed an overall reduction by the three-month follow-up. Finally, for participant 10 (P10), the frequency decreased after the first intervention session and continued to drop following the third session. By the fifth intervention session she did not report any intrusive memories and reported zero intrusions at both one-month and three-month follow-up.

Table 5. Mean number of intrusive memories and percentage reduction per week across all phases; baseline, intervention, at the one-month, and the three-month follow-ups and total targeted and non-targeted intrusions for each participant.

Intrusions	Baseline (A)	Intervention (B)	% reduction	1-month	% reduction	3-month	% reduction

					follow-up		follow-up	
P1	Total	28.6	2.5	91.4%	0	100	0	100%
	Total targeted	28.6	2.5		0		0	
	Total non-targeted	-	-		-		-	
P2	Total	26.2	23.2	11.3%	44	-68.1%	26	-
	Total targeted	21.2	14.7		21		20	
	Total non-targeted	5	8.6		23		6	
P3	Total	17.1	10.1	41.0%	15	12.3%	10	41.5%
	Total targeted	13.6	8.5		2		10	
	Total non-targeted	3.5	1.6		13		0	
P4	Total	50.3	28.9	42.5%	19	62.2%	-	-
	Total targeted	47.3	27.8		19		-	-
	Total non-targeted	3	1.1		0		-	-
P5	Total	7.5	0.5	93.3%	5	33.3%	3	60.0%
	Total targeted	6.5	0.5		3		3	
	Total non-targeted	1	0		2		0	
P7	Total	32	24.1	24.8%	11	65.7%	9	71.9%

	Total targeted	27	21.3		11		8	
	Total non-targeted	5	2.8		0		1	
P9	Total	9.6	9	6.3%	7	27.1%	4	58.3%
	Total targeted	9.6	9		7		4	
	Total non-targeted	-	-		-		-	
P10	Total	19.9	3.8	81.1%	0	100%	0	100%
	Total targeted	19.9	3.8		0		0	
	Total non-targeted	-	-		-		-	

The mean number of targeted and non-targeted intrusive memories per week across the baseline, intervention, one-month, and three-month follow-up phases is presented in Table 5. Overall, the number of intrusive memories decreased for all participants from the baseline to the intervention phase. However, the reduction was minimal for two participants (P2 and P9). The percentage reduction from baseline to post-intervention ranged from 6.3% to 93.3%. For five of the eight participants, the reduction was greater at the one-month follow-up than immediately post-intervention, ranging from 27% to 100%. Similarly, for six of the eight participants, the percentage reduction at the three-month follow-up exceeded that observed during the intervention phase, with reductions ranging from 58.3% to 100%. P2 had an 68% increase at one-month follow-up. She reported a similar number of intrusive memories at the three-month follow-up as at baseline (26 intrusions per week), while P5 reported a slight increase in intrusive memories at the three-month follow-up (three intrusions per week) compared to the intervention phase (0.5 intrusions per week).

5.5.2 Change in the number of targeted intrusive memories relative to non-targeted memories

Table 5 displays the mean number of targeted and non-targeted intrusive memories per week across all study phases (baseline, post-intervention, one-month and three-month follow-ups). The mean number of individual targeted intrusive memories was

8.95 per week during the baseline phase and decreased to 6.11 per week during the intervention phase. The mean number of non-targeted intrusive memories was relatively low compared to targeted ones, averaging 2.74 per week at baseline. The number of non-targeted memories decreased minimally per week during the intervention phase to 2.67. The mean number of targeted memories continued to decrease at the one-month follow-up to 2.33 per week, while non-targeted memories declined to 1.80 per week. By the three-month follow-up, the mean number of targeted intrusive memories had further decreased to 1.67 per week, and non-targeted memories were reduced to 0.33 per week.

5.5.3 Self-report measures on PTSD, depressive and anxiety symptoms and general functioning

Participants completed questionnaires assessing PTSD, depression and anxiety symptoms, and general functioning at baseline, after the final intervention session, and at both follow-up points (see Table 6). Across the participant group, PTSD symptoms, as measured by the PCL-5, decreased from a mean score of 47.6 at baseline to 32.8 post-intervention. Scores continued to decline at follow-up, reaching 27.9 at one month and 27.0 at three months, indicating a sustained reduction in posttraumatic stress symptoms. Depressive symptoms, as measured by the PHQ-9, were reduced from a mean of 12.9 at baseline to 9.9 post-intervention, with slight increases observed at follow-up (10.4 at one month and 10.3 at three months). Anxiety symptoms, measured by the GAD-7, declined from a mean of 10.8 at baseline to 6.6 post-intervention, remained stable at 6.4 at the one-month follow-up, and increased to 7.7 at the three-month follow-up. Functional impairment, assessed using the Sheehan Disability Scale, showed a clinically significant reduction from 18.3 at baseline to 10.4 post-intervention. This improvement continued at follow-up, with mean scores of 9.6 at one month and 7.4 at three months, suggesting ongoing gains in daily functioning related to the reduction of intrusive memories (see Table 6).

Table 6. Self-report measures for secondary outcomes and impact of intrusive memories on concentration, sleep, stress, and daily functioning for all participants.

Item	Baseline interview *M* (*SD*)	Post-intervention *M* (*SD*)	1-month follow-up *M* (*SD*)	3-month follow-up *M* (*SD*)
PCL-5[a]	47.6 (15.2)	32.8 (16.5)	27.9 (19.4)	27.0 (17.9)
PHQ-9[b]	12.9 (8.0)	9.9 (6.7)	10.4 (7.1)	10.3 (7.4)
GAD-7[c]	10.8 (4.5)	6.6 (4.8)	6.4 (4.8)	7.7 (5.4)
SDS[d]	18.3 (8.2)	10.4 (5.7)	9.6 (8.0)	7.4 (7.0)
Concentration[e]	5.9 (1.7)	2.5 (2.2)	2.9 (2.2)	2.6 (2.1)

General concentration[f]	7.0 (1.7)	4.4 (2.9)	4.5 (3.4)	4.4 (3.2)
Duration of disruption[g]	2.3 (1.2)	1.8 (0.7)	1.4 (0.7)	0.7 (0.5)
Sleep[h]	4.8 (2.9)	1.5 (2.6)	1.9 (2.8)	1.3 (2.2)
Nightmares[i]	2.8 (3.6)	1.9 (2.9)	1.3 (2.6)	1.3 (2.4)
Stress[j]	5.8 (2.4)	3.4 (2.5)	2.8 (2.3)	2.4 (1.9)
Daily functioning[k]	4.4 (3.2)	2.0 (1.9)	2.3 (1.9)	2.1 (1.8)

Note. [a]The Posttraumatic Stress Disorder Checklist; scores ranging from 0–80; [b]The Patient Health Questionnaire-9; scores ranging from 0–27; [c]The Generalized Anxiety Disorder scale; scores ranging from 0–21; [d]The Sheehan Disability Scale; scores ranging from 0 (unimpaired) to 30 (highly impaired). [e]In the past week, how much did your intrusive memories disrupt your concentration? 0=not at all disruptive; 10=extremely disruptive; [f]In the past week, how much difficulty did you have concentrating generally? 0=no concentration at all; 10=extremely accurately; [g]When you had an intrusive memory, how long did it disrupt your concentration (in minutes), in the past week? 0(<1 min); 5(>60 min); [h]Did your intrusive memories interfere with sleep during the night in the past week? 0=not at all; 0=interfered very much; [i]Did you experience any nightmares that interfered with your sleep during the night in the past week? 0=did not experience any nightmares; 10=experienced a lot of nightmares; [j]In the past week, did your intrusive memories affect how stressed you felt? 0=not at all; 10=affected very much; [k]Have the intrusive memories affected your ability to function in your daily life? 0=not at all; 10=affected very much.

5.5.4 Impact of intrusive memories on concentration, sleep, stress, and daily functioning

Table 6 also presents ratings of the impact of intrusive memories on concentration, stress, sleep, and daily functioning across all study phases. Difficulties in concentration related to intrusive memories decreased from baseline to post-intervention and were maintained at follow-up. Ratings of overall concentration showed a similar pattern. The estimated duration of concentration disruption following an intrusion was reduced from 2.3 at baseline to 1.8 post-intervention, 1.4 at the one-month follow-up, and 0.7 at the three-month follow-up. The impact of intrusive memories on sleep decreased markedly, from 4.8 at baseline to 1.5 post-intervention, with these improvements maintained throughout the follow-up phases. Participants also reported a reduction in nightmares from baseline to post-intervention and further improvement at follow-up. Stress levels associated with intrusive memories decreased from 5.8 at baseline to 3.4 post-intervention, continuing to decline to 2.8 at the one-month follow-up and 2.4 at the three-month follow-up. The perceived impact of intrusive memories on participants' ability to function in daily life was reduced from 4.4 at baseline to 2.0 post-intervention, with this improvement sustained across both follow-up assessments.

5.5.5 Feasibility and acceptability for using a gameplay intervention.

All participants rated the intervention as an acceptable method for reducing the frequency of intrusive memories, with a mean rating of 9.5 (SD 0.8). Seven out of the eight participants self-administered the intervention at home during the intervention phase after having an intrusive memory (P1, P2, P4, P5, P7, P9 and P10). Four out of eight participants continued to use Tetris gameplay from the intervention phase to the follow-ups (P2, P4, P7 and P9).

6 Discussion

The overall aim of this doctoral research project was to investigate whether a brief imagery competing task intervention, specifically after a memory reminder engaging in Tetris gameplay with mental rotation for approximately 25 minutes, could reduce the frequency of intrusive memories of trauma among Icelandic women. Three studies were conducted to evaluate the intervention's efficacy and feasibility.

The primary aim was to determine whether participants would report fewer intrusive memories during the intervention phase compared to the preceding baseline phase. Furthermore, whether the reduction would be maintained at one-month and three-month follow-ups. It was also hypothesized that targeted intrusive memories would decrease more than non-targeted ones. In addition, it was explored whether reductions in intrusive memories would be associated with improvements in functioning and reductions in symptoms of post-traumatic stress disorder (PTSD), depression, and anxiety, as well as the feasibility and acceptability of the intervention.

6.1 Main results

The results were promising across all three studies. In study I (a single case) the frequency of intrusive memories decreased by approximately 50% from baseline to the intervention phase. The reduction in frequency of intrusive memories continued to reduce to 76% at one-month follow-up and by 92% at the three-month follow-up.

In study II, the first case series of three participants, the results were similar. P3 had the number of intrusive memories reduced by 53% from baseline to the intervention phase. The reduction was 80% during the one-month follow-up week compared to baseline and 67% reduction at the three-month follow-up. For P4 the reduction from baseline to the intervention phase was 56% and her number of intrusive memories reduced by 91% at the one-month follow-up compared to baseline and the reduction was 100% at the three-month follow-up. P5 had a 39% reduction from baseline to the intervention phase. The number reduced to 85% at the one-month follow-up compared to baseline and the reduction was 76% at the three-month follow-up.

In study III, the second case series involving eight participants, the results were replicated overall. The percentage reduction from baseline to the intervention phase ranged from 6.3% to 93.3%, with a minimal reduction for two participants (P2 and P9). The reduction was overall and continued from baseline to the one-month follow-up for five out of eight participants, ranging from 27% to 100%. At the three-month follow-up the number of intrusive memories continued to reduce even further for six out of eight participants, reductions ranging from 58% to 100%. Two participants reported zero intrusive memories at both the one-month and three-month follow-ups (P1 and P10).

When comparing reductions in frequency between targeted and non-targeted memories, the overall trend in our results was that the frequency of targeted intrusions reduced more than the frequency of non-targeted ones. The number of intrusive memories that were non-targeted tended to be lower than targeted ones at baseline. In Study II however, two participants (P3 and P5) had a considerably high number of intrusive non-targeted memories at baseline which reduced in number during the intervention phase.

When looking at the overall results of reductions in the mean number of intrusive memories from baseline compared to intervention phase in Study II we found the following: The mean number of individual targeted memories was 7.6 memories per week during the baseline phase and decreased to 5.8 memories per week during the intervention phase. The mean number of non-targeted memories decreased from 2.5 memories per week during baseline to 0.2 memories per week during the intervention phase. The number of targeted intrusions continued to decline at the one-month follow-up, reaching a mean of two per week, while non-targeted memories were reduced to zero. At the three-month follow-up, the mean frequency of targeted intrusions was three memories per week, and non-targeted intrusions remained at zero.

In Study III the number of non-targeted memories was very low at baseline compared to targeted ones, the highest number of non-targeted memories was five per week for P2 and P5 compared to about 21 and 27 of targeted memories. The mean number of individual targeted intrusive memories was 8.95 per week during the baseline phase and decreased to 6.11 per week during the intervention phase. The mean number of non-targeted memories was 2.74 per week at baseline. The number of non-targeted memories decreased minimally per week during the intervention phase to 2.67 per week. The mean number of targeted memories continued to decrease at the one-month follow-up to 2.33 memories per week, while non-targeted memories decreased to 1.80 memories per week. At the three-month follow-up, the mean frequency of targeted intrusive memories had further decreased to 1.67 per week, and non-targeted memories were reduced to 0.33 per week.

One possible explanation for the considerable reduction in the frequency of non-targeted memories is that often both targeted and non-targeted memories were from the same traumatic event and therefore may be interconnected. Furthermore, targeted memories were often reported to be more distressing than non-targeted memories, and may, therefore, require more time to be reduced in frequency. In fact, we did, as described above, find a long-term effect for targeted memories. However, non-specific factors, such as empathy and positive regard, cannot be ruled out. This raises the need for randomized controlled trials with a credible control task to be able to better examine the efficacy of the intervention over and above non-specific factors.

Across all three studies, the reduction in frequency of intrusive memories from baseline to the intervention phase was consistent with the primary aim, results followed the same trend as in other studies that investigated the effects of the intervention for already established intrusive memories of trauma (Hardarson et al., 2024; Iyadurai et al., 2020; Kanstrup et al., 2020., Singh et al., 2021).

Findings from the present doctoral thesis align with theories of memory reconsolidation (Nader et al., 2000; Dudai, 2004) and visuospatial interference (Holmes et al., 2009, 2010). Reconsolidation theory proposes that when a consolidated memory is reactivated, it temporarily becomes malleable and can be modified before restored. Engaging in a demanding visuospatial task during this reconsolidation window is thought to compete for working memory resources required to restabilize the sensory-perceptual aspects of the traumatic memory (Baddeley & Andrade, 2000; James et al., 2015). As a result, the intrusive sensory and emotional memory can become less emotional and less vivid.

Interestingly, the reduction in frequency did not only remain stable at follow-up as we expected but continued to reduce from the intervention phase to follow-up for most participants. One possible explanation is the simplicity of the intervention, which allows participants to self-administer it independently as needed. Majority of participants (all in Study II and seven out of eight in Study III) used the intervention independently after having an intrusive memory during the intervention phase. Some participants continued to self-administer the intervention from the intervention phase to the follow-ups (P5 in Study II and P2, P4, P7 and P9 in Study III).

6.2 Secondary outcomes

The secondary aim was to explore whether reductions in intrusive memories would be associated with improvements in a broader sense, regarding PTSD, depressive and anxiety symptoms, and improvements in functioning.

Overall, PTSD symptom severity decreased from baseline to post-intervention and continued to decline at follow-ups. For most participants, continued decrease was observed at follow-up periods. Participants reported reductions of depressive

symptoms from baseline to post-intervention. In general, these reductions were maintained to follow-ups (with some variability). Anxiety symptoms were also reduced from baseline to post-intervention. Overall, reductions were maintained at follow-up (some with minimal increase at the three-month follow-up). Improvements in functioning were observed from baseline to post-intervention, which remained stable longer term in most cases. Furthermore, most participants demonstrated improvements across other symptoms and functioning measures. The extent of symptom reductions varied and for a few participants the baseline symptom levels were very low, making it harder to draw firm conclusions. In conclusion, the intervention was associated with reductions in PTSD symptoms, and depressive and anxiety symptoms, as well as improvements in daily functioning. These gains were sustained to longer-term in most cases.

These results of secondary outcomes are in accordance with previous findings, about half of participants in Kessler et al. (2018) reported reductions in symptoms of PTSD, depression and anxiety. In a single case study by Iyadurai et al. (2020), the patient reported less PTSD symptoms and improvements in mood post intervention. In Kanstrup et al. (2020) all four participants reported improved functioning. Participants reported reductions in PTSD symptoms and improved functioning in Singh et al. (2020) and PTSD, depressive and anxiety symptoms were reduced in Hardarson et al. (2024), where participants also reported improved functioning.

These results also support network models of PTSD that put intrusive memories as one of the core clinical features of PTSD. When intrusive memories are targeted, it can have beneficial effects not only in reducing the frequency of the memories themselves, but the impairment directly related to them, leading to improvement in other symptoms in the symptom network overall (McNally, 2012; 2017).

Reduction in the frequency of intrusive memories was followed by reduction in other PTSD symptoms such as hyperarousal, negative affect, and avoidance. Improvements in concentration, sleep, and daily functioning further demonstrate that reducing cognitive and emotional distress related to intrusive memories can meaningfully enhance quality of life. This pattern supports the hypothesis that targeting a single, tractable symptom may have positive effects on mental health overall.

Conventional trauma-focused therapies have been found to be effective, such as prolonged exposure and cognitive therapy (NICE, 2018; Lewis et al., 2020a). They require, however, extensive training, making capable clinicians too few to be able to deliver therapy for all those in need. They also involve factors that often limit accessibility and contribute to dropout. This includes the need for people to discuss their traumatic events in detail (Kantor et al., 2017; Najavits, 2015).

The current intervention, in contrast, is brief, low-cost, and does not require the patient to recall and talk about their traumatic experiences in detail. Moreover, the intervention can be delivered by trained non-specialists, making delivery much simpler. Training for trauma-focused therapies often entails workshops for two to three days followed by supervision for approximately six months as well as a requirement of having completed treatment for a certain number of patients. The intervention is also scalable due to its simplicity and can be delivered in geographically dispersed or low-resource settings.

High acceptability ratings across participants suggest that the intervention is a feasible way to address intrusive memories. Participants described feeling emotionally calmer, less distressed, and more in control while playing Tetris and following the gameplay. The ability to self-administer the task after learning it in session further enhances its practical utility. These findings mirror earlier research demonstrating the feasibility of Tetris gameplay interventions among diverse populations, including refugees (Holmes et al., 2017) and healthcare workers (Singh et al., 2021). The broad scope of findings to date suggest that the intervention might be a promising option for trauma-related intrusive memories across populations.

6.3 Remote and non-specialist delivery

A major methodological innovation was the transition to remote delivery in part in study II and to fully remote in study III. The change from face-to-face delivery was prompted by the COVID-19 pandemic. The University of Iceland was closed March 19th, 2020, and forced researcher to switch to remote delivery of the intervention via online communication during the data collection for study II. This unexpectedly revealed that face-to-face interaction is not essential for intervention efficacy, since this arrangement did not influence the participants´ reduction of the frequency of intrusive memories nor other symptom reduction. This is consistent with subsequent research showing similar outcomes for remotely delivered imagery-competing task interventions (Hardarson et al., 2024; Singh et al., 2021).

In study III we added to the scalability of the intervention by training bachelor's degree graduates and master level students in clinical psychology to use it. This did not affect the results, indicating that the intervention could well be delivered by non-specialists. The intervention could, therefore, be made accessible in settings with limited access to empirically validated trauma therapy.

6.4 Limitations and future directions

Several limitations must be acknowledged. The very small sample size, divided between three small studies, limits the generalizability of the findings. Furthermore, the sample was homogenous, and therefore the findings cannot be generalized to more culturally diverse populations. Future studies should therefore evaluate the

intervention in larger and diverse samples to examine whether cultural, contextual, or gender-related factors influence the efficacy or the acceptability of the intervention.

Future research should also explore optimization of the intervention. This could include further investigation of fully digitalized monitoring of the frequency of intrusive memories, as well as exploring whether fewer intervention sessions could yield similar results. In addition, the feasibility and effectiveness of entirely self-guided use of the intervention warrants further study. Such an approach could be supported by structured psychoeducational materials explaining the underlying cognitive mechanisms of intrusive memories and providing clear guidance on how to self-administer the intervention. Initial work by Hardarson et al. (2024) has been conducted to explore the feasibility of these adaptations and reported promising findings. However, additional research with larger samples and controlled designs is required to evaluate effectiveness of such adaptations.

A further limitation of the current research is the absence of a control condition. Without a comparison group, it is not possible to determine to what extent observed improvements can be attributed specifically to the active components of the intervention. Future studies should, therefore, employ randomized controlled trial designs incorporating credible control tasks to evaluate whether the gains could be accounted for by non-specific factors, such as credibility of the intervention, attention from a researcher or clinician, structured monitoring, repeated assessment and therapeutic engagement.

7 Conclusions

This line of studies investigated whether a brief imagery competing task intervention, Tetris gameplay with mental rotation following a memory reminder, could reduce intrusive trauma memories, among Icelandic women after trauma. The results across all three studies were promising, showing reductions in the frequency of intrusive memories from baseline to the intervention phase. Furthermore, the frequency of memories continued to reduce in frequency during the follow-up phase for most participants. The drop in frequency was accompanied by improvements in symptoms of PTSD, depressive and anxiety symptoms, and functioning.

The intervention was found to be acceptable and feasible, and it could be delivered just as effectively remotely and by non-specialists. It is, therefore, a scalable, low-barrier option for individuals who might otherwise not seek trauma treatment due to cost or limited access.

Further research, in particular randomized controlled trials and cross-cultural replications, is needed to establish efficacy and generalizability. The present findings, however, offer a significant step toward accessible, scalable, cost-effective and low-burden interventions available to reduce the distress of individuals suffering from intrusive trauma memories.

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Paper I

Original Paper

Reducing Intrusive Memories of Childhood Trauma Using a Visuospatial Intervention: Case Study in Iceland

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Abstract

Background: Additional interventions are needed for survivors of psychological trauma because of several barriers to and limitations of existing treatment options (eg, need to talk about the trauma in detail). Case studies are an important step in exploring the development of novel interventions, allowing detailed examination of individual responses to treatment over time. Here, we present a case study that aims to test a novel intervention designed to disrupt memory reconsolidation, taking a single-symptom approach by focusing on intrusive memories of a traumatic event.

Objective: This study aims to examine a novel brief cognitive intervention to reduce the number of intrusive memories of trauma in an Icelandic setting and to extend previous studies by examining long-term effects for up to 3 months. The intervention was guided by a clinical psychologist and comprised a brief memory reminder, followed by Tetris gameplay with mental rotation, targeting one memory at a time in each session.

Methods: This was a single case study in Iceland with a woman in her 50s (drawn from an epidemiological study of trauma) with subthreshold posttraumatic stress disorder and a diagnosis of obsessive-compulsive disorder and social anxiety disorder. The participant had four different intrusive memories from a traumatic event that happened in her childhood. The primary outcome was the change in the number of intrusive memories from baseline to intervention phase and to follow-ups. The number of intrusions was monitored in a daily diary for 4 weeks preintervention, 8 weeks during the intervention, and 1 week at 1-month and 3-month follow-ups. Intrusions were targeted one by one over six intervention sessions, creating four *repetitions* of an *AB design* (ie, length of baseline *A* and intervention phase *B* varied for each memory). We examined changes in both *the total* number

of intrusions (summed across all four memories) and individually for each memory. In addition, we explored whether having fewer intrusive memories would have an impact on functioning, posttraumatic stress, and depression or anxiety symptoms.

Results: The total number of intrusions per week was 12.6 at baseline, 6.1 at the intervention phase (52% reduction from baseline), 3.0 at the 1-month follow-up (76% reduction), and 1.0 at the 3-month follow-up (92% reduction). Reductions in the symptoms of posttraumatic stress and depression were observed postintervention. Sleep, concentration, stress, and functioning improved. The participant considered the gameplay intervention acceptable and helpful in that she found that the memories disappeared while she was playing.

Conclusions: This guided brief cognitive intervention reduced the number of intrusive memories over the intervention phase and follow-ups. The brief memory reminder was well tolerated, removing the need to discuss trauma in detail. The next steps require an extension to more cases and exploring remote delivery of the intervention.

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KEYWORDS

psychological trauma; intrusive memories; case report; visuospatial interference task; Tetris gameplay; mental imagery; mobile phone

Introduction

Background

Psychological trauma (eg, disasters, accidents, or interpersonal violence) is experienced by most people at some point during their lifetime [1,2]. Many individuals who have been exposed to trauma (approximately 1 in 4) go on to develop posttraumatic stress disorder (PTSD) [3,4]. The core clinical symptom of PTSD is intrusive memories related to traumatic events [1,5]. Other symptoms of PTSD include avoidance of stimuli associated with trauma, along with negative alterations in cognition, mood, arousal, and reactivity [1]. Approximately half of those diagnosed with PTSD do not spontaneously recover within 40 months of diagnosis [6]. PTSD, even when subthreshold, is associated with substantial distress, functional impairment, and comorbidities [1,7]. Although many patients respond well to current PTSD treatments, approximately one-third of patients who enter psychological treatment for PTSD still meet the diagnostic criteria for the disorder following treatment [8].

Current evidence-based treatments for PTSD include individualized trauma-focused cognitive behavioral therapy interventions and eye movement desensitization and reprocessing [3,8]. However, there are some limitations to existing psychological treatment options for PTSD, including the limited number of qualified therapists, geographic distances to such clinical expertise (eg, in rural areas), high cost of treatment, and stigma being a barrier to individuals seeking treatment [9]. Dropout rates from PTSD treatment are high, approximately 18% overall (ranging from 0%-48%) in clinical trials and are thought to be even higher in clinical practice outside of clinical trials [10-12]. Furthermore, only a minority of those who need PTSD treatment receive it [13]. The common denominator in existing treatment options is a requirement for patients to recall and talk about the traumatic experience in detail, which many trauma survivors are reluctant to do [9]. Many therapists are also reluctant to deliver trauma-focused therapies, such as prolonged exposure, because of fear of exacerbation of symptoms or concerns with patient dropout [12].

Another barrier to treatment is the lack of service provision [9]. Iceland, for instance, is one of many countries that lack the mental health services capacity to offer treatment to all trauma survivors. New, briefer approaches that reach more people or can be delivered to remote places in geographically dispersed countries via the internet are needed [9]. Moreover, people who do not meet the full diagnostic criteria for PTSD are typically unable to access existing services, meaning that treatments for trauma survivors with subthreshold but impairing symptoms are needed.

Overall, these limitations and barriers create the need for additional complementary approaches to current treatments. One option that has been suggested is to focus on reducing one single, tractable symptom (here, the core clinical symptom) rather than a full diagnosis of PTSD [5,14]. Intrusive memories (ie, criterion B1 as defined in the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* [*DSM-5*]) are repeated and unwanted memories of scenes from a traumatic event, and they are predominantly visual [15-17]. They can evoke the same emotions experienced during the traumatic event [16] and often have a sense of nowness, that is, as if they are happening in the present rather than in the past [15]. Intrusive memories can cause significant distress and interfere with everyday functioning, making them an important target for treatment [17].

A relatively simple and brief intervention to reduce the number of intrusive memories after trauma has recently been developed, building on principles from cognitive science [14,18,19]. It is in line with calls to develop new therapeutic approaches for PTSD, such as those that target memory reconsolidation [20]. The intervention comprised a brief memory reminder for a specific intrusive memory of trauma, practice in mental rotation (ie, actively playing the game by rotating the blocks in one's mind; for further details, see Holmes et al [21], chapter 11), followed by Tetris gameplay with mental rotation for 25 minutes, guided in person by a researcher.

Initial work toward clinical translation was for recent memories of trauma [22-24]. For older, intrusive memories of trauma, the effect has been explored using case study and case series approaches [19,25,26]. Kessler et al [19] conducted a case series

of inpatients (n=20) with complex PTSD and trauma memories from childhood. The intervention comprised a memory reminder (here, writing a brief description of the memory, then shredding it) followed by Tetris gameplay with mental rotation for 25 minutes for one intrusive memory at a time. Memories (here, many different memories) were targeted one by one, that is, each intrusive memory in a different session, and memories were tracked individually in a diary. The results showed that targeting a specific intrusion was followed by a drop in the frequency of that intrusion (some to zero). The frequency of targeted intrusions reduced by 64% overall from baseline to postintervention, whereas the frequency of nontargeted intrusive memories reduced by 11%.

Kanstrup et al [25] adapted the intervention for a new target group—people who were refugees (n=4) and used it to target already established trauma memories such as of war. The memory reminder used here was a brief list of intrusive memories (ie, hotspot sheet) where participants were asked to briefly describe in a few words the imagery content of their intrusions, either by writing it themselves or by telling the researcher what to write. The intervention was delivered in a community setting, such as a library. All 4 participants showed a decrease in the number of intrusive memories (again targeted one by one) after the intervention and reported improved functioning. For example, participant 1 had a decrease from 10 memories at baseline to 0 after the first intervention week, and for participant 3, the 28 memories at baseline decreased to 14 after the first intervention week.

Study Design and Aims

Given the small-scale but promising results of this single-symptom intervention approach for older memories of trauma, we were interested in adapting it for women with a trauma history in Iceland. Thus, in this case study (n=1), we aim to investigate the effects of the intervention adapted to Iceland for a woman from a population-based sample experiencing intrusive memories of childhood trauma, delivered with guidance from a clinical psychologist and seen in a university research setting. Importantly, we aim to extend the previous literature testing this intervention by including a significantly longer follow-up period than previous studies (ie, 1 month and 3 months postintervention) to examine whether effects are maintained in the long term.

When evaluating the efficacy of novel interventions and refining intervention protocols, single-case designs are a crucial step [27,28], giving researchers the chance to examine individual variability over time [29]. The *N-of-1* trials are also gaining popularity as modern medicine moves toward individualized patient-centered care [30]. Typically, a replication of AB (ABAB) is considered necessary to establish intervention effects [27]. However, Kanstrup et al [25] argued that a classic ABAB design was not optimal for evaluating this specific intervention as, unexpectedly, the effects lasted after one intervention session and did not rebound (ie, could not be reduced again, as assumed by a classic ABAB). Kanstrup et al [25] instead recommended a within-person *multiple baseline AB design*, as in the study by Kessler et al [19]. In this approach, if a person has more than one different intrusive memory, then each specific intrusive memory is targeted one at a time, with separate intervention sessions allowing focused assessment of the effect of each intervention on each memory over time. This is the design adopted in this study. However, to avoid confusion with other case series designs (such as those with multiple *randomized* baselines), we refer to this design as a *repeated AB design.*

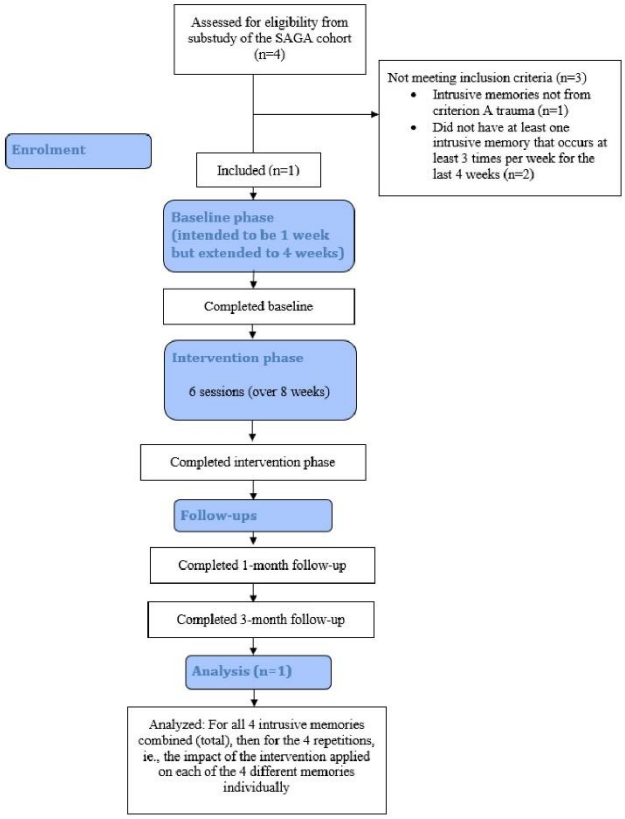
We predict that our participant (here with four different intrusive memories of trauma) would report fewer intrusive memories (primary outcome) during the intervention phase than in the preceding baseline phase and that the reduction in the number of intrusions would be maintained at the 1-month and 3-month follow-ups. We also aim to explore whether having fewer intrusive memories would be associated with improvements in general functioning and reductions in symptoms of PTSD, depression, and anxiety (secondary outcomes). In addition, we aim to explore the feasibility and acceptability of the intervention (similar to Holmes et al [31]).

Methods

Participants

Women who took part in a substudy of the stress-and-gene-analysis (SAGA) cohort study were screened for eligibility. The SAGA cohort study is a population-based longitudinal cohort study of Icelandic women who completed an extensive questionnaire on trauma history and mental health (baseline data collection finished on July 1, 2019). The substudy (the Social Trauma Project) involves comparing two samples of women from the SAGA cohort study with either likely PTSD (ie, having a score on the PTSD Checklist-5 [PCL-5; see the *Measures* section] of ≥33) or not likely PTSD (ie, scores in the lowest one-fifth on the PCL-5), using clinical interviews. When taking part in the substudy, two semistructured interviews were administered (ie, the Mini International Neuropsychiatric Interview [MINI], also used to assess the exclusion criteria for this study, and the Clinician Administered PTSD Scale [CAPS]; see the *Measures* section). When taking part in the substudy, women were screened for the presence of intrusive memories of trauma. The screening included a short description of the symptom, followed by questions about the presence of the symptom to assess their eligibility for this study. A total of 4 women from the substudy who provided consent to be contacted regarding additional research were assessed for inclusion in this case study. A total of 3 women did not meet the inclusion criteria (CONSORT [Consolidated Standards of Reporting Trials] diagram in Figure 1). The included participant was a woman in her 50s who had four different intrusive memories from a single traumatic event involving physical violence in childhood (ie, occurring around four decades previously).

Figure 1. Adapted Consolidated Standards of Reporting Trials participant flow diagram for this study. SAGA: Stress and Gene Analysis.



The inclusion criteria were as follows: (1) having experienced criterion A trauma as defined by *DSM-5* [6]; (2) having at least one intrusive memory that occurs at least three times per week for the last 4 weeks; (3) being able and willing to attend three to eight sessions with the researcher; (4) being able and willing to monitor intrusive memories in daily life; (5) having access to a smartphone; and (6) being able to speak Icelandic and read study materials in Icelandic. Exclusion criteria were as follows: (1) current psychotic disorder; (2) current manic episode; and (3) being acutely suicidal. Exclusion criteria were assessed with the MINI.

The participant reported clinically significant past-month PTSD symptoms from physical violence experienced in childhood, with a total symptom severity score of 22 of 80 on the CAPS and missing one symptom in the E cluster to meet full diagnostic criteria (had five symptoms in cluster B, two in cluster C, three in cluster D, and one in cluster E). This assessment took place 2 months before participation in this study as part of the substudy of the SAGA cohort using the CAPS (see the *Measures* section). The participant also met criteria for social anxiety disorder and obsessive-compulsive disorder according to the MINI diagnostic interview (see the *Measures* section). The participant received psychological treatment in the past for problems related to work but had never received trauma-related psychological treatment. She reported not taking any psychotropic medication in the 3 months before taking part.

Design

This single case study took a specific single-symptom probe approach, whereby each of the four intrusive memories was targeted one at a time in different sessions [19]. Critical to this approach, the participant distinguishes the content of their different intrusive memories (here, for four intrusions, eg, (1) red curtain, (2) man's face, (3) blood on floor, and (4) closed door; these examples are fictitious to protect anonymity) and tracks the frequency of each intrusion over time. We describe this design here as a *repeated AB design*, wherein the length of baseline (*A*, preintervention; monitoring only) and intervention (*B*) phases varied across each of the four intrusive memories,

depending on when each memory was targeted. The baseline phases for each individual memory are used as control periods to compare their numbers before and after being targeted by the intervention.

The number of each intrusive memory was monitored in a daily diary for 4 weeks preintervention, over 8 weeks of the intervention, and then for 1 week at the 1-month and 3-month follow-ups, that is, the participant monitored the occurrence of her intrusive memories in a daily diary before each intervention session to establish a baseline level of intrusion. This baseline phase was intended to be 1 week; however, the diary was kept for 4 weeks, as the participant was not able to meet with the researcher when planned. The intervention phase lasted 8 weeks rather than 6 weeks, as planned for the same reason. However, the participant did monitor the frequency of her intrusive memories in these extended periods, and we included all the data in the analyses. The daily diary was kept again for 1 week at the 1-month and 3-month follow-ups.

The participant's four different intrusive memories were targeted one by one over six intervention sessions guided by a clinical psychologist who specialized in trauma-focused cognitive behavioral therapy. The design thus involved four repetitions of an AB design. In addition to the six guided sessions, the participant could also self-administer the intervention at any time after the first session if she so chose for memories already targeted in the session. The primary outcome was the change in the number of intrusive memories from baseline to the intervention phase and to long-term follow-ups (1 and 3 months). The participant also completed self-report measures for PTSD, depression and anxiety symptoms, and functional impairment at baseline, the last intervention session, and the 1-month and 3-month follow-ups.

Procedure

Training

To promote adequate intervention delivery and protocol adherence, the researcher delivering the intervention (JPH, a licensed clinical psychologist and specialist in trauma therapy) received training and clinical supervision from experienced researchers or clinical psychologists who had expertise in delivering the novel intervention (EAH and MK). Training included two in vivo workshops for 3 days and then approximately 6 months later for 2 days. Workshops covered theoretical and practical aspects of intervention delivery and included role-plays with trainers until adequate performance was reached. Training also included how to explain and capture the primary outcome measure (intrusive memory diary). During data collection, the researcher received continued supervision, adherence checks, and support regarding any adaptations necessary from a clinical supervisor via telephone after sessions with the participant and weekly supervision meetings. The researcher also participated in remote group training meetings twice a month with other researchers using the intervention.

Baseline Session

In the first session, the participant answered baseline questionnaires (relating to secondary outcomes), and the researcher explained what intrusive memories are (ie, memories that include sensory impressions such as sight and sound; are predominantly visual in form, similar to pictures or a film clip in the mind's eye; and are distressing and occur involuntarily). The participant identified her different intrusive memories by briefly describing them to the researcher using only a few words to indicate their visual content; the researcher wrote the description on a *hotspots* sheet that was clearly visible to the participant. The participant did not talk about the trauma with the researcher or about the intrusive memories in detail. The participant labeled each of her intrusive memories with a symbol (ie, first memory labeled *A* and second memory labeled *B*) and was instructed on how to monitor the daily frequency of them in a diary (primary outcome measure). When indicating experiencing a memory, the participant noted the symbol corresponding to that specific memory in a specific time frame of that day. Each diary included 7 days and four periods each day (see the *Measures* section).

Intervention Sessions

In each of the intervention sessions (six sessions), the participant selected one memory at a time to target that week and completed the intervention procedure, guided by the clinical psychologist. The intrusion selected first can be the one that is most troublesome or frequent or one for any other reason the participant wishes to try reducing first. The intervention consisted of a brief memory reminder (ie, briefly thinking about the intrusive memory to bring the image to mind without it becoming emotionally overwhelming; this approach is different from the memory reminder used by Kessler et al [19]). After the memory reminder, the participant was trained in mental rotation, followed by Tetris gameplay for 25 minutes with an emphasis on mental rotation (see Holmes et al [21], chapter 11). The Tetris gameplay was delivered with the videogame Tetris DS in the Nintendo DS, set to *marathon* mode and ghost piece off, on a 10.1-inch screen. Between sessions, the participant was invited to self-administer the intervention using a Tetris app [32] on her smartphone, that is, to repeat the intervention for already targeted intrusions (instructed to play in the same way as in session when the intrusion came to mind involuntarily). Only one intrusion was targeted per session; when the next intrusion was targeted, the participant again (not the therapist) selected the memory to target. At the start of the last intervention session, the participant also completed the secondary outcome measures.

Follow-up

At the 1-month and 3-month follow-ups, the participant recorded the number of intrusions in the diary daily for 1 week and completed secondary outcomes. All data were recorded on a laptop computer using the REDCap (Research Electronic Data Capture) database, an encrypted electronic software, and stored on secure servers [33]. At the 1-month follow-up, the participant was in quarantine because of the COVID-19 pandemic, and thus, all follow-up measures were administered remotely through the REDCap platform; see the *Procedure* section.

Measures

Eligibility Assessments (Part of the SAGA Cohort Substudy)

The CAPS-5 is a 30-item semistructured interview used to assess symptoms of PTSD from physical violence in childhood and symptom severity in the past month, according to the *DSM-5* [1]. Each item is scored on a 5-point Likert scale (0=mild or subthreshold; 4=extreme or incapacitating) with a threshold symptom rating of 2 (ie, moderate) for a possible diagnosis. Frequency and intensity of each symptom were assessed and rated separately. The CAPS-5 has excellent internal consistency (Cronbach α=.88) and test-retest reliability (0.83), along with good convergent validity (0.83 [34]), making it a useful tool for diagnosing PTSD.

The MINI is a structured diagnostic interview that assesses axis 1 psychiatric disorders according to the *DSM-4*. The MINI has been shown to have good sensitivity and specificity for most diagnoses [35]. Interrater and test-retest reliability has been shown to be good, with kappa values in the high to very high range (κ=0.79-1.00 [36]).

Primary Outcome Measure

The intrusive memory diary was adapted from previous studies [22,25]. Each diary included a daily pen-and-paper record of four timeframes per day (morning, afternoon, evening, and night) for 7 days. Instructions on how to use the diary included a definition of intrusive memories of trauma as mental images (in the form of pictures or a film clip in the mind's eye) that are distressing and occur involuntarily. The participant was instructed not to record voluntary thoughts or verbal thoughts about the trauma without sensory content. The participant monitored the occurrence of her intrusive memories in a daily diary for 4 weeks before any intervention sessions, for 8 weeks while intervention sessions were administered, and again for 1 week at the 1-month and 3-month follow-ups. Throughout this, the participant noted which of the four different memories each intrusion was, allowing us to examine changes in each memory individually. The primary outcome was the change in the number of intrusive memories from baseline to the intervention phase and to long-term follow-ups (1- and 3-month follow-ups).

Secondary Outcome Measures

PTSD symptoms were assessed with the PCL-5, a 20-item self-report scale used to assess the severity of PTSD symptoms in the past month from physical violence in childhood, corresponding to the *DSM-5* criteria for PTSD [34]. Each symptom is rated on a 4-point Likert scale (0=not at all; 4=extremely). The PCL-5 has strong internal and test-retest reliability, with good convergent and discriminant validity [37]. The Icelandic translation of the PCL-5 had excellent internal consistency in the SAGA cohort study (α=.95). Assessment of clinical significance is not yet clear for the PCL-5; however, a score of 33 is likely to correspond to a *DSM-5* PTSD diagnosis, and a score of ≤24 posttreatment is likely to represent clinically significant change [38].

Depression symptoms were assessed with the Patient Health Questionnaire-9 (PHQ-9), a nine-item self-report measure of depressive symptoms and their severity in the prior 2 weeks [39]. Each item is rated on a 4-point Likert scale (0=not at all; 3=nearly every day). The PHQ-9 has excellent internal reliability (Cronbach α ranging from .86 to .89) and good test-retest reliability (r=0.84 [39]). The Icelandic version had good internal consistency in the SAGA cohort study (α=.89). A five-point change in the PHQ-9 score is considered clinically significant [40].

Anxiety symptoms were assessed with the Generalized Anxiety Disorder-7 (GAD-7) scale, a brief self-report questionnaire used as a screening tool for GAD symptoms and their severity in the prior 2 weeks [41]. Each item is rated on a 4-point Likert scale (0=not at all; 3=nearly every day). The GAD-7 has excellent internal consistency (Cronbach α=.92) and good test-retest reliability (r=0.83 [41]). The GAD-7 has been reported to be useful in screening for anxiety disorders in general [42]. The Icelandic version had good internal consistency in the SAGA cohort study (α=.90). A four-point change in the total score is considered clinically significant on the GAD-7 [43].

Functional impairment was assessed with the Sheehan Disability Scale (SDS), a self-report measure designed to assess functional impairment in the prior week across three domains: (1) work or school, (2) social, and (3) family life [44]. These domains are measured on an 11-point scale (0=not at all; 10=extremely). The scale was adjusted to assess functional impairment associated with intrusive memories. This scale has been shown to have good psychometric properties [44]. A three-point change in the SDS score has been used as a measure of treatment response [45]. The Icelandic version has good internal consistency in clinical groups (α=.70-.84 [46]).

Self-guided adherence to the use of the gameplay intervention in daily life was assessed with a question regarding how often Tetris was played after experiencing an intrusive memory (11-point scale; 0=not at all; 10=every time).

Feasibility and acceptability rating for using the smartphone gameplay intervention was assessed with two self-rated items: whether the participant would recommend the intervention to a friend and whether she thought gameplay was an acceptable way to reduce intrusive memories. Scores could range from 0 to 10, with higher scores indicating greater acceptability or feasibility. Two open-ended questions were also asked: "How did you feel about playing Tetris after you had an intrusive memory?" and "Did you find the intervention helpful? If yes, how?"

The impact of intrusive memories on concentration, sleep, and stress was assessed with six self-rated items about the past week: two items assessing concentration difficulties in general and because of intrusive memories (11-point scale; high scores indicating more difficulties); one item assessing duration of disruption after experiencing intrusive memories (five response options ranging from <1 minute to >60 minutes); two items assessing sleep disturbances because of intrusive memories (sleep in general and nightmares; 11-point scale; higher scores indicating more sleep disturbance); and one item assessing the degree to which intrusive memories affected stress levels (0=not at all; 10=affected very much).

Ratings of the general impact of intrusive memories were obtained with two items: one assessing distress caused by intrusive memories and the other assessing how vivid they were in the past week, both rated on an 11-point scale (0=not at all; 10=very distressing or vivid).

Intrusion diary adherence was assessed with one item addressing the accuracy of filling out the diary (0=not at all; 10=very accurately).

The impact of intrusive memories on daily functioning was assessed with two items. One question was open-ended: "How have the intrusive memories affected your ability to function in your daily life in the past week?" The other question was self-rated: "Have the intrusive memories affected your ability to function in your daily life?" (11-point scale, a higher score indicating a greater impact on functioning).

Data Analysis

Changes in the Total Number of Intrusive Memories

The primary outcome was change in the number of intrusive memories from baseline to the intervention phase and to long-term follow-ups (1 month and 3 months). We first examined the primary outcome in terms of the *total* number of intrusions (before examining separately for each memory). For this, we summed the number of all intrusions occurring across the 4-week baseline period, then across the 8-week intervention period, and then at each of the 1- and 3-month follow-ups. Given that these periods differed in duration, we calculated the total number of intrusions *per week* to generate a measure that was comparable across periods. Missing data were dealt with by excluding these time points from calculations. For example, the baseline period was 29 days, but data were present for 22.25 days; thus, the total number of intrusions per week was calculated as 40 intrusions/22.25 days × 7=12.6 intrusions per week at baseline.

To examine changes over time, we calculated the percentage reduction in total intrusions per week from baseline to the other periods. For example, as there were 6.1 intrusions per week in the intervention phase, this was calculated as (1−[6.1/12.6]) × 100=52% reduction in the intervention phase compared with baseline.

Change in the Number of Each of the Four Specific Intrusive Memories

Next, we examined the data per intrusive memory. Here, each intrusion acts as its own control, that is, the specific baseline phase for each individual memory is used as a control period to compare its number before and after being targeted by the intervention. There is a different baseline (*A*) and intervention (*B*) phase per memory, depending on which session it was targeted. The percentage reduction in each intrusion after being targeted was calculated as 1−(mean number per week during intervention phase/mean number per week during baseline) × 100. Percentage reductions were then calculated in the same way for the 1- and 3-month follow-ups compared with baseline.

Other Symptoms and Functioning

We also used a descriptive approach to investigate whether there were clinically significant changes over time in the overall symptoms of PTSD, depression, anxiety, and functional impairment.

Ethics Statement

The study was approved by the National Bioethics Committee of Iceland (Number VSNb2017110046/03.01). The participant provided written and informed consent. All sessions followed a written protocol. No adverse events were reported by the participant.

Open Science Statement

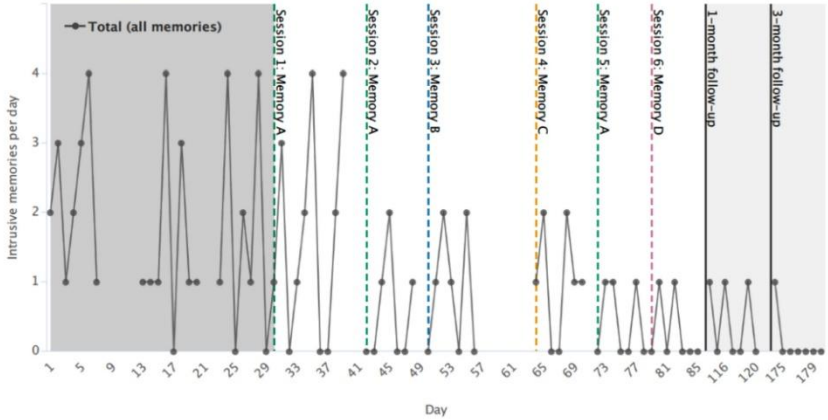
This single case study was not preregistered but precedes and is similar to the design and procedures of a case series (n=5) that we later registered on ClinicalTrials.gov (NCT04209283) on December 4, 2019. All anonymized summary-level data are reported in this manuscript. Study materials may be made available upon reasonable request with an appropriate materials transfer agreement with University of Iceland. It should be noted that the delivery of this intervention requires extensive training and supervision (see the Procedure: Training section).

Results

Overview

The participant had four different intrusive memories that were all predominantly visual and tracked each intrusion over time. All her intrusive memories were from a single traumatic event that took place roughly four decades before participation. All four intrusive memories were targeted with the intervention at different time points during the intervention phase (Figure 2).

Figure 2. Graph for visual inspection of primary outcome data (total number of intrusive memories) on the y-axis as total per day. Days since enrollment is shown on the x axis, which includes baseline (gray), intervention (white), and follow-up periods (light gray). Dashed colored vertical lines show when each intervention session was administered and which specific memory (memories A, B, C, or D) was targeted (eg, session 1; memory A in green). Memories are labeled in the order of when they were targeted (eg, memory A was targeted in the first intervention session). Solid black vertical lines show the 1-month and 3-month follow-ups. Gaps in the time series in the baseline and intervention periods reflect the missing data (for each specific intrusive memory data, see Figure 3).



One memory (memory A) was targeted three times (reported as the most distressing and frequent by the participant), and the other memories were targeted once. The participant readily understood the instructions given and successfully completed the intervention sessions and procedures. Intrusive memory diary data were missing for days 8-12 and 21-22 during the baseline phase and for days 40-41, day 49, days 57-63, and day 71 during the intervention phase; the diary was fully completed at follow-ups. Most missing diary data were because of extra days passing in between sessions, that is, when the participant had completed their current diary (covering a period of only 1 week) but had not received their next diary. No attempt was made to retrieve data for the missing days. In total, the diary was completed successfully for 82% (81/99 days) of the study period.

Primary Outcome

Change in the Total Number of Intrusive Memories

Across the 4-week baseline period, the total number of intrusions was relatively stable and approximately 12.6 per week (summed across all four memories). This number reduced to 6.1 per week across the 8-week intervention phase (52% reduction from baseline), to 3.0 per week at 1-month follow-up (76% reduction), and to 1.0 per week at the 3-month follow-up (92% reduction; Table 1).

Table 1. Number of intrusive memories per week at baseline, intervention, 1-month follow-up, and 3-month follow-up, and relative reduction (in percentage) from baseline for total intrusions and for each memory separately (n=1).

Intrusions	Baseline (A; number per week)	Intervention (B; number per week)	Reduction (%)	1-month follow-up (number per week)	Reduction (%)	3-month follow-up (number per week)	Reduction (%)
Total[a]	12.6	6.10	52	3.0	76	1.0	92
Memory A	3.8	2.0	46	1.0	74	1.0	74
Memory B	3.6	0.5	86	0	100	0	100
Memory C	2.4	1.0	59	1.0	59	0	100
Memory D	1.4	1.0	26	1.0	28	0	100

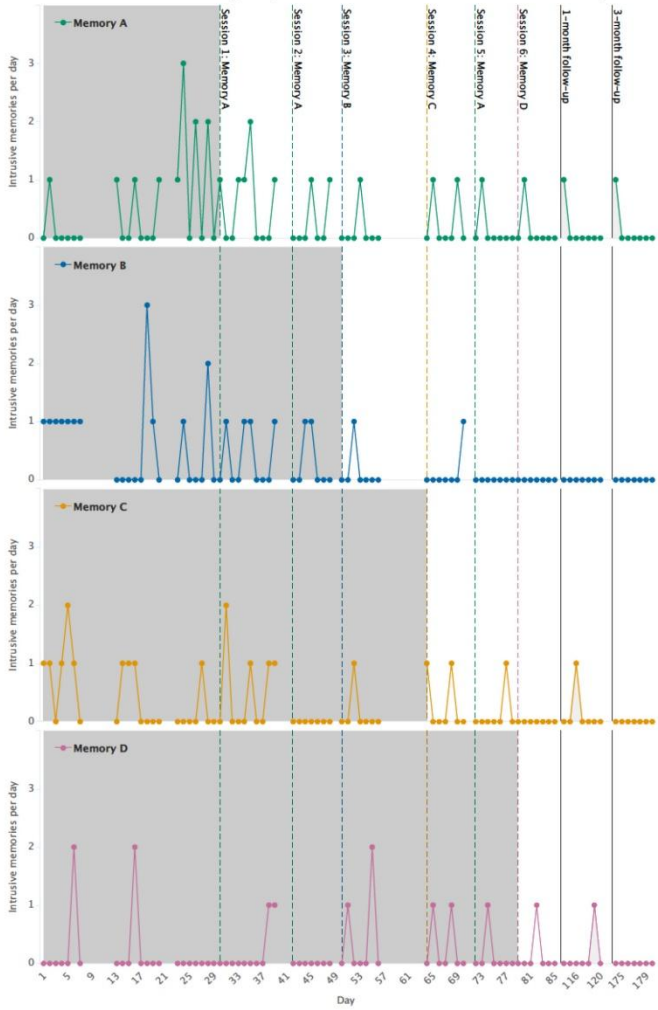
[a]Total intrusions are not equal to the sum of the intrusions for each memory. This is because the length of the baseline and intervention phases differ across memory and the total. See the Data Analysis section for more details on how these numbers were calculated.

Figure 2 displays the total number of intrusive memories per day (summed across all four intrusive memories) throughout all phases. Visual inspection indicated that after the second intervention session, the total number of intrusions reduced. The number of intrusive memories remained relatively stable between sessions 2 (day 43) and 5 (day 73) when a further drop in frequency was evident, maintained at the 1-month follow-up, and then continued to drop further at the 3-month follow-up.

Change in the Number of Each of the Four Specific Intrusive Memories

Figure 3 displays the frequency of each intrusive memory during all phases (baseline, intervention, and 1-month and 3-month follow-ups). All four intrusive memories dropped in number per week after being targeted, that is, reductions of 46%, 86%, 58%, and 26% for memory A, B, C, and D, respectively, from their specific baselines to intervention periods. Three of the four intrusions were eliminated completely at the 3-month follow-up (Table 1).

Figure 3. Graph for visual inspection of the number of intrusive memories (on the y-axis as number per day) for each of the four specific intrusive memories reported by the participant (memories A, B, C, and D). Days since enrollment is shown on the x-axis, which includes baseline (gray), intervention (white), and follow-up periods (light gray). Different baseline and intervention lengths for each memory reflect that this is a repeated AB design. Dashed colored vertical lines show when each intervention session was administered and which specific memory was targeted (eg, session 1: memory A in green). Memories are labeled in the order of when they were targeted (eg, memory A was targeted in the first intervention session). Solid black vertical lines show the 1-month and 3-month follow-ups. Gaps in the time series in the baseline and intervention periods reflect missing data.



Memory A was targeted in intervention sessions 1, 2, and 5 at the participant's request. Visual inspection of Figure 3 shows a drop in frequency in the week after intervention session 1 and a further decrease in the week after session 2. The reduction appears to be stable at the 1-month and 3-month follow-up. However, there appears to be an increase in frequency between days 65 and 73, which resulted in that intrusion being targeted again. In session 5, the participant disclosed that she had come across a person who was present during the traumatic experience (ie, seeing the person triggered that memory).

Memory B was targeted in session 3, and a drop in frequency was evident in the subsequent week, which was maintained throughout the follow-ups. A drop in frequency for memory C was shown in the week after intervention session 1 (memory A targeted), and the frequency reduction remained stable at follow-up. Less changes in frequency were visible for memory D throughout the intervention phase (targeted in intervention session 6), whereas there was a reduction in frequency at the 3-month follow-up.

Secondary Outcomes

Ratings of Adherence and General Impact of Intrusive Memories

Table 2 shows that the participant rated her intrusions in general as becoming less vivid and distressing over the intervention and follow-up phases. Ratings of self-guided adherence to Tetris gameplay between sessions are also shown in Table 2, indicating that it was most used during the intervention period, and self-reported accuracy for completing the intrusive memory diary was high throughout the study period (mean 8.25, SD 0.5).

Table 2. Ratings of adherence to intrusive memory diary and general impact of intrusive memories (n=1).

Item	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	1-month follow-up	3-month follow-up
Diary accuracy[a]	8	9	8	9	8	9	7	8
Intrusions vividness[b]	7	8	6	9	8	6	4	3
Intrusions distress[c]	6	6	4	8	5	4	3	1
Tetris gameplay[d]	N/A[e]	4	10	5	2	4	1	0

[a]How accurately did you fill out the diary? 0=not at all; 10=very accurately.

[b]During the last week, how vivid were your intrusive memories? 0=not at all; 10=very vivid.

[c]During the last week, how distressing were your intrusive memories? 0=not at all; 10=very distressing.

[d]How often did you manage to play Tetris after you experienced an intrusive memory? 0=never; 10=every time.

[e]N/A: not applicable.

Feasibility and Acceptability for Using a Smartphone Gameplay Intervention

The participant rated whether she would recommend the intervention to a friend as 10/10 (meaning she would certainly recommend it). She also rated whether she considered gameplay to be an acceptable way to reduce intrusive memories as 10/10 (very acceptable). When asked how she felt about playing Tetris after she had an intrusive memory, she reported the intervention to be "very good," and when asked if she found the intervention helpful, she said, "Yes, I forgot time and place and the memory went away immediately."

Self-report Measures on PTSD, Depression and Anxiety Symptoms, and General Functioning

Initial high levels of PTSD symptoms (a PCL-5 score of 51) were reduced by over half at postintervention, and the reduction was clearly clinically significant at the 3-month follow-up, with a score of only 6 [38]. Depression symptoms were reduced from moderate levels (PHQ-9; 10-14) at baseline to mild (5-9) postintervention, indicating a clinically significant change [40]. Depression symptoms were further reduced to minimal (0-4) at the 3-month follow-up. At baseline, the participant reported mild levels of anxiety (GAD-7; 5-10) and did not report a clinically significant change in symptoms until the 3-month follow-up, when her symptoms were reduced to little or no anxiety (GAD-7; 0-4) [43]. Functional impairment (as measured by the SDS) improved clinically significantly in the follow-up period [45]. The score was 15 at baseline and reduced to zero at the 3-month follow-up (Table 3).

Table 3. Self-report measures for secondary outcomes (posttraumatic stress disorder, depression and anxiety symptoms, and general functioning) and impact of intrusive memories on concentration, sleep, stress, and daily functioning (n=1).

Item	Baseline interview	Postintervention	1-month follow-up	3-month follow-up
PCL-5[a]	51	35	30	6
PHQ-9[b]	13	7	8	2
GAD-7[c]	9	7	7	2
SDS[d]	15	15	5	0
Concentration[e]	5	3	3	1
General concentration[f]	7	3	5	3
Duration of disruption[g]	4	2	2	1
Sleep[h]	5	3	2	0
Nightmares[i]	4	6	2	0
Stress[j]	5	3	3	1
Daily functioning[k]	5	1	3	0

[a]PCL-5: Posttraumatic Stress Disorder Checklist; scores ranging from 0 to 80.

[b]PHQ-9: Patient Health Questionnaire-9; scores ranging from 0 to 27.

[c]GAD-7: Generalized Anxiety Disorder scale-7; scores ranging from 0 to 21.

[d]SDS: Sheehan Disability Scale; scores ranging from 0 (unimpaired) to 30 (highly impaired).

[e]In the past week, how much did your intrusive memories disrupt your concentration? 0=not at all disruptive; 10=extremely disruptive.

[f]In the past week, how much difficulty did you have concentrating generally? 0=no concentration difficulty at all; 10=extreme concentration difficulty.

[g]When you had an intrusive memory, how long did it disrupt your concentration (in minutes) in the past week? 0 (<1 minutes) to 5 (>60 minutes).

[h]Did your intrusive memories interfere with sleep during the night in the past week? 0=not at all; 0=interfered very much.

[i]Did you experience any nightmares that interfered with your sleep during the night in the past week? 0=did not experience any nightmares; 10=experienced many nightmares.

[j]In the past week, did your intrusive memories affect how stressed you felt? 0=not at all; 10=affected very much.

[k]Have the intrusive memories affected your ability to function in your daily life? 0=not at all; 10=very much affected.

Impact of Intrusive Memories on Concentration, Sleep, Stress, and Daily Functioning

Table 3 shows ratings of the impact of intrusions on concentration, sleep, and stress. Critically, the impact of intrusive memories on *concentration* reduced from 5 at baseline to 1 at the 3-month follow-up, and estimated duration of concentration disruption per intrusion reduced from 4 (30-60 minutes) at baseline to 1 (1-5 minutes) at follow-up. The impact intrusions had on sleep reduced from 5 at baseline to 0 at the 3-month follow-up. The impact intrusions had on stress reduced from 5 at baseline to 1 at the 3-month follow-up. The impact intrusive memories had on the participant´s ability to function in her daily life reduced from 5 at baseline to 1 postintervention and was 0 at the 3-month follow-up.

At baseline, the participant responded to an open question on how her intrusive memories had affected her ability to function in daily life: "I don't sleep very well, and that leads to fatigue which interferes with my daily functioning." In the last intervention session, she said, "It took some energy to try not to think about them, but they bother me very little anymore," and at the 1-month follow-up she reported, "I can´t concentrate when I have an intrusive memory, but the memories don't really bother me anymore even though I have been in quarantine. Usually when I am not busy that has meant more memories." She also said, "I have not needed to play Tetris, but it's nice to know that I can if I have an intrusive memory." At the 3-month follow-up, she responded, "They have not been bothering me in the past weeks. It is a little uncomfortable that they may come, but they bother me very little."

Discussion

Principal Findings

In this single case study, we investigated the effects of a brief visuospatial intervention designed to disrupt memory reconsolidation, thereby reducing the number of intrusive memories of trauma. Different intrusive memories were targeted one by one over six sessions, guided by a clinical psychologist. The intervention stemmed from earlier laboratory studies [18,47] as well as clinical studies [19,25]. The total number of intrusive memories per week (primary outcome) was approximately halved from baseline to the intervention phase, similar to what Kessler et al [19] found in a study involving inpatients with complex PTSD. Of particular interest in this study is that the reduction in the number of intrusions continued to 76% at the 1-month follow-up and to 92% at the 3-month follow-up, meaning that three of the four intrusions were eliminated entirely

at 3 months. This critically extends previous studies by examining the *long-term effects* at 3 months postintervention and, in this case, at least suggests that symptoms may continue to improve in the long term rather than rebound. This is perhaps because of the fact that the intervention is simple to use independently once it has been learned so that the participant can self-administer booster doses if needed.

The specific symptom probe design allowed us to zoom in on the effect of each intervention session on each of the participant's four intrusive memories. All four memories reduced after being targeted, with reductions ranging between 26% and 86% (from baseline to intervention phase). By the 3-month follow-up, only the most distressing intrusive memory (*memory A*) was still present, occurring only once during the past week. This quantitative reduction was mirrored in the participant's qualitative feedback, with her noting that the intrusive memories bothered her *very little* at this time.

Symptoms of PTSD (subthreshold for this participant) were reduced postintervention, and the same pattern was observed for symptoms of both depression and anxiety. This change was similar to the results reported by Kessler et al [19]. Interestingly, symptoms of PTSD, depression, and anxiety continued to decrease along with the number of intrusive memories and were minimal at follow-up.

The intrusive memories affected the participant's general functioning at baseline, for example, it affected her sleep, leading to fatigue, which affected her daily functioning. After the intervention, her functioning improved as the intrusions no longer interfered with her day-to-day life at the 3-month follow-up. Her concentration improved considerably from baseline to postintervention and further at follow-up. The participant, in effect, gained back hours during which her concentration was not disrupted by intrusive memories. Both sleep and stress improved postintervention and continued to improve at follow-up.

Importantly, the participant found the gameplay to be a very acceptable way to reduce the frequency of intrusive memories, similar to the Holmes et al [31] study with refugees. The participant also indicated that the intrusive memory diary was straightforward and not burdensome to complete. Most diary data were successfully recorded, although some days in the baseline and intervention phases were missing, mostly because of extra days passing in between sessions where the participant had not received the next diary provided in sessions.

This intervention approach (currently under development, not evidence based), intended not to treat the whole of PTSD but rather a single symptom, is unlike existing treatment options and potentially removes some common barriers to them. For example, barriers include a sparse number of qualified psychological therapists in Iceland (particularly in rural areas) as well as the high cost of treatment and high dropout rates, stigma, and patients' reluctance to talk about the traumatic experience [10-12].

This intervention removes patients' need to talk about and describe the trauma in detail, is low cost, and because of its simplicity, it may be delivered by nonexperts after training. It is important to explore further how this intervention approach can address other common barriers in existing treatments. Future research should explore remote delivery of the intervention (eg, communication via web-based platforms) instead of in-person meetings [48]. This would remove geographical constraints and make it possible to reach people even when immobilized or isolated (eg, in quarantine because of the COVID-19 pandemic), which is increasingly important in today's uncertain circumstances [49].

Conclusions

Overall, the results of this single case study indicate that the intervention is promising, showing initial signs of effectiveness in reducing the frequency of intrusive memories of trauma that had occurred 4 decades ago and improving mental health and functioning in an Icelandic setting at least for the first participant. The intervention was well tolerated and acceptable, and the effects of the intervention may even continue after the intervention phase. The next step will be to examine whether such effects extend to other participants (eg, in a case series) and to explore remote delivery of the intervention, to explore whether it is possible to deliver by *non*clinicians, and to further tailor the intervention to this setting based on feedback from target users.

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Conflicts of Interest

EAH reports serving on the board of the charity MQ: Transforming Mental Health (UK). She also receives book royalties from Oxford University Press (Imagery and Cognitive Therapy) and Guilford Press (Imagery-Based Cognitive Therapy for Bipolar Disorder and Mood Instability) and occasional fees from clinical workshops and conference keynotes.

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Abbreviations

CAPS: Clinician Administered PTSD Scale
CONSORT: Consolidated Standards of Reporting Trials
***DSM*:** *Diagnostic and Statistical Manual of Mental Disorders*
GAD-7: Generalized Anxiety Disorder–7
MINI: Mini International Neuropsychiatric Interview
PCL-5: Posttraumatic Stress Disorder Checklist-5
PHQ-9: Patient Health Questionnaire-9
PTSD: posttraumatic stress disorder
REDCap: Research Electronic Data Capture
SAGA: stress and gene analysis
SDS: Sheehan Disability Scale

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Paper II

Original Paper

Using a Brief Mental Imagery Competing Task to Reduce the Number of Intrusive Memories: Exploratory Case Series With Trauma-Exposed Women

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Abstract

Background: Novel interventions should be developed for people who have undergone psychological trauma. In a previous case study, we found that the number of intrusive memories of trauma could be reduced with a novel intervention. The intervention included a brief memory reminder, a visuospatial task and mental rotation, and targeted trauma memory hotspots one at a time in separate sessions.

Objective: This case series (N=3) extended the first case study with 3 new cases to determine whether a similar pattern of beneficial results is observed. We explored whether the brief intervention would result in reduced numbers of intrusive memories and whether it would impact symptoms of posttraumatic stress, depression and anxiety, and general functioning. Acceptability of the intervention was also explored.

Methods: A total of 3 women completed the study: 2 with posttraumatic stress disorder and other comorbidities and 1 with subthreshold posttraumatic stress disorder. The primary outcome was the change in the number of intrusive memories from the baseline phase to the intervention phase and at the 1-month follow-up, with an assessment of the intrusion frequency at 3 months. Participants monitored the number of intrusive memories in a daily diary for 1 week at baseline, for maximum of 6 weeks during the intervention phase and for 1 week at the 1-month and 3-month follow-ups. The intervention was delivered in person or digitally, with guidance from a clinical psychologist. A repeated AB design was used (*A* was a preintervention baseline phase and *B* intervention phase). Intrusions were targeted individually, creating repetitions of an AB design.

Results: The total number of intrusive memories was reduced from the baseline to the intervention phase for all participants. The total number for participant 3 (P3) reduced from 38.8 per week during the baseline phase to 18.0 per week in the intervention phase. It was 13 at the 3-month follow-up. The total number for P4 reduced from 10.8 per week at baseline to 4.7 per week in the intervention phase. It was 0 at the 3-month follow-up. The total number for P5 was reduced from 33.7 at baseline to 20.7 per week in the intervention phase. It was 8 at the 3-month follow-up. All participants reported reduction in posttraumatic stress

symptoms in the postintervention phase. Depression and anxiety symptoms reduced in 2 of the 3 participants in the postintervention phase. Acceptability was favorable.

Conclusions: We observed good compliance with the intervention and intrusive memory diary in all 3 cases. The number of intrusive memories was reduced for all participants during the intervention phase and at the 1-month follow-up, with some improvement in other symptoms and functioning. Further research should explore the remote delivery of the intervention and whether nonspecialists can deliver the intervention effectively.

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KEYWORDS

trauma; intrusive memories; visuospatial task; Tetris gameplay; mental imagery; imagery competing task; case series; mobile phone; posttraumatic stress

Introduction

Background

Most people experience psychological trauma (eg, accidents or interpersonal violence) in their lives [1,2], and many (up to 37%) develop posttraumatic stress disorder (PTSD) after such experiences [3]. Intrusive memories are the core clinical symptoms of PTSD and are within the intrusion symptoms criterion of PTSD in the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) [1,4]. Intrusive memories are persistent, unwanted upsetting memories of the traumatic event [1]. In their most extreme form, they can include reliving the traumatic event as if it were happening again (flashbacks). Other intrusion symptoms include dreams or nightmares about the traumatic event and emotional distress or physical reactivity after exposure to reminders of the traumatic event. Other symptom criteria include avoidance of memories or reminders of the trauma, along with negative alterations in cognition and mood [1]. Posttraumatic stress symptoms, even when subthreshold for a diagnosis of PTSD, can be associated with substantial distress, functional impairment, and comorbidity [5].

As noted previously [6], although evidence-based treatments for PTSD exist [7,8], the existing treatment options have some limitations. For example, current treatments require trauma survivors to talk in detail about the traumatic experience, which can be distressing, and many are reluctant to discuss their trauma in depth [9]. Dropout rates during PTSD treatment are high, up to 48% in clinical trials and approximately 18% overall and may be higher outside research trial settings in clinical practice [10-12]. Finally, existing options are time consuming, typically requiring numerous sessions, and there is often a lack of treatment providers specializing in empirically validated treatment of PTSD. Similar to numerous other countries, Iceland has mental health services that lack the capacity to offer treatments when needed by trauma survivors at the scale needed. These limitations to current treatments make the search for additional scalable treatment alternatives imperative.

A novel brief and simple intervention to reduce the number of intrusive memories after trauma has been developed based on cognitive science, as described elsewhere [13,14]. This intervention takes a single-symptom approach (not an entire disorder). The intervention includes a *brief memory reminder* cue for one *specific* intrusive memory of trauma, followed by a 25-minute Tetris gameplay with mental rotation (ie, actively rotating the blocks in one's mind eye to best make lines; [15]). The intervention was initially examined based on recent memories of trauma [16-18]. It has been further explored for *older memories* of trauma using case studies and case series approaches [6,19-21]. These studies involved in-person delivery, that is, face-to-face sessions guided by a clinical psychologist or researcher.

We adapted the intervention for women in Iceland who experienced intrusive memories of trauma, as reported in a recent case study [6]. Some of the details of this case are now summarized for context and comparison with the 3 new cases presented here. As previously reported, the participant was a woman in her fifties with 4 distinct intrusive memories from a traumatic event that happened in childhood, that is, the intrusive memories were decades old. Each specific memory was targeted in a session (in person) with a clinical psychologist with expertise in trauma. The memory reminder used was to *briefly* bring the visual content of the memory to mind without becoming emotionally overwhelmed by a method agreed with the participant (here, for example, choosing 1 of her 4 specific memories to be targeted using the diary, then thinking about the memory for a few seconds only, and letting the psychologist know when the memory was in their mind). Next, the participant was taught to use mental rotation. She then played Tetris for 25 minutes using mental rotation. She monitored her specific intrusive memories in a daily diary so that the impact of the intervention on a distinct intrusive memory could be easily observed. The total number of intrusive memories decreased from 12.6 per week at baseline to 6.1 per week in the postintervention phase. Furthermore, the number of intrusive memories continued to reduce to only 1 memory per week at the 3-month follow-up. Symptoms of posttraumatic stress and depression and anxiety reduced in the postintervention phase, whereas functioning improved. The participants considered the intervention to be an acceptable way to reduce the number of intrusive memories. The next step in exploring the effects of the intervention involves examining if they extend to other cases of women after trauma and whether remote (rather than in person) delivery is a feasible delivery method given restrictions occurring during the COVID-19 pandemic (eg, isolation) [22].

Objectives

In this case series, we aimed to extend our previous case study to a short case series of trauma-exposed women in Iceland, drawn from an epidemiological study of trauma experienced

by women in Iceland. The intervention sessions took place either in person in a university setting or remotely using a web-based platform. We examined whether the novel intervention approach could reduce the number of intrusive memories of trauma (primary outcome) and whether reductions were maintained at follow-up (1 and 3 months). As before, the brief intervention was guided by a clinical psychologist, targeting one distinct intrusive memory at a time per session. The acceptability of the intervention was also explored along with adaptions in intervention delivery. Again, we explored whether having fewer intrusive traumatic memories would also be associated with improvements in general functioning, posttraumatic stress, and depression and anxiety symptoms (secondary outcomes). The design adopted here can be described as a within-subject *repeated* AB design in which each specific memory is targeted in separate sessions, so that we can consider the effects of an individual intervention session on each specific memory over time [6,20].

As in our previous study [6], we predicted that participants would report fewer intrusive memories (primary outcome) during the intervention phase than in the preceding baseline phase and that the reduction in the number of intrusions would be maintained at the 1-month follow-up in the diary. In addition, we explored a 3-month follow-up using a diary. We expected that the number of targeted intrusive memories would decrease relative to that of nontargeted memories. We also examined whether having fewer intrusive memories would be associated with reductions in symptoms of posttraumatic stress and depression and anxiety and associated with improvements in general functioning (secondary outcomes). Furthermore, we explored the feasibility and acceptability of the intervention, alongside adaptions in intervention delivery format, that is, remote (web-based) delivery.

Methods

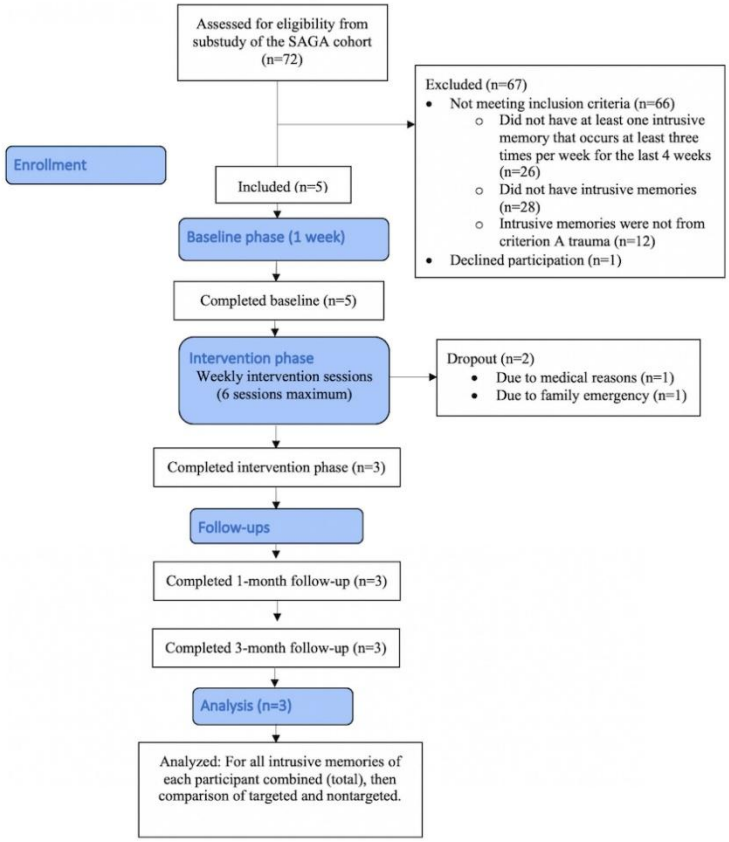
Participants

Participants were drawn from an epidemiological study of trauma experienced by women in Iceland (as in our previous case study [6]). As described previously [6], women who participated in a substudy of the Stress-And-Gene-Analysis (SAGA) cohort study were screened for eligibility. The SAGA cohort study was a population-based longitudinal cohort study of women in Iceland who completed an extensive questionnaire on trauma history and mental health (baseline data collection was completed on July 1, 2019). The Social Trauma Project substudy compared 2 samples from the SAGA cohort study, with a probable diagnosis of PTSD (ie, Posttraumatic Stress Disorder Checklist-5 [PCL-5] score of ≥33; see *Measures* section) or not likely PTSD (ie, PCL-5 score in the lowest fifth), using clinical interviews. In all, 2 semistructured interviews were administered in the substudy (ie, the Mini International Neuropsychiatric Interview [MINI], which was also used to assess the exclusion criteria for this study, and the Clinician-Administered PTSD Scale for DSM-5 (CAPS-5; see *Measures* section).

Women who took part in the Social Trauma Project substudy (both likely PTSD group and not likely PTSD group) were screened for the presence of intrusive memories of trauma, as in our previous case study [6]. As before, screening included a short description of intrusive memories (memories that include sensory impressions such as sight, sound, and so on; often pictures or a film clip that pops into the mind's eye; are distressing and occur involuntarily). Next, they were asked questions regarding the presence of this symptom to assess their eligibility for participation in this study ("Do you have intrusive memories of trauma? If yes, how often in the past week have you experienced such memories?" and "How often have you experienced intrusive memories a week in the past four weeks?").

In this study, 72 women from the substudy, who provided their consent to be contacted for further research were assessed for inclusion in this study (Figure 1).

Figure 1. Adapted CONSORT (Consolidated Standards of Reporting Trials) flow diagram for the study. SAGA: Stress-And-Gene-Analysis.



Inclusion criteria were (1) having experienced criterion A trauma as defined by DSM-5 [1] (using criterion A on CAPS-5), (2) having at least one intrusive memory that occurs at least three times per week for the last 4 weeks (How many intrusive memories have you experienced in the last 4 weeks on average?), (3) being able and willing to attend 3 to 8 sessions with the researcher, (4) being able and willing to monitor intrusive memories in daily life, (5) having access to a smartphone, and (f) being able to speak and read study materials in Icelandic. The exclusion criteria were (1) current psychotic disorder (assessed with the MINI), (b) current manic episode (assessed with MINI), and (c) being acutely suicidal (assessed with the MINI).

In all, 5 women who met the inclusion criteria were included, ranging in age from 39 to 66 years (mean 49, SD 11 years). Participants are referred to as P1, P2, P3, P4, and P5. The initial 2 participants recruited did not complete the intervention sessions due to nonsuitability of the study timing in their lives (medical and family issues). Both P1 and P2 were excluded from the data analyses, although data from the baseline were collected. After P1 and P2 wished to cease their participation, a question was added to the recruitment process asking if the participants foresaw any obstacles to their participation in the study. P1 did not meet any diagnostic criteria for psychological disorders according to the MINI. P2 met the diagnostic criteria for bipolar disorder and reported subthreshold PTSD symptoms.

A total of 3 patients completed the study, 2 (67%) with PTSD and other comorbidities and 1 (33%) with subthreshold PTSD. P3, woman aged ≥40 years, met the criteria for major depressive disorder and PTSD. P4, a woman aged ≥60 years, did not meet any diagnostic criteria but reported subthreshold PTSD according to the CAPS-5. P5, a woman aged ≥50 years, met the diagnostic criteria for major depressive disorder, social anxiety disorder, and PTSD. P3 reported having 10 different intrusive memories of physical violence that occurred in childhood. P4 reported having 3 different intrusive memories from childhood sexual abuse, and P5 reported 6 different intrusive memories from childhood sexual abuse.

Design

The case series used a single-symptom approach, in which each intrusive memory was targeted in different sessions, that is, one at a time [6,19]. Specifically, participants distinguished the content of their different intrusive memories and described them briefly; for example, for a participant who had four distinct intrusions, they may label them as (1) broken glass, (2) man's face, (3) blood on door, and (4) red car (the examples used are fictitious to preserve anonymity). Participants then monitored the occurrence of each distinct intrusion over time.

Thus, the design for each participant was a *repeated AB design* whereby the length of baseline (*A*, before intervention, monitoring only) and intervention (*B*) phases varied for each distinct intrusion, according to which intervention session the intrusive memory was targeted in. Thus, the baseline phases for each distinct intrusive memory were used as control periods in the comparison with the intervention, that is, the number before and number after being targeted.

A daily diary was used to monitor the number of each intrusive memory over time. That is, for 1 week before intervention, then over 6 weeks (maximum) of intervention; then for 1 week at the 1- and 3-month follow-ups. Intrusive memories were targeted individually in up to 6 intervention sessions. These sessions were guided by a clinical psychologist, who was a specialist in trauma-focused cognitive behavior therapy. After the first session, participants were able to self-administer the intervention if they wished for memories that they had already targeted in the session. P3 received 2 repetitions of an AB design, P4 only targeted 1 memory (and thus no repetitions of an AB design), and P5 received 4 repetitions of an AB design.

The primary outcome was the change in the number of intrusive memories per week from baseline to the intervention phase and to the long-term follow-ups (1 and 3 months). Participants further completed secondary outcomes—self-report measures for posttraumatic stress, depression and anxiety symptoms, and functional impairment—at baseline, the last intervention session, and 1- and 3-month follow-ups.

Procedure

Training

Researchers delivering the intervention (KT and JH; both licensed clinical psychologists trained in trauma-focused cognitive behavior therapy) underwent training and received clinical supervision, promoting adequate intervention delivery and protocol adherence. Training involved 2 in vivo workshops for 3 days and then again approximately 6 months later for 2 days, delivered by psychologists with expertise in developing the intervention and delivering it in other settings (MK and EAH). The theoretical background and practical aspects of the intervention (eg, how to explain and use the primary outcome measure) were covered in the workshops, as well as role-playing with trainers and feedback until sufficient performance was reached. While data collection was ongoing, the researchers received supervision. Such supervision included weekly supervision meetings, as well as more *in real time* support from a clinical supervisor via telephone directly after participant sessions regarding any case specific adaptions needed (EAH, MK, and AB). Twice a month, the researchers joined remote (Zoom; Zoom Video Communications) peer-group training meetings with other international researchers about the intervention (convened by EAH and LS).

Baseline Session

A similar procedure was followed as in our previous case study [6]; in the baseline session, the researcher explained the nature of intrusive memories (ie, memories that include sensory impressions such as sight, sound, and so on; are predominantly similar to pictures or a film clip in the mind's eye; and are distressing and occur involuntarily). Participants identified their intrusive memories by giving a brief verbal account of the intrusion's visual content using only a few words. Researchers noted down the image's description on a *hotspots* sheet in a way that the participant could also see it. Participants then labeled each intrusive memory with a symbol (the first memory was labeled *A*, the second memory *B*, etc) and were instructed on how to monitor their frequency each day in a pen-and-paper diary (primary outcome measure). To indicate when a certain memory was experienced, the participants recorded the symbol corresponding to a given memory for each time frame of that day. Each diary was divided into 7 days and each day, into 4 periods (see *Measures* section). The participants also completed baseline questionnaires (secondary outcomes) in the baseline session.

Intervention Sessions

In each intervention session (maximum 6 sessions), the participant chose 1 intrusive memory to target (by looking through their diary entries) and completed the intervention procedure (guided by the researcher). The memory chosen could be the most distressing or frequent or one chosen to be targeted by the participant for other reasons. As in our previous case study [6], the intervention consisted of a brief memory reminder, that is, briefly thinking about the intrusive memory to bring the image to mind without it becoming emotionally overwhelming. Please note that the approach to bringing the memory to mind here differs procedurally from the memory reminder method in the studies by Kessler et al [19] or Kanstrup et al [20]. Participants were told, "To make the game as useful as possible, we first had to make sure the memory was in your mind before using the intervention. So, I want to ask you what do you think would be the best way for you to bring this memory to mind without it becoming emotionally overwhelming?" They then discussed with the researcher options for the best way for them to bring the memory into mind without it emotionally becoming overwhelming. To do this, they were given examples of writing it down briefly and not discussing it with the psychologist, thinking about it briefly again and not talking about it in detail, or finding another method. Here, all participants chose to bring to mind the memory they had chosen to target by briefly thinking about it for a few seconds with their eyes open and telling the psychologist when it had come fully to mind (without talking about it in detail). The psychologist confirmed that the participants were able to picture their memory (ie, see it in their mind's eye) before moving to the instructions about the gameplay.

After the memory reminder procedure, participants were trained on how to use the Tetris game and practiced using mental rotation. They then played Tetris using mental rotation for 25 minutes [15]. For in-person meetings, the Tetris gameplay was delivered with a Nintendo DS 10.1-inch screen, set to *Marathon* mode with the ghost piece off. When an intervention session took place remotely with a video call, Tetris gameplay was performed on the participants' own computer with a shared screen so that the researcher could monitor the gameplay, especially regarding mental rotation. Only one distinct intrusion was targeted for each session. To select which intrusion was targeted, the participant (not the researchers) selected which intrusive memory it was. At the end of the last intervention session, secondary outcome measures were completed again.

Participants were invited to self-administer the intervention for memories already targeted in a session using a mobile version of the Tetris created by Electronic Arts [23]. For example, when the intrusion came to mind involuntarily in daily life, they were told to use a similar procedure as they had learned with the researcher in session.

When the COVID-19 pandemic started (the University of Iceland closed on March 19, 2020), researchers switched to remote (rather than in person) delivery through Kara Connect, which is a General Data Protection Regulation–compliant web-based platform certified by the Icelandic Directorate of Health. The last intervention session for P3 was performed remotely, intervention sessions 2 and onward were performed remotely for P4, and all sessions were remotely delivered for P5. Tetris was played on the web on the participants' computers (ghost piece off and sound set to 0%) with a shared screen so that the researcher could monitor participants' gameplay via Kara Connect, which increased the likelihood of instruction adherence, especially regarding the use of mental rotation.

Follow-up

At both the 1- and 3-month follow-up time points, participants recorded the number of intrusions in their diary daily again for 1 week and completed the secondary outcome measures. Data were entered via laptop into a REDCap (Research Electronic Data Capture; Vanderbilt University) database (REDCap), an encrypted electronic software stored on a secure server [24].

Measures

Eligibility Assessments (Part of the SAGA Cohort Substudy)

Please note that the measures described here have already been described in our previous case study [6] and are repeated here for clarity.

The Clinician-Administered PTSD Scale (CAPS-5) is a 30-item semistructured interview used to assess symptoms of PTSD from an index of trauma and symptom severity (in the past month) according to DSM-5 [1]. Items are scored on a 5-point Likert scale (0=mild or subthreshold; 4=extreme or incapacitating). A symptom rating of 2 (ie, moderate) was the threshold for a possible diagnosis. For each symptom, frequency and intensity were assessed and rated separately. The CAPS-5 has excellent internal consistency (Cronbach α=.88), test-retest reliability (α=.83), and good convergent validity (α=.83) [25]

The MINI for the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, assesses Axis I psychiatric disorders according to the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, using a structured diagnostic interview. For most diagnoses, the MINI has good sensitivity and specificity [25]. Interrater and test-retest reliability is good, with κs in the high to very high range (κs=0.79-1.00) [26].

Primary Outcome Measure

The intrusive memory diary, a pen-and-paper diary similar to that used in Thorarinsdottir et al [6], was adapted from previous experimental and clinical studies [16,20]. It involves daily recording, for 4 time points each day (morning, afternoon, evening, and night) for 1 week. The diary instructions defined the nature of intrusive memories as distressing and involuntary mental images (such as visual images or a film in the mind's eye). Participants were asked not to record voluntary (ie, deliberately recalled) thoughts or involuntary verbal thoughts without sensory content (intrusive verbal thoughts that had an imagery component could be included). Participants monitored the occurrence (or nonoccurrence) of their intrusive memories in the daily diary for 1 week before the intervention (baseline phase), for a maximum of 6 weeks during the intervention phase and then again for 1 week at both the 1- and 3-month follow-ups (note this was a daily diary, see retrospective amendment to clinical trial registration [CTR] NCT04209283). When indicating having an intrusion, participants used the symbol corresponding to that specific memory (eg, A or B as noted earlier), and therefore, it was possible to examine change in frequency (here calculated as the number per week) for each distinct memory individually.

The primary outcome was the change in the number of intrusive memories from the baseline to the intervention phase and at the 1-month follow-up. The original CTR additionally prespecified a measure of intrusive memories at the 3-month follow-up ("Change in the number of intrusive memories of trauma from baseline to 3 month follow-up") but incorrectly stated that the measure was "Questions about the frequency of intrusive memories for the past day or week (for each intrusive memory, to be tallied to arrive at a mean frequency for the memories for the previous day and for the week)," specifically "How often did this memory come up yesterday?" and "How often did this memory come up per day in the past week?" However, this was incorrect, as we had changed this measure at the study start to use the same diary as for the earlier time points (ie, daily diary), that is the "Number of intrusive memories of traumatic event recorded by participants in a diary daily (morning, afternoon, evening, night) per week over the baseline phase and during one week at three month follow-up." The measure has been updated retrospectively in the CTR for this 3-month period and should be interpreted with caution.

Secondary Outcome Measures

PTSD symptoms in the past month were evaluated using the PCL-5, a self-report scale with 20 items. Each symptom is rated on a 5-point Likert scale (0=not at all; 4=extremely), with higher

scores indicating greater severity. The PCL-5 evaluates the severity of PTSD symptoms according to DSM-5 criteria. It has strong internal and test-retest reliability and good convergent and discriminant validity [27]. Criteria for clinical significance are not available for the PCL-5; however, posttreatment scores of ≤24 can be interpreted as clinically significant change [28]. The Icelandic version of this measure in the SAGA cohort study had excellent internal consistency (α=.95).

Depression symptoms in the past 2 weeks were evaluated using the Patient Health Questionnaire-9 (PHQ-9), a self-report measure with 9 items rated on a 4-point Likert scale (0=not at all; 3=nearly every day) [29]. The PHQ-9 evaluates depression symptoms and their severity and has good internal reliability and test-retest reliability [29]. The Icelandic version of the SAGA cohort study had good internal consistency (α=.89). A 5-point change in the total PHQ-9 score was considered clinically significant [30].

Anxiety symptoms in the past 2 weeks were evaluated using the Generalized Anxiety Disorder-7 scale (GAD-7). In this self-report questionnaire, each item is rated on a 4-point Likert scale (0=not at all; 3=nearly every day). The GAD-7 assesses symptoms of general anxiety disorder and its severity and has great internal reliability and good test-retest reliability [31]. In general, the GAD-7 has presumably been useful for screening anxiety disorders [32]. The Icelandic version of the SAGA cohort study had good internal consistency (α=.90). A 4-point change on the GAD-7 is considered clinically significant [33].

Functional impairment in the previous week was evaluated using the Sheehan Disability Scale (SDS). This self-report measure has three domains: (1) work or school, (2) social, and (3) family life, assessing functional impairment using a 11-point scale (0=not at all; 10=extremely) [34]. A 3-point change on the SDS scale has been considered indicative of response to treatment [35]. To assess the impairment associated with intrusive memories, scale adjustments were made. The SDS has been found to have good internal and test-retest reliability and good construct validity [34]. The Icelandic version of the SDS has been found to have good internal consistency in clinical groups (α=.84) [36].

Self-guided adherence for daily life using the gameplay part of the intervention was rated "How often did you manage to play Tetris after you experienced an intrusive memory?" (11-point scale: 0=not at all; 10=every time).

Feasibility and acceptability ratings for the intervention were assessed with 2 ratings "Would you recommend playing Tetris to a friend?" and "Do you consider gameplay to be an acceptable way to reduce the daily frequency of intrusive memories?" The scores ranged from 0 to 10. Higher scores indicated greater acceptability. Open-ended questions included (1) "How did you feel about playing Tetris after you had an intrusive memory?" and (2) "Did you find the intervention helpful? If yes, how?"

The impact of intrusive memories on concentration, sleep, and stress in the past week was evaluated using 6 self-rated items: a total of 2 items assessed general concentration difficulties and difficulties in concentration due to intrusive memories (11-point scales; higher scores indicated greater difficulties), 1 item assessed concentration disruption in minutes in the past week, and 2 items assessed the impact of intrusive memories on sleep (11-point scale; higher scores indicated greater sleep disturbance). An item assessed the impact of intrusive memories on stress levels (0=not at all; 10=affected very much).

General impact of intrusive memories was assessed using 2 ratings of intensity and vividness of the intrusions on a 11-point scale (0=not at all; 10=very distressing or vivid).

Intrusion diary adherence item was assessed using the rating "How accurately did you fill out the diary?" (0=not at all; 10=very accurate).

Impact of intrusive memories on daily functioning was evaluated via an open-ended question: "How have the intrusive memories affected your ability to function in your daily life in the past week?" and a self-rated question, "Have the intrusive memories affected your ability to function in your daily life?" (11-point scale, a higher score indicated greater impact).

Data Analysis

Number of Intrusive Memories

The number of intrusive memories of trauma was recorded by participants in the diary daily (morning, afternoon, evening, and night) during the baseline phase and each week during the intervention phase (weeks 1-6) and during 1 week at the 1-month follow-up. The primary outcome was the change in the number of intrusive memories of the trauma. The timeframe was baseline week to the intervention phase (weeks 1-6) and follow-up (1 month). In practice, owing to scheduling reasons, the baseline phase was longer than 1 week, and as anticipated, the number of intervention weeks varied. Therefore, because these periods had different time lengths, the mean number *per week* was calculated for comparability. Missing data were dealt with by excluding these time points from the calculations and using available data (see *Results* section). For example, a participant had a baseline period of 14 days, but data were present for only 6.5 days; thus, the total number of intrusions per week was calculated as 10 intrusions / 6.5 days × 7 = 10.8 intrusive memories per week during baseline.

When examining change over time, the percentage reduction in total intrusions per week was calculated from the baseline phase to the intervention phase to other periods as follows: 1– (mean number per week during intervention phase / mean number per week during baseline) × 100. For example, for the same participant there were 4.7 intrusions per week in the intervention phase, which was calculated as 1 – (4.7 / 10.8) ×100 = 57% reduction in the intervention phase compared with the baseline.

Please note that at the 3 month-follow-up, we did not use the telephone questions on the CTR (NCT04209283) about the frequency of intrusive memories for the past day or week (eg, "How often did this memory come up per day in the past week?") but instead replaced this with the same 1 week diary used at earlier time points. We noted the use of a diary at 3 months in our ethics submission, but we incorrectly specified it in our CTR and did not update the CTR on this point until the submission of this paper.

Change in the Number of Targeted Intrusive Memories Relative to Nontargeted Memories

We examined the number per week of targeted memories in comparison with nontargeted memories. This was done by calculating the number in the same way as described above for targeted memories (ie, each of targeted memories have different baseline and intervention periods). However, standard baseline and intervention periods were established for nontargeted memories (ie, same length of periods for all nontargeted memories), as they were not targeted by the intervention. The baseline for each nontargeted memory was 1 week (ie, before any memory was targeted), and the intervention phase was determined as the period from when any memory was targeted with the intervention.

Other Symptoms and Functioning

A descriptive approach was used to explore whether clinically meaningful changes were observed in the overall symptoms of posttraumatic stress, depression, anxiety, and functional impairment.

Ethics Approval

This study was approved by the National Bioethics Committee of Iceland (VSNb2017110046/03.01). The participants provided written informed consent before the start of the study. All the sessions followed a written protocol. No adverse events related to the intervention were reported. Participants were asked to briefly consider the visual content of the traumatic memories they selected, which might have resulted in some distress. Previous research has indicated that this intervention approach is well tolerated, including in inpatients with complex PTSD [19]. However, given the early stage of this research, an arrangement was made with an independent clinical psychologist who specializes in trauma for an interview free of charge to the participant and to be referred to a licensed clinical psychologist for treatment if needed. None of the participants had used these services.

Open Science Statement

The study was registered before the start of the study on ClinicalTrials.gov (NCT04209283) on December 24, 2019. The manuscript contains anonymized summary-level data. The study materials may be made available upon reasonable request with an appropriate material transfer agreement with the University of Iceland or Uppsala. We note that delivery of this intervention at present requires prerequisite training and supervision by psychologists with experience of developing it (see *Procedure*, *Training* section).

Results

Overview

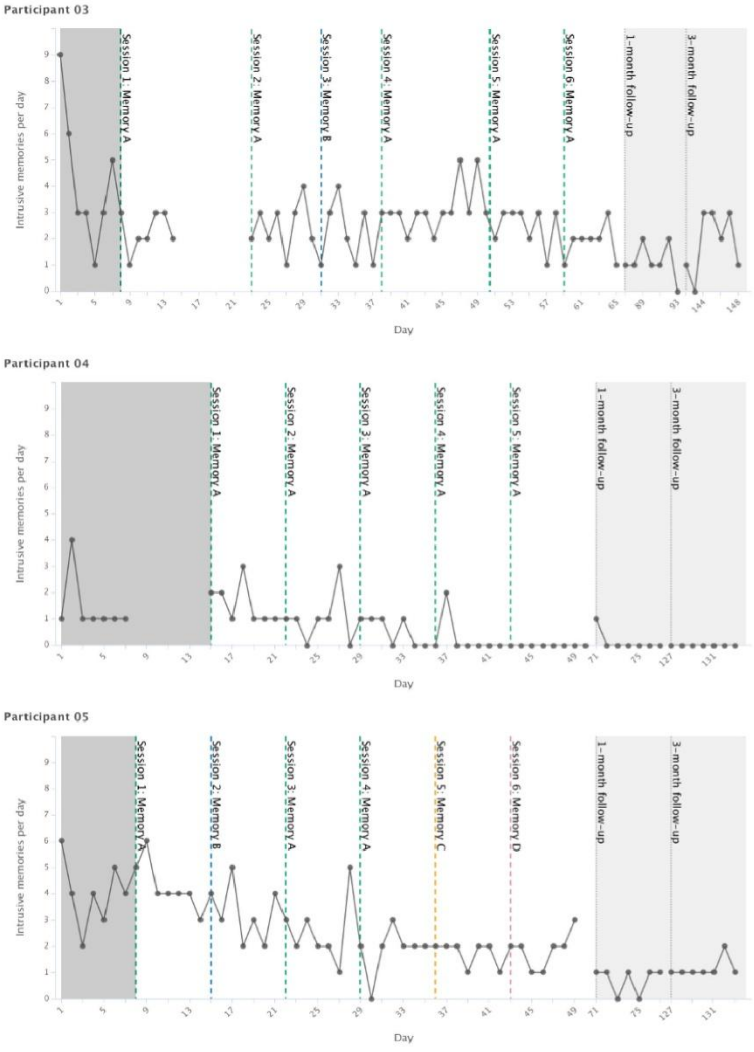
The number of intrusive memories and how many were targeted varied among participants. P3 reported having 10 different intrusive memories of physical violence during childhood. In all, 2 of the intrusions were targeted with the intervention; one of the memories (Memory A) was targeted 5 times and the other (Memory B) was targeted once. P3 monitored the memories quite accurately, but data were missing for days 15 to 22 during the intervention phase. P4 reported having 3 intrusive memories of childhood sexual abuse, of which only 1 (Memory A) was targeted with the intervention 5 times. P4 monitored the memories accurately, and data were missing for half of day 1 and for days 8 to 15 during the baseline phase. P5 reported having 6 intrusive memories of childhood sexual abuse, 4 of which were targeted. One of the memories (Memory A) was targeted 3 times, whereas the others (Memories B, C, and D) were targeted once. P5 accurately monitored their memories with no missing data. No attempts were made to retrieve the missing data. On average, 90% of the diary data were completed for all 3 participants. No data were missing for the secondary outcome measures.

Primary Outcome

Change in the Total Number of Intrusive Memories

The total number of intrusive memories per day throughout all phases for each participant (baseline, intervention, and 1 month) is shown in Figure 2. In addition, as it is on the same measure, the diary used at 3 months is also shown in Figure 2. Diary compliance was good for the outcome phases, with most missing data in the baseline phase. The number of intrusive memories per day fluctuated during the baseline phase for all the participants (N=3). P3 had 38.8 intrusive memories (summed across all 10 distinct intrusive memories) per week during the baseline phase. The number was reduced to 18.0 per week (54% reduction from baseline) during the intervention phase and further reduced to 8 at the 1-month follow-up week (80% reduction from baseline). P4 had 10.8 intrusions (summed across all 3 memories) per week during the baseline phase, and the number reduced to 4.7 per week (57% reduction from baseline) during the intervention phase and was further reduced to 1 (91% reduction from baseline) at the 1-month follow-up week (Figure 2). P5 had 33.7 intrusive memories (summed across all 6 distinct intrusive memories) per week during the baseline phase, which reduced to 20.7 per week (39% reduction from baseline) during the intervention phase. The number further reduced at the 1-month follow-up to 5 that week (85% reduction from baseline).

Figure 2. Graphs for visual inspection of primary outcome data for each participant (on the y-axis as total number of intrusive memories per day, ie, for all distinct memories combined). Days since study start are shown on the x-axis, which includes baseline (gray), intervention (white), and follow-up periods (light gray). Dashed vertical lines show when each intervention session was administered and which specific traumatic memory was targeted. Memories are labeled in order of when they were targeted (eg, Memory A was targeted in the first intervention session). Dotted vertical lines show the 1-month and 3-month follow-up periods. Gaps in the time series; for example, in the baseline, represent missing data.



We now consider each of the participant graphs shown in Figure 2. Visual inspection of P3 showed that relative to baseline after the first intervention session, the number of intrusions decreased. The number persisted with some fluctuation through the intervention period (days 8-65) and the 1-month and 3-month follow-ups. Visual inspection for P4 showed that relative to baseline (which included missing data), the number of intrusions remained relatively steady until the fourth intervention session targeting the same memory (day 36), when there was a noticeable drop in occurrence to 0 that was maintained in the last intervention session and 1-month (and 3-month) follow-up. Visual inspection of P5 showed a slight drop in the frequency

of intrusions after the second intervention session with some fluctuations, until intervention session 5 (day 36), where the reduction in frequency became more stable (Figure 2). The frequency decreased even further at the 1-month follow-up (and at 3 months).

Data for the 3-Month Follow-up Diary

P3 had 13 intrusive memories in their diary at the 3-month follow-up (67% reduction from baseline). P4 had 0 intrusive memories (100% reduction from baseline) at the 3-month follow-up, whereas P5 had 8 in the week of the 3-month follow-up (76% reduction from baseline; Figure 2). Patterns in relation to diaries at earlier time points are noted in the *Change in the Total Number of Intrusive Memories* section; however, please see earlier notes about the change in measures at this time point in contrast to the original CTR.

Change in the Number of Targeted Intrusive Memories Relative to Nontargeted Memories

The number of targeted and nontargeted intrusions per week at baseline, in the postintervention phase, and at the 1- and 3-month follow-ups are displayed in Table 1. The mean number of individual targeted memories was 7.6 (SD 4.3) per week in the baseline phase and reduced to 5.8 (SD 2.7) per week in the intervention phase. For individual memories, refer to Table 1. However, for nontargeted intrusions, the baseline rate for individual memories was very low, such as 1 per week. Therefore, these percentages are not included in Table 1. The mean number of nontargeted memories was 2.5 (SD 3.3) per week in the baseline phase and reduced to 0.2 (SD 0.4) memories per week in the intervention phase. The number of targeted memories continued to decrease at the 1-month follow-up week to 2.0 (SD 2.5), and nontargeted memories were reduced to 0 memories. At the 3-month follow-up, the mean number of targeted memories was 3.0 (SD 3.4), and the frequency for nontargeted memories was again 0 that week.

Table 1. Number of intrusive memories per week in the baseline phase, postintervention phase, and at 1 and 3-month follow-ups from baseline phase for each participant (P)[a].

Participant and intrusions	Baseline phase	Postintervention phase	1-month follow-up	3-month follow-up
P3				
Memory 1 (A[b])	14	11.2	6	3
Memory 2 (B[b])	8.8	6.4	2	10
Memory 3 (C)	6	0.3	0	0
Memory 4 (D)	1	0	0	0
Memory 5 (E)	0	0	0	0
Memory 6 (F)	3	0	0	0
Memory 7 (G)	1	0	0	0
Memory 8 (H)	3	0.1	0	0
Memory 9 (I)	0	0	0	0
Memory 10 (J)	2	0	0	0
Total	38.8	18.0	8	13
Total targeted[b]	22.8	17.6	8	13
Total nontargeted	16	0.4	0	0
P4				
Memory 1 (A)[b]	8.6	3.9	1	0
Memory 2 (B)	1.1	0.8	0	0
Memory 3 (C)	1.1	0	0	0
Total	10.8	4.7	1	0
Total targeted[b]	8.6	3.9	1	0
Total nontargeted	2.2	0.8	0	0
P5				
Memory 1 (A)[b]	10.6	6.5	0	2
Memory 2 (B)[b]	7	2.8	0	2
Memory 3 (C)[b]	2.6	4.2	0	4
Memory 4 (D)[b]	2.0	5.6	5	0
Memory 5 (E)	11.6	0.5	0	0
Memory 6 (F)	0	1	0	0
Total	33.7	20.7	5	8
Total targeted[b]	22.1	19.2	5	8
Total nontargeted	11.6	1.5	0	0

[a]Total intrusions do not equate to the sum of intrusions for each memory here because the length of the baseline and intervention phases differ across each memory and the total. See the *Data analysis* section for further details.

[b]Specific intrusive memories targeted by the intervention.

Secondary Outcomes

Ratings of Adherence to Completing the Diary, General Impact of Intrusive Memories (Vividness and Distress), and Use of the Intervention in Daily Life

Self-reported accuracy for filling out the daily intrusion diaries was high throughout the study period (Table 2). For the general impact of intrusive memories, the ratings for vividness of the intrusions did not change considerably, although if anything, showed some decline (Table 2). Distress associated with intrusions more clearly diminished during the intervention and follow-up phases for all 3 participants (Table 2). For use of the gameplay intervention in daily life, ratings of the self-guided

adherence to Tetris gameplay after experiencing an intrusive memory between sessions are also shown in Table 2.

Table 2. Ratings for adherence to intrusive memory diary, general impact of intrusive memories, and use of the gameplay intervention in daily life (N=3).

Ratings and participant	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	1-month follow-up	3-month follow-up
Diary accuracy[a]								
P[b]3	8	7	8	7	8	7	7	7
P4	9	8	7	9	8	__[c]	8	10
P5	8	9	8	8	8	8	7	9
Intrusions' vividness[d]								
P3	8	8	7	8	7	6	6	7
P4	7	6	5	7	4	—	5	0
P5	7	8	7	7	7	6	6	5
Intrusions' distress[e]								
P3	7	9	7	7	7	6	6	4
P4	6	5	4	4	2	—	1	0
P5	8	8	7	7	7	6	5	3
Intervention use in daily life[f]								
P3	—	3	3	1	4	3	1	1
P4	—	3	2	7	0	—	0	0
P5	—	7	7	6	8	8	6	2

[a]How accurately did you complete the diary? 0=not at all; 10=very accurately.

[b]P: participant.

[c]Missing data.

[d]During the last week, how vivid was your intrusive memory? 0=not at all; 10=very vivid.

[e]During the last week, how distressing were your intrusive memories? 0=not at all; 10=very distressing.

[f]How often did you manage to play Tetris after you experienced an intrusive memory? 0=never; 10=every time.

Feasibility and Acceptability of Using a Computer Gameplay Intervention

Participants were asked if they would recommend the intervention to a friend. P3 rated this item at 9, P5 gave it a rating of 8 (highly likely to recommend to a friend), and P4 rated the item at 3 (unlikely to recommend to a friend). They also rated if they considered gameplay to be an acceptable way to reduce intrusive memories. P3 and P5 rated the item at 8 (high acceptability), and P4 rated it at 3 (low acceptability). When participants were asked to rate how they felt about playing Tetris after having an intrusion, P3 noted that "It reduced the emotion, sometimes I was able to concentrate and think my way through it. Sometimes I experienced a kind of peace within." P4 said, "I played so there was no room for other thoughts," and P5 reported, "Sometimes it's difficult to play for 25 minutes, but I played as many times as I could, for 5 to 25 minutes." When the participants were asked if they found the intervention helpful, P3 reported, "When I was able to plan ahead while playing the game, my brain could not interrupt me. The emotion that causes distress fades." P4 said, "Yes, I could not think about anything else whilst playing," and P5 reported, "I felt a physical calmness, like the pit in my stomach was shrinking."

Self-report Measures for Posttraumatic Stress, Depression and Anxiety Symptoms, and General Functioning

There was a clear reduction in posttraumatic stress symptoms (PCL-5) from baseline to the postintervention phase, which tended to continue to drop further during follow-up for all 3 participants who completed the intervention, suggesting clinical improvement (Table 3). Depression symptoms (on the PHQ-9) and anxiety symptoms (on the GAD-7) seemed to follow a similar pattern for 2 (P3 and P5) out of the 3 participants, showing reductions in the postintervention phase and during follow-up. Functional impairment (as measured by the SDS) was reduced for the same 2 out of 3 participants (P3 and P5) from baseline to the postintervention phase and at the 1-month follow-up, but for P3, it increased at 3 months. It should be noted that P4's ratings for all of these measures were low at baseline (Table 3).

Table 3. Self-report measures of secondary outcomes (posttraumatic stress, depression and anxiety symptoms, and general functioning) and impact of intrusive memories on concentration, sleep, stress, and daily functioning for each participant (P).

Item and participant	Baseline interview	Postintervention interview	1-month follow-up	3-month follow-up
PCL-5[a]				
P1	6	—[b]	—	—
P2	54	—	—	—
P3	54	35	20	35
P4	26	14	6	11
P5	64	49	51	31
PHQ-9[c]				
P1	3	—	—	—
P2	19	—	—	—
P3	13	8	6	9
P4	5	3	3	2
P5	19	11	14	11
GAD-7[d]				
P1	2	—	—	—
P2	8	—	—	—
P3	14	7	6	10
P4	2	3	5	1
P5	18	9	17	4
SDS[e]				
P1	7	—	—	—
P2	20	—	—	—
P3	20	16	13	21
P4	4	3	0	0
P5	21	16	8	7
Concentration disruption related to intrusive memories[f]				
P1	3	—	—	—
P2	3	—	—	—
P3	7	5	3	5
P4	2	2	1	0
P5	7	4	4	3
General concentration[g]				
P1	0	—	—	—
P2	6	—	—	—
P3	7	6	5	6
P4	2	2	2	0
P5	7	4	3	—
Duration of disruption[h]				
P1	1	—	—	—
P2	3	—	—	—
P3	4	4	3	4

Item and participant	Baseline interview	Postintervention interview	1-month follow-up	3-month follow-up
P4	2	1	2	1
P5	4	4	2	2
Sleep[i]				
P1	0	—	—	—
P2	5	—	—	—
P3	4	4	3	4
P4	1	1	1	0
P5	10	8	7	5
Nightmares[j]				
P1	0	—	—	—
P2	4	—	—	—
P3	7	2	2	4
P4	0	1	1	0
P5	10	8	8	5
Stress[k]				
P1	0	—	—	—
P2	4	—	—	—
P3	6	2	0	2
P4	1	1	2	0
P5	7	3	3	3
Daily functioning[l]				
P1	0	—	—	—
P2	8	—	—	—
P3	7	5	2	5
P4	0	0	0	0
P5	7	0	2	0

[a]PCL-5: Posttraumatic Stress Disorder Checklist-5; score range 0 to 80.

[b]Missing data.

[c]PHQ-9: Patient Health Questionnaire-9; score range 0 to 27.

[d]GAD-7: Generalized Anxiety Disorder-7 scale; score range 0 to 21.

[e]SDS: Sheehan Disability Scale; score range 0 (unimpaired) to 30 (highly impaired).

[f]In the past week, how much did your intrusive memories disrupt your concentration? 0=not at all disruptive; 10=extremely disruptive.

[g]In the past week, how much difficulty did you have concentrating generally? 0=no concentration difficulty at all; 10=extreme concentration difficulty.

[h]When you had an intrusive memory, how long did it disrupt your concentration (in minutes) in the past week? 0 (<1 min) to 5 (>60 min).

[i]Did your intrusive memories interfere with sleep during the night in the past week? 0=not at all; 10=interfered very much.

[j]Did you experience any nightmares that interfered with your sleep during the night in the past week? 0=did not experience any nightmares; 10=experienced a lot of nightmares.

[k]In the past week, did your intrusive memories affect how stressed you felt? 0=not at all; 10=affected very much.

[l]Have the intrusive memories affected your ability to function in your daily life? 0=not at all; 10=affected very much.

Impact of Intrusive Memories on Concentration, Sleep, Stress, and Daily Functioning

The ratings of the impact of intrusive memories on concentration, stress, and sleep are included in Table 3. P5 reported improved concentration after her intrusions over the course of the intervention and follow-up period. At baseline, when P5 experienced an intrusive memory, her concentration was disrupted for 10 to 30 minutes on average, and this time was reduced to 1 to 5 minutes at follow-up. P3 reported a slight improvement in concentration with respect to intrusive memories specifically but not in general. Ratings on concentration disruption from intrusive memories were low at baseline for P4 and did not change in the postintervention phase. The effect of

intrusive memories on sleep did not change for P3 or P4, whereas P5 showed some reduction. Nightmares were reduced for both P3 and P5, whereas nightmares were almost nonexistent for P4. The stress levels associated with intrusions were reduced during the intervention and follow-up periods for P3 and P5.

The reported impact of intrusive memories on the ability to function in daily life over the intervention and follow-up periods showed improvement (except for P4, who scored 0 at baseline). At baseline, the participants were asked to respond to an open question about how their intrusive memories impacted their ability to function in daily life. At baseline, P3 said, "When I have this overwhelming feeling, I find it difficult to be around other people, the worst thing is how it affects my ability to stay present for my daughters." P4 said, "I have anger inside me, I constantly think back to how no-one noticed what was done to me." P5 reported, "I get very stressed and anxious; it takes a lot of energy to get out of the emotion..." In the last intervention session, P3 reported, "The intrusions disrupt my concentration," and P5 said, "I experience distress and nightmares." At the 1-month follow-up, P3 disclosed, "When I am under a lot of stress, they disturb me more." P5 reported, "The images no longer have color, cause less disruption and are less frequent." At the 3-month follow-up, P3 said, "I am under a lot of stress and dealing with a certain communication problem which triggers my PTSD and the intrusions" and that "I can now comprehend that this is only a memory, and I don't feel as distressed." P5 reported, "They mostly impact my anxiety" and "I am not a person that easily believes in things, but this intervention works." For all phases following the baseline, P4 reported, "The memories have no impact anymore."

Discussion

Principal Findings

The aim of this case series was to extend our previous case study by evaluating a novel visuospatial intervention designed to reduce the number of intrusive memories of trauma [6,14,37]. The intervention was adapted to the Icelandic setting from previous clinical studies [6,19,20]. The total number of intrusive memories per week (primary outcome) was reduced between 38% and 56% from baseline to the intervention phase, in line with earlier results found by Kessler et al [19] and what we found in our earlier case study [6]. Importantly, we also found in this case series that the frequency of intrusive memories continued to decrease at the 1-month follow-up (the reduction from baseline was approximately 85%). In the diary used at the 3-month follow-up, the reduction from baseline was from 66% to 100%; although this measure replaced another one and was not prespecified, further investigation is required. These results are similar with what we found in the earlier case study [6] in which the frequency also continued to reduce from 52% in the postintervention phase to 76% at the 1-month follow-up and to 92% at the 3-month follow-up. These results indicate that the reduction in the frequency of intrusions might continue rather than rebound, which could be because of the simplicity of self-administered use of the intervention, giving participants the chance to use it independently, if needed. Reductions in distress related to intrusive memories were evident in all participants. A limitation of the study is that the 3-month diary data must be treated as exploratory, as it was not preregistered in the CTR (though it was in our ethics approval), and further studies should include this.

Not only did the targeted intrusions reduce in this case series but nontargeted intrusions were also reduced in the intervention phase. Although this appears relatively more so than the targeted ones, results must be treated with caution because of the potential floor effects on the low baseline number of nontargeted intrusions rendering comparisons misleading. Kessler et al [19] found that overall, targeted memories were reduced by 64% and nontargeted memories by 11%. The sample of participants in the study by Kessler et al [19] was inpatients with a diagnosis of complex PTSD with a larger number of different memories and baseline symptom rates, whereas the participants in this case series were non–treatment seeking with less symptom severity. Furthermore, targeted memories were reported to be much more distressing than nontargeted ones and may, in some cases, need more time to reduce in frequency (hence, the long-term effect described earlier in this section). It would be clinically interesting in future studies to see if there were links between treating a memory (say from the same trauma) that could generalize to reductions in nontargeted memories of the same episode.

We examined whether a reduction in the number of intrusions would have an impact on the symptoms of posttraumatic stress, depression and anxiety symptoms, and general functioning (secondary outcomes). The general pattern was that posttraumatic stress symptoms were reduced for all participants in the postintervention phase (cutoffs for clinical significance were not available for this measure). Depression and anxiety symptoms were reduced at times suggestive of a clinically significant change for 2 (P3 and P5) of the 3 participants in the postintervention phase [30,33], whereby a 5-point change in the PHQ-9 total score and a 4-point change on the GAD-7 can be considered clinically significant. Symptoms tended to be reduced further at follow-up. It should be noted that P4 had very low levels of distress, depression and anxiety symptoms, and impaired function at baseline. The overall findings are similar to those of our previous case study [6] and the study by Kessler et al [19]. These results provide preliminary evidence that a reduction in the number of intrusions from using this intervention could possibly reduce other symptoms connected to intrusive memories after trauma and improve functioning, with important implications for the quality of life. For the 2 (out of 3) participants who had a reduction in posttraumatic stress symptoms, depression and anxiety, and impairments in concentration and other factors related to intrusive memories, the overall pattern for secondary measures was that some improvements tended to continue for a longer term.

P3 and P5 rated the intervention as acceptable; using Tetris gameplay was an acceptable method to reduce the frequency of their intrusive memories and noted that they would recommend the intervention to a friend. This is similar to what Holmes et al [38] found among refugees and what we found in our earlier case study [6]. However, P4 did not rate the intervention as acceptable and was unlikely to recommend it to a friend, although she noted that it was helpful. It is important

to further develop how the intervention can be made more feasible and acceptable to a range of users.

Two of the participants ceased participation in the study after the baseline phase; the reasons were unrelated to the intervention but were related to scheduling issues in their daily life. However, it is important to determine who is most likely to benefit from the intervention and how to educate individuals about it in a way that increases the chance of people making an informed choice of whether they are able to try it or have the time to take part in a course of treatment. It could also be explored whether the intervention could have an impact on the frequency of intrusive memories with fewer guided intervention sessions, which would reduce the participation load.

Owing to the COVID-19 pandemic, the delivery of the intervention was changed from face to face to remote (eg, web-based communication via Kara Connect). Originally, our plan was to gradually move toward remote delivery in future studies. When the pandemic struck, it forced the change to occur more quickly during the intervention phase of the study. This turned out to be a positive development, as the data did not suggest that the intervention became less effective by being delivered remotely. Recent research by Singh et al [39] indicated that this novel intervention delivered remotely could be an acceptable method to reduce the number of intrusive memories among health care staff. The number of intrusive memories was reduced to 0 at the 5-week follow-up in all 3 participants [39]. Continued remote delivery using a web-based platform instead of face-to-face delivery will be important in future studies [40], thereby removing geographical restraints and making it possible to reach people regardless of where they live or whether they are in quarantine (eg, owing to the COVID-19 pandemic) [22].

Conclusions

Targeting established intrusive memories of trauma that participants had been experiencing for some years (eg, from childhood sexual abuse) with a brief visuospatial intervention, involving a brief memory reminder and Tetris gameplay with mental rotation, seems to show promise for further exploration as a method to reduce their frequency. These early data suggest that the intervention might also result in symptom reduction related to posttraumatic stress, anxiety and depression, and improved functioning; however, further studies are needed. Because of its simplicity, this intervention might be capable of removing common barriers to existing treatment options after trauma, such as for PTSD, including some patients' reluctance to talk about and describe their trauma in detail to a therapist, high costs, and a limited number of qualified therapists [9]. The intervention might even be delivered by nonexperts in evidence-based trauma-focused therapy after brief training, with ongoing supervision—something that should be further examined.

The results of this study are encouraging, and the effects of the intervention on the number of intrusive memories need to be further explored. Continuing to develop this kind of scalable intervention is crucial to reach a large number of people in need of treatment after experiencing trauma. Future research should further examine the feasibility and acceptability of remote delivery by nonexperts in mental health (rather than only qualified clinical psychologists) and whether fewer intervention sessions can yield similar results. Randomized controlled trials are required to assess the intervention.

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Conflicts of Interest

EAH served on the board of charity MQ: Transforming Mental Health (United Kingdom). She received book royalties from Oxford University Press (Imagery in Cognitive Therapy) and Guilford Press (Imagery-Based Cognitive Therapy for Bipolar Disorder and Mood Instability) and occasional fees from clinical workshops and conference keynotes.

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Abbreviations

CAPS-5: Clinician-Administered Posttraumatic Stress Disorder Checklist-5 Scale for Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition
CTR: clinical trial registration
DSM-5: Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition
GAD-7: Generalized Anxiety Disorder-7 scale
MINI: Mini International Neuropsychiatric Interview
PCL-5: Posttraumatic Stress Disorder Checklist-5
PHQ-9: Patient Health Questionnaire-9
PTSD: posttraumatic stress disorder
REDCap: Research Electronic Data Capture
SAGA: Stress-And-Gene-Analysis
SDS: Sheehan Disability Scale

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Paper III

Reducing intrusive trauma memories using a brief mental imagery competing task intervention: A case series of trauma exposed women in Iceland

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Abstract

Background: There is a need for scalable and simple interventions for trauma exposed people. In this case series, we built on our previous case study and case series findings and further explored the utility and potential effectiveness of a brief novel intervention to reduce the number of past intrusive memories of trauma. The imagery competing task intervention consists of a memory reminder, and the visuospatial task Tetris played with mental rotation, targeting one intrusive memory at a time. Here we test remote delivery of the intervention, including guidance from researchers without specialist mental health training, in a sample of women in Iceland with current intrusive memories from trauma occurring several years previously.

Objective: In a case series of trauma exposed women, we aimed to explore whether this brief novel intervention reduces the number of established intrusive memories (primary outcome) and improves general functioning and symptom reduction in post-traumatic stress, depression and anxiety (secondary outcomes). Acceptability of the intervention along with adaptations i.e., delivery by psychology students without specialist mental health training and digital delivery, were explored.

Methods: Participants (N=8) monitored the number of intrusive memories from an index trauma (occurring 3 – 16 years previously) in a daily diary at baseline, during the intervention phase (ranging from three to six weeks), and post intervention at 1-month and 3-month follow-ups. The intervention was delivered digitally with guidance from clinical psychologists/psychology students. A repeated AB design was used ("A": pre-intervention baseline, "B": intervention phase). Intrusions were targeted one-by-one, creating repetitions of an AB design (i.e., length of baseline 'A' and intervention 'B' varied for each memory).

Results: The number of intrusive memories reduced for all participants from the baseline phase compared to the intervention phase, although the reduction was minimal for 2 participants (6.3% - 93%). The number of intrusive memories continued to reduce for 6 out of 8 participants (58% - 100% reduction at 1-month follow up; 72% - 100% reduction at 3-month follow up). Symptoms of post-traumatic stress, depression and anxiety were reduced for most participants post intervention and continued to

decrease during the follow-up periods. Functioning was improved for 7 of the 8 participants from baseline to post intervention and continued to improve at the follow-up assessments for three participants. The intervention delivered digitally and partly by students was perceived to be an acceptable way to reduce the frequency of intrusive memories by all participants (mean rating 9.5 out of 10).

Conclusions: Data from this case series of traumatized women provide preliminary evidence for the effectiveness of this novel brief intervention in reducing intrusive memories of trauma occurring several years ago and in improving functioning and reducing core symptom burden. This study will inform a randomized controlled trial of this novel intervention, which may have considerable implications for large scale clinical management of traumatized populations. Clinical Trial: The study was approved by the National Bioethics Committee in Iceland (No: VSNb2017110046/03.01).
The study was preregistered prior to study start on ClinicalTrials.gov (NCT04209283) on 2020-11-03.

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Original Manuscript

Reducing intrusive trauma memories using a brief mental imagery competing task intervention: A case series of trauma exposed women in Iceland

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Abstract

Background: There is a need for scalable and simple interventions for trauma exposed people. In this case series, we built on our previous case study and case series findings and further explored the utility and potential effectiveness of a brief novel intervention to reduce the number of past intrusive memories of trauma. The imagery competing task intervention consists of a memory reminder, and the visuospatial task Tetris played with mental rotation, targeting one intrusive memory at a time. Here we test remote delivery of the intervention, including guidance from researchers without specialist mental health training, in a sample of women in Iceland with current intrusive memories from trauma.

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Method: Participants (N=8) monitored the number of intrusive memories from an index trauma (occurring 3 – 16 years previously) in a daily diary at baseline, during the intervention and post-intervention at 1-month and 3-month follow-ups. The intervention was delivered digitally with guidance from clinical psychologists/psychology students. A repeated AB design was used ("A": pre-intervention baseline, "B": intervention phase). Intrusions were targeted one-by-one, creating repetitions of an AB design (i.e., length of baseline 'A' and intervention 'B' varied for each memory).

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Symptoms of post-traumatic stress, depression and anxiety were reduced for most participants post-intervention and continued to decrease during the follow-up periods. Functioning was improved for 7 of the 8 participants from baseline to post-intervention and continued to improve at the follow-up assessments for three participants. The intervention delivered digitally and partly by students was perceived to be an

acceptable way to reduce the frequency of intrusive memories by all participants (mean rating 9.5 out of 10).

Conclusion: Data from this case series of traumatized women provide preliminary evidence for the effectiveness of this novel brief intervention in reducing intrusive memories of trauma occurring several years ago and in improving functioning and reducing core symptom burden. This study will inform a randomized controlled trial of this novel intervention, which may have considerable implications for large scale clinical management of traumatized populations.

Keywords: trauma, intrusive memories, post-traumatic stress disorder, imagery competing task, visuospatial task, Tetris gameplay, mental imagery, case series

Background

Over 70% of people experience traumatic events (e.g., interpersonal violence, accidents, or disasters) at some point in their lives [1]. The lifetime prevalence for post-traumatic stress disorder (PTSD) has been estimated as 5.6% among people that have been exposed to trauma [2]. PTSD, even when symptoms are subthreshold, is associated with substantial distress, functional impairment and comorbidities, such as depression and anxiety [3–5]. Given the scope of this detrimental health outcome, there is a need for scalable and simple interventions for trauma exposed people.

A core clinical feature of PTSD is intrusive memories of trauma. They are often visual, e.g. pictures, or short clips that replay a distressing moment from the trauma. They can disrupt daily functioning and cause significant distress by evoking the same emotional reaction that was experienced during the traumatic event [6] According to network studies [7], intrusive memories activate the other three PTSD symptoms clusters (avoidance; alterations in cognitions and mood; hyperarousal), making them a suitable treatment target [8]. This single symptom focus may allow a post-trauma intervention to be simpler and easier to scale.

Existing evidence-based treatment options for PTSD [9,10], while clearly important, also carry some limitations. These treatments require the patients to recall and describe the traumatic event in detail which many are reluctant to do [11]. In addition, dropout rates from clinical trials focusing on PTSD treatments are high, up to 48% (on average 18%) and are thought to be even higher in general treatment settings [12–14]. Furthermore, there are not enough therapists that are trained in delivering evidence-based PTSD treatment [11] and current treatment options are time consuming and costly [11]. With these challenges in mind, a simple and low intensity intervention has recently been developed, aimed to reduce one key symptom of PTSD, that is, intrusive trauma memories [15] rather than the full diagnosis of PTSD[16]. The intervention consists of a brief memory reminder for a specific intrusive memory, followed by 20-minutes Tetris gameplay with mental rotation (i.e., actively rotating the blocks in one's mind while playing the game; for further details, see Holmes et

al., 2019, chapter 11[17]).

Recent clinical trials have yielded promising results when the intervention is used to target memories of very recent trauma [18–20]. In several case studies and case series, the intervention has also been investigated with focus on older intrusive memories of trauma with promising results[21–27]. These studies involved both in person and remote delivery of the intervention with sessions being guided by a clinical psychologist/researcher.

In a recent case study [22], we adapted the intervention for Icelandic women who experience intrusive memories of trauma. In the initial case study, the participant (N=1) was a woman in her fifties with four intrusive memories of a single traumatic event from her childhood. She reported a total of 12.6 intrusive memories per week at baseline which reduced to 6.1 per week during the intervention phase. Notably, her intrusive memories continued to decrease to 1.0 per week at the 3-month follow-up. The participant's general functioning, along with symptoms of PTSD, depression, and anxiety, improved post-intervention and continued to improve at the follow-up. She found the intervention to be an acceptable way to reduce the frequency of intrusive memories [22].

Following the case study, we investigated the effects of the intervention in an exploratory case series (N =3 [23]). Given restrictions that came along with the COVID-19 pandemic (e.g., isolation)[28], we also explored the feasibility of delivering the intervention remotely, using videoconferencing. The total number of intrusive memories for the first participant went from 38.6 per week at baseline to 18.0 per week during the intervention phase, for the second participant from 10.8 per week at baseline to 4.7 per week during the intervention phase, and for the third participant from 33.7 per week at baseline to 20.7 per week during the intervention phase. The frequency of intrusive memories also continued to decrease at 1-month follow-up for all three participants, indicating that the intervention may have longer-term effects. As in Kessler et al. 2018 [26], we hoped to compare targeted relative to non-targeted memories, however the number of non-targeted memories per week was too low to make that comparison. In addition to the reduced total number of intrusive memories,

PTSD symptoms were reduced for all three participants. Furthermore, depression and anxiety symptoms were reduced for two out of three participants post-intervention and continued to reduce at follow-up. Two out of three participants rated the intervention to be an acceptable way to target intrusive memories of trauma. Remote delivery – here using videoconferencing with the researcher - was achieved and appeared acceptable although the feasibility of remote delivery needs to be further explored.

In the current case series, we build on these two previous studies [22,23], investigating the effects of the intervention (up to six sessions) delivered remotely in a larger case series sample of women (N = 8) experiencing established intrusive memories of older trauma occurring some years before (3 – 16 years). In this study, a novel aspect was also that non-specialists (psychology students without a professional mental health qualification) delivered the intervention remotely after training in how to use the intervention.

We predicted that participants would report fewer intrusive memories of trauma (primary outcome) during the intervention phase (maximum five weeks) than in the preceding baseline phase (one week), and that the reduction would be maintained at the 1-month and 3-month follow-up. We predicted that the number of targeted intrusive memories would decrease relative to non-targeted memories. Furthermore, we explored whether having fewer intrusive memories would be associated with improvements in general functioning and reductions in symptoms of PTSD, depression, and anxiety (secondary outcomes). In addition, we explored the feasibility and acceptability of digital and non-specialist delivery of the intervention.

Method

Participants

As in our previous studies [22,23], participants were recruited from a sub-study of the Stress and Gene analysis (SAGA) Cohort which is a population-based longitudinal cohort study of Icelandic women (see e.g., [29,30]**.** The sub-study compared two samples of women from the SAGA cohort

study, women with a probable diagnosis of PTSD (i.e., having a score of 33 or higher on the PCL-5) and women not likely to have a diagnosis of PTSD (i.e., scores on the PCL-5 in the lowest one fifth of the distribution), using clinical interviews. Women who took part in the sub-study were assessed for eligibility for the present study using two semi-structured diagnostic interviews (i.e., the Mini International Neuropsychiatric Interview (MINI) and the Clinician-Administered PTSD Scale for DSM-5 (CAPS-5) to determine the presence of mental disorders and to assess exclusion criteria in the current study. Women from the sub-study who provided consent to be contacted regarding future studies were assessed for inclusion into this case series.

Screening included a short description of intrusive memories (as involuntary and distressing memories that include sensory impressions such as sight, sound etc., that pop into mind often in the form of pictures or short film clips). The presence of the symptom was then assessed.

In the current study, 53 women from the sub-study who provided consent to be contacted for further research were assessed for inclusion (see CONSORT diagram in Figure 1). Inclusion criteria were: (a) having experienced at least one criterion A trauma according to DSM-5 [31]; (b) having at least one intrusive memory that occurs at least 3 times per week in the past four weeks; (c) being able to attend 3-8 sessions with the researcher; (d) being willing to monitor intrusive memories in daily life; (e) having access to a smartphone; (f) being able to speak Icelandic and read study materials in Icelandic. Exclusion criteria were (a) current psychotic disorder; (b) current manic episode; (c) being acutely suicidal.

Ten participants met the inclusion criteria (see Figure 1) and were initially recruited, ranging in age from 22 to 65 years (M = 43.2, SD = 15.67). Participants will hereafter be referred to as P1, P2, P3, etc. Two participants (P6 and P8) did not complete the intervention sessions due to personal reasons. P6 did not complete the baseline session, no data were therefore collected for P6. P8 completed the baseline session and one intervention session. P8 found the timing of study participation not suitable due to changes in her personal life. Hence, P6 and P8 were excluded from

the data analysis. Eight women completed the study (see Table 1 for demographics, traumatic event details and clinical diagnoses for the final sample). Time since the traumatic event took place that participants were experiencing intrusive memories from varied from 3 – 16 years (M = 7.25, SD = 6.60).

Table 1. Participant demographics, traumatic event details and clinical diagnoses.

Participant	Age	Traumatic event	Number of different intrusive memories	Clinical diagnoses					
				PTSD [1a]	Agoraphobia [2b]	PD [2c]	GAD [2d]	SAD [2e]	MDD [2f]
P1	60s	Accident in adulthood	3	(x)	x				
P2	40s	Accident in adulthood	8	x	x	x	x		
P3	50s	Accident in childhood	6	(x)				x	
P4	30s	Physical violence in adulthood	5					x	x
P5	50s	Physical and sexual violence in childhood	7			x			
P7	30s	Physical and sexual violence in childhood*	7	x					
P9	30s	Physical and sexual violence in childhood	3	x			x	x	x
P10	30s	Physical and sexual violence in childhood	3	(x)				x	

Note: [1]assessed with CAPS, [2]assessed with MINI, subthreshold diagnoses are marked by (x). *One of P7's memories was from an accident in adulthood. [a]Post traumatic stress disorder. [b]Agoraphobia. [c]Panic disorder. [d]Generalized anxiety disorder. [e]Social anxiety disorder. [f]Major depressive disorder.

[Insert Figure 1 here]

Figure 1. Adapted CONSORT Flow Diagram for the study.

Study design

This study is a case series that used a single symptom approach in which one intrusive memory was targeted at a time in different sessions [22,23,26]. Participants distinguished between different intrusive memories with a brief description. For example, if a participant had 4 different intrusive memories the labels for each might be as follows (a): angry face; (b): door opens; (c): clenched fist; (d): blood (*note*: these examples are fictitious to protect anonymity). Participants then monitored the occurrence of each intrusive memory over time. The study design was the same as in our previous studies [22,23] and is described as a *repeated AB design* in which the length of the baseline ("A" preintervention, monitoring only) and intervention phases ("B") varied for each specific memory, depending on which intervention session each memory was targeted in. Therefore, the baseline phase for each individual memory was used as a control period to compare their numbers before and after being targeted with the intervention.

Participants monitored the number of each intrusive memory in a daily diary for one week during the baseline phase; over a 6-week period maximum during the intervention phase and then for one week during 1-month and 3-month follow-ups. Intrusive memories were targeted one at a time in up to 6 intervention sessions delivered remotely through a secure video platform. Participants could self-administer the intervention after the first intervention session if they chose to for the memories already targeted in session. The number of AB repetitions varied across participants, P1 received 3 repetitions, P2 received 4 repetitions, P3 received 2 repetitions, P4 received 3 repetitions, P5 received 2 repetitions, P7 received 6 repetitions, and P9 and P10 received 3 repetitions of AB design.

The primary outcome was the change in number of intrusive memories per week from baseline to the intervention phase, and to the longer-term follow ups (1- and 3-months). Participants also completed self-report measures for posttraumatic stress, depression and anxiety symptoms, and functional impairment (secondary outcomes) at baseline, the last intervention session, and the 1-

month and 3-month follow-ups.

Procedure

All sessions were delivered remotely through Kara Connect, a GDPR compliant online platform allowing videoconferencing, certified by the Icelandic Directorate of Health. All data were recorded on a laptop computer using the REDCap database (Research Electronic Data Capture), an encrypted, electronic software, and stored on secure servers [32]. The intervention was delivered by clinical psychologists (KT and JPH) who are experts in trauma-focused cognitive-behavior therapy, one master level student in clinical psychology and 2 bachelor's degree graduates.

Training of researchers in intervention delivery

All people delivering the intervention underwent training, feedback and continued clinical supervision from researchers/clinical psychologists (EAH and MK who are experts in this intervention) to promote adequate intervention delivery and protocol adherence. Training for the clinical psychologists (N =2) included two in-vivo workshops, the first for three days and then again approximately six months later for two days delivered by psychologists with expertise in developing and delivering the intervention in other settings, [22,23]. The students (master level student and the bachelor's degree graduate, (N = 3) participated in training workshops remotely via online video sessions. The workshops included topics such as theoretical background, practical aspects (including how to explain and use the primary outcome measure) as well as roleplaying with trainers, with individual feedback provided until adequate performance was reached. Furthermore, all persons delivering the intervention received ongoing clinical supervision and support after each session via telephone from a clinical supervisor and in weekly group supervision meetings (EAH, MK and ASB).

Baseline session

Consistent with our procedure in previous studies [22,23], the researchers gave a brief description of intrusive memories in the baseline session. Participants then identified each of their different

intrusive memories by giving a short verbal account of their visual content, using only a few words. Participants then labelled each intrusive memory with a symbol (e.g., first memory labelled “A”, second memory “B” etc.) and then were instructed on how to monitor their occurrence in a daily diary (primary outcome measure). Participants indicated the frequency of each memory with the corresponding symbol in a specific time frame of that day. Each diary included seven days and each day four time periods (see Measures), the baseline phase was one week in duration. Participants also completed baseline questionnaires in the baseline session (see under ‘secondary outcomes’).

Intervention sessions

In each intervention session (six sessions maximum; intervention phase six weeks maximum) the participants selected one memory at a time to target that week, and completed the intervention procedure, guided by the researcher. The memory reminder here was the same one that was used in Thorarinsdottir et al. [22,23](2021; 2022) where the participants were asked to briefly bring the visual content to mind without it becoming emotionally overwhelming. Participants were then taught how to use mental rotation and practiced before they played the Tetris® computer game while using mental rotation for 25 minutes (i.e., visualizing where to place and rotate game pieces before being played; for further information see Holmes et al., 2019, chapter 11[17]). Participants played Tetris® online (http://tetris.com/) on their computer (with marathon mode, selecting in the menu “ghost piece off” and sound set to 0%). Participants used share screen mode on Kara Connect (videoconferencing) so the researcher could watch the participant playing and give feedback on using mental rotation throughout the duration of gameplay. Between sessions, the participants were invited to play Tetris® at home in the same way as in sessions (i.e. playing for 25 minutes using mental rotation), using either their smartphone or computer, for already targeted intrusive memories, when an intrusion came to mind involuntarily. In the last intervention session, participants completed post-intervention measures.

Follow-up

At the 1-month and 3-month follow-ups, participants monitored the occurrence of intrusive memories in a daily diary for one week and completed follow-up measures.

Measures

Eligibility assessments (part of the SAGA cohort sub-study)

The Clinician Administered PTSD Scale (CAPS-5) is a 30 item semi-structured interview that assesses PTSD diagnosis and symptom severity in the past month, according to the PTSD criteria in the Diagnostic and Statistical Manual of Mental Disorders [31]. Each item is scored on a 5-point Likert scale (0 = mild/subthreshold; 4 = extreme/incapacitating) with a symptom rating of 2 (i.e., moderate) as a threshold for a possible diagnosis. The CAPS-5 has excellent internal consistency (Cronbach's alpha = .88), test-retest reliability (0.83) and good convergent validity (.83) [33].

The MINI International Neuropsychiatric Interview (MINI) is a short, structured interview designed to assess Axis I psychiatric disorders according to the DSM-4. The interview has been shown to have good sensitivity and specificity for most diagnoses as well as good inter-rater reliability (κ = 0.88–1.0) and test-retest reliability (κ = 0.76–0.93;[34,35].

Primary Outcome Measure

Intrusive memory diary. The intrusive memory diary was adapted from previous studies [18,20,36]. The number of intrusive memories was recorded in a daily pen-and-paper diary of four time points per day (morning, afternoon, evening, and night) for each week. The diary included a definition of intrusive memories of trauma as being mental images (pictures or a film clip in the mind's eye) that occur involuntarily and cause distress. The participants are instructed not to record voluntary thoughts about the trauma or verbal thoughts without imagery. The participants monitored the occurrence of their intrusive memories daily for one week (baseline phase); for 6 weeks while intervention sessions were administered; and again, for one week at 1-month and 3-month follow-ups. Participants noted which intrusions came up, allowing us to investigate the change in frequency

of each individual intrusive memory. The primary outcome was the number of intrusive memories from baseline phase to the intervention phase, and again to 1- and 3-month follow ups.

Secondary Outcome Measures

PTSD symptoms were assessed with the Posttraumatic Stress Disorder Checklist (PCL-5), a brief 20-item self-report scale that assesses the severity of PTSD symptoms in the past month according to the DSM-5 criteria for PTSD [37]. Symptoms are rated on a 4-point Likert scale (0= not at all; 4= extremely). The scale has been shown to have good internal consistency and test-retest reliability as well as good convergent and discriminant validity [37]. The Icelandic translation of the PCL-5 also has excellent internal consistency (α = .95) in the SAGA cohort study. A score of 33 on the PCL-5 is considered likely to detect PTSD cases according to DSM-5 and a score of 24 or below post-treatment is considered clinically significant [38].

Depressive symptoms were assessed with the Patient Health Questionnaire-9 (PHQ-9), a 9-item self-report measure of depression symptoms in the past two weeks, according to the DSM-5 criteria [39]. Each item is rated on a 4-point Likert scale (0= not at all; 3= nearly every day). The PHQ-9 has good internal reliability (α = ranging from .86-.89) and good test-retest reliability (r = .84;[39]. The Icelandic version had good internal consistency in the SAGA cohort study (α = .89). A 5-point change on the PHQ-9 from pre- to post-treatment is considered clinically significant [40].

Anxiety symptoms were assessed with the Generalized Anxiety Disorder-7 scale (GAD-7), a brief self-report questionnaire that screens for symptoms of GAD and their severity in the past two weeks. Each item is scored on a 4-point Likert scale (0= not at all; 3= nearly every day). The GAD-7 has good test-retest reliability (r = .83) and good convergent validity [41]. The Icelandic version has excellent internal consistency in the SAGA cohort study (α = .90). A 4-point change on the GAD-7 from pre- to post-treatment is considered clinically significant [42].

Functional impairment was assessed with the Sheehan Disability Scale (SDS), a self-report questionnaire used to assess functional impairment in the past week across three domains: (1)

work/school, (2) social, and (3) family life [43]. These domains are measured on an 11-point scale (0= not at all; 10= extremely) which was adjusted to assess functional impairment associated with intrusive memories. The SDS has good internal consistency (α = .89) and construct validity [43], as well as the Icelandic version having good internal consistency in clinical groups (α = .84; [44]. A 3-point change on the SDS has been used as a measure of treatment response [45].

Self-guided adherence for the usage of the intervention in daily life was assessed with a question regarding how often Tetris was played after experiencing an intrusive memory (11-point scale; 0 = not at all; 10 = every time).

Feasibility and acceptability for using a gameplay intervention to reduce intrusive memories were assessed with two self-rated items: "Would you recommend playing Tetris to a friend?" and "Do you consider gameplay to be an acceptable way to reduce the daily frequency of intrusive memories?" (10-point scale, higher score indicating greater acceptability/feasibility). In addition, two open-ended questions were asked: "How did you feel about playing Tetris after you had an intrusive memory?" and "Did you find the intervention helpful? If yes, how?"

The impact of intrusive memories on concentration, sleep, and stress was assessed with six self-rated items regarding the past week: Two items assessing difficulties with concentration in general and due to intrusive memories (11-point scale; higher scores indicating more difficulties); duration of disruption following an intrusive memory (<1 minute to > 60 minutes), two items assessing sleep difficulties due to intrusive memories (11-point scale; higher scores indicating more sleep difficulties), and one item assessing how much intrusive memories affected stress levels (0 = not at all; 10 = affected very much).

Ratings of general impact of intrusive memories involved two items on an 11-point scale (0= not at all; 10= very distressing/vivid), one assessing distress caused by intrusive memories and the other assessing how vivid they were in the past week.

Intrusion diary adherence was assessed with one item: "How accurately did you fill out the

diary?" (0 = not at all; 10 = very accurately).

Impact of intrusive memories on daily functioning was assessed with two questions; one was open-ended: "Have the intrusive memories affected your ability to function in your daily life in the past week? If yes, how?" and the other one was self-rated: "Have the intrusive memories affected your ability to function in your daily life?" (11-point scale, higher score indicating greater impact on functioning).

Data analysis

Change in the total number of intrusive memories. Number of intrusive memories of trauma were recorded by participants in a diary daily (morning, afternoon, evening and night) during the baseline phase, for one week and each week during the intervention phase (weeks 1-6) and during one week at one month and three-month follow-up. The primary outcome was the change in the number of intrusive memories of trauma. The timeframe was baseline week, to the intervention phase (weeks 1-6), and to follow-up (1-month and 3-month). In practice, due to scheduling reasons, in some instances, the baseline phase was longer than 1 week, and as anticipated, the number of intervention weeks varied. Therefore, since these periods had different time lengths, the mean number *per week* was calculated for comparability. Missing data were dealt with by excluding these time points from the calculations (see Results section).

When examining change over time, percentage reduction in total intrusions per week was calculated from the baseline phase to intervention phase to other time periods as following [1 - (mean number per week during intervention phase/mean number per week during baseline)] * 100). For example, for one participant there were 19.87 intrusions per week in the baseline phase and 3.75 intrusions per week in the intervention phase, this was calculated as [1 - (3.75 / 19.87)] × 100 = 81.09% reduction in the intervention phase compared to baseline.

Change in the number of targeted intrusive memories relative to non-targeted memories. Next, we examined the data per intrusive memory. Specifically, we examined the number per week

of targeted memories in comparison to non-targeted ones. This was done by calculating the number in the same way as described above for targeted memories (i.e., each of the targeted memories has different baseline and intervention periods). However, a standard baseline and intervention periods were established for non-targeted memories (i.e. same length of periods for all non-targeted memories) since they were not targeted with the intervention. The baseline for each non-targeted memory was one week (i.e., before any memory was targeted) and the intervention phase was determined as the period from when any memory was targeted with the intervention.

Change in other symptoms and functioning. A descriptive approach was used to investigate whether clinically meaningful changes were observed in overall symptoms of posttraumatic stress, depression, anxiety, and functional impairment.

Ethics statement

The study was approved by the National Bioethics Committee in Iceland (No: VSNb2017110046/03.01). All participants provided their written and informed consent. All sessions followed a written protocol. No adverse events related to the intervention were reported by participants.

Open Science statement

The study was preregistered prior to study start on ClinicalTrials.gov (NCT04209283) on 2020-11-03. Anonymized summary-level data are reported in this manuscript. Study materials may be made available upon reasonable request with an appropriate material transfer agreement (MTA) with Uppsala University (for the imagery competing task intervention and diary) or University of Iceland (all other measures). We note that delivery of this intervention at present requires the prerequisite training and supervision by psychologists with experience of developing it (see Procedure: Training).

Results

Participants had varying numbers of intrusive memories at baseline (see Table 1 and Figure 2 for an

overview). P1 monitored the frequency well but data were missing for day 8 during baseline and for days 16-17 during the intervention phase. P2 monitored the frequency accurately with no missing data. P3 monitored the frequency quite accurately but data were missing for day 7 during baseline and for days 20-21 and day 25 during the intervention phase. P4 monitored the frequency accurately with no missing data. P5 accurately monitored the frequency of her intrusive memories with no missing diary data. P7's diary data were missing for day 22 during the intervention phase. P9 had missing diary data for eight days during the intervention phase (day 36 – 43) and P10 had no missing diary data. No attempts were made to retrieve missing diary data, 97.5% of diary data was completed for all eight participants.

Primary outcome

Change in the total number of intrusive memories.

[Insert Figure2 here]

Figure 2. *Total number of intrusive memories per day for each participant across phases; baseline, intervention, and follow-ups.* Graphs for visual inspection of primary outcome data for each participant (on the y axis as total number of intrusive memories per day, i.e., for all distinct memories combined). Days since study start are shown on the x-axis, which includes baseline (grey), intervention (white), and follow-up periods (light grey). Dashed vertical lines show when each intervention session was administered, and which specific traumatic memory was targeted. Memories are labelled in order of when they were targeted (e.g., 'Memory A' was targeted in the first intervention session). Dotted vertical lines show the 1-month and 3-month follow-up periods. Gaps in the time series represent missing data.

The total frequency per week for all intrusive memories during each phase for each participant (baseline, intervention, 1-month, and 3-month follow-up) can be seen on Figure 2. It should be noted that each figure shows the frequency of intrusive memories over the whole week *after* the baseline session (leading up to the first intervention session), and the frequency of intrusive memories the week *after* the first intervention session etc. Visual inspection for P1 shows that after the first intervention session the total frequency of intrusions was reduced. The frequency continued to drop during the intervention phase and was zero at the follow-up periods. Visual inspection for P2 shows fluctuations in frequency over the intervention phase and an increase in frequency at follow-up. Visual inspection for P3 shows a noticeable drop in frequency after the first intervention session followed by an increase after the second session. However, the frequency goes down in the third

session and increases slightly over the rest of the intervention phase. The frequency increases at 1-month follow-up and then decreases again at 3-month follow-up. For P4, visual inspection shows the frequency of intrusions reducing after the first intervention session and remaining stable with some fluctuations over the intervention phase. The reduction is maintained at 1-month follow-up. Visual inspection for P5 shows the frequency going down after the second intervention session and continuing to reduce over the intervention phase, although that reduction is not maintained during follow-up. For P7 there are fluctuations in the number of intrusive memories until after the fifth intervention session where there is a clear drop in the frequency which is maintained through the follow-up periods. Visual inspection for P9 shows fluctuations in the number of intrusive memories from baseline, throughout the intervention period but the frequency is reduced at the 3-month follow-up period. For P10 the frequency seems reduced after the first intervention session and continues to drop after the third intervention session, the number of intrusive memories is zero after the fifth intervention session and remains so for the follow-up periods.

The mean number of targeted and non-targeted intrusions per week at the baseline phase, intervention phase, at 1-month and 3-month follow-up is shown in Table 2. Overall, the number of intrusive memories reduced for all participants from the baseline phase to the intervention, although the reduction was minimal for 2 participants. The range of percentage reduction from baseline to post-intervention varied from 6.3% to 93.3%. For five out of eight participants the percentage reduction was larger at 1-month follow-up than postintervention from baseline, ranging from 27% to 100%. For six out of eight participants the percentage reduction was larger at 3-month follow-up than during the intervention phase compared to baseline, ranging from 58.3% to 100%. For P2 the number of intrusive memories was roughly the same at 3-month follow up as at baseline (26 intrusive memories per week). The number of intrusive memories for P5 was higher (3 memories per week) at the 3- month follow-up than during the intervention phase (0.5 memories per week).

Table 2. Mean number of intrusive memories and percentage reduction per week across all phases;

baseline, intervention, at the 1-month, and the 3-month follow-ups and total targeted- and non-targeted intrusions for each participant.

	Intrusions	Baseline (A)	Intervention (B)	% reduction	1-month follow-up	% reduction	3-month follow-up	% reduction
P1	Total	28.6	2.5	91.4%	0	100	0	100%
	Total targeted	28.6	2.5		0		0	
	Total non-targeted	-	-		-		-	
P2	Total	26.2	23.2	11.3%	44	-68.1%	26	-
	Total targeted	21.2	14.7		21		20	
	Total non-targeted	5	8.6		23		6	
P3	Total	17.1	10.1	41.0%	15	12.3%	10	41.5%
	Total targeted	13.6	8.5		2		10	
	Total non-targeted	3.5	1.6		13		0	
P4	Total	50.3	28.9	42.5%	19	62.2%	-	-
	Total targeted	47.3	27.8		19		-	-
	Total non-targeted	3	1.1		0		-	-
P5	Total	7.5	0.5	93.3%	5	33.3%	3	60.0%
	Total targeted	6.5	0.5		3		3	
	Total non-targeted	1	0		2		0	
P7	Total	32	24.1	24.8%	11	65.7%	9	71.9%
	Total targeted	27	21.3		11		8	
	Total non-targeted	5	2.8		0		1	
P9	Total	9.6	9	6.3%	7	27.1%	4	58.3%
	Total targeted	9.6	9		7		4	

	Total non-targeted	-	-		-		-	
P10	Total	19.9	3.8	81.1%	0	100%	0	100%
	Total targeted	19.9	3.8		0		0	
	Total non-targeted	-	-		-		-	

Change in the number of targeted intrusive memories relative to non-targeted memories.

The number of targeted and non-targeted intrusions per week at baseline, post-intervention, at 1-month, and 3-month follow-up, is displayed in Table 2. The mean number of individual targeted memories was 8.95 per week in the baseline phase and reduced to 6.11 per week over the intervention phase. The mean number of individual non-targeted memories was low or 2.74 per week in the baseline phase and reduced to 2.67 memories per week in the intervention phase. The number of individual targeted memories continued to reduce at 1-month follow-up week to 2.33 and the number of non-targeted reduced to 1.80 at 1-month follow-up. At the 3-month follow-up week the mean number of individual targeted memories was further reduced to 1.67 and the mean of individual non-targeted memories was reduced to 0.33.

Secondary outcomes

Ratings of adherence and general impact of intrusive memories.

The participants filled out the intrusion diaries quite accurately throughout the study (mean rating was 8.7/10, *SD* = 1.16). The participants rated their intrusions in general as becoming less vivid and distressing over the intervention and follow-up phase. Seven out of the eight participants self-administered the intervention at home during the intervention phase.

Feasibility and acceptability for using a smartphone gameplay intervention.

All participants rated the intervention to be an acceptable way to reduce the frequency of intrusive memories (*M* = 9.5; *SD* = 0.8).

Self-report measures on PTSD, depressive and anxiety symptoms and general functioning.

The participants filled out questionnaires for PTSD, depressive and anxiety symptoms and general functioning at baseline, after the last intervention session and at follow-ups; see Table 3. For the participant group, there was a reduction in PTSD symptoms for participants from a score of 47.6 at baseline measures on the PCL-5 to a score of 32.8 post-intervention.

The scores were further reduced in the 1-month follow- up to 27.9 and to 27.0 at the 3-month follow-up. Depressive symptoms were reduced from 12.9 at baseline to 9.9 post-intervention, although slightly elevated at the follow-up phases (10.4 at 1 month follow-up and 10.3 at 3-month follow up). Anxiety symptoms reduced from 10.8 at baseline to 6.6 post-intervention and remained stable at 6.4 at the 1-month follow-up but were slightly increased to 7.7 at the 3- month follow-up. Functional impairment was reduced in a clinically significant way for participants from 18.3 at baseline to 10.4 post-intervention. At follow-ups, the reduction in impairment in functioning related to the intrusions continued to drop to 9.6 at 1-month follow-up and to 7.4 at the 3-month follow-up (see Table 3).

Table 3. Self-report measures for secondary outcomes and impact of intrusive memories on concentration, sleep, stress, and daily functioning mean for all participants.

Item	Baseline interview *M* (*SD*)	Post-intervention *M* (*SD*)	1-month follow-up *M* (*SD*)	3-month follow-up *M* (*SD*)
PCL-5[a]	47.6 (15.2)	32.8 (16.5)	27.9 (19.4)	27.0 (17.9)
PHQ-9[b]	12.9 (8.0)	9.9 (6.7)	10.4 (7.1)	10.3 (7.4)
GAD-7[c]	10.8 (4.5)	6.6 (4.8)	6.4 (4.8)	7.7 (5.4)
SDS[d]	18.3 (8.2)	10.4 (5.7)	9.6 (8.0)	7.4 (7.0)
Concentration[e]	5.9 (1.7)	2.5 (2.2)	2.9 (2.2)	2.6 (2.1)
General concentration[f]	7.0 (1.7)	4.4 (2.9)	4.5 (3.4)	4.4 (3.2)

Duration of disruption[g]	2.3 (1.2)	1.8 (0.7)	1.4 (0.7)	0.7 (0.5)
Sleep[h]	4.8 (2.9)	1.5 (2.6)	1.9 (2.8)	1.3 (2.2)
Nightmares[i]	2.8 (3.6)	1.9 (2.9)	1.3 (2.6)	1.3 (2.4)
Stress[j]	5.8 (2.4)	3.4 (2.5)	2.8 (2.3)	2.4 (1.9)
Daily functioning[k]	4.4 (3.2)	2.0 (1.9)	2.3 (1.9)	2.1 (1.8)

Note. [a]*The Posttraumatic Stress Disorder Checklist*; scores ranging from 0 – 80; [b]*The Patient Health Questionnaire-9;* scores ranging from 0 – 27; [c]*The Generalized Anxiety Disorder scale*; scores ranging from 0 – 21; [d] *The Sheehan Disability Scale*; scores ranging from 0 (unimpaired) to 30 (highly impaired). [e]In the past week, how much did your intrusive memories disrupt your concentration? 0 = not at all disruptive; 10 = extremely disruptive; [f]In the past week, how much difficulty did you have concentrating generally? 0 = no difficulty concentrating; 10 = extremely difficult to concentrate; [g]When you had an intrusive memory, how long did it disrupt your concentration (in minutes), in the past week? 0 (<1 min); 5 (>60 min); [h]Did your intrusive memories interfere with sleep during the night in the past week? 0 = not at all; 10 = interfered very much; [i]Did you experience any nightmares that interfered with your sleep during the night in the past week? 0 = did not experience any nightmares; 10 = experienced a lot of nightmares; [j]In the past week, did your intrusive memories affect how stressed you felt? 0 = not at all; 10 = affected very much; [k]Have the intrusive memories affected your ability to function in your daily life? 0 = not at all; 10 = affected very much.

Impact of intrusive memories on concentration, sleep, stress, and daily functioning.

Table 3 also shows ratings of the impact of intrusions on concentration, stress, sleep and daily functioning during all phases. Concentration difficulties related to the intrusions were lowered from baseline to post-intervention and were maintained at follow-up. Ratings on concentration in general showed a similar pattern. The effect on estimated duration of disruption following an intrusion was reduced from 2.3 at baseline to 1.8 post-intervention, to 1.4 at 1-month follow-up and to 0.7 at 3-month follow-up. The effect the intrusive memories had on sleep reduced from 4.8 at baseline to 1.5 post-intervention. These improvements on sleep were maintained at follow-up. Participants' nightmares reduced from baseline to post-intervention and to follow-up phases. Participants reported less stress related to the intrusive memories post-intervention (3.4) compared to baseline (5.8), which continued to reduce to 2.8 at 1-month follow-up and to 2.4 at 3-month follow-up. The impact that

intrusive memories had on the ability to function in daily life was 4.4 at baseline and was reduced to 2.0 post-intervention, this reduction was maintained at follow-up phases.

Discussion

In this case series, we built on our previous case study (N=1) [22] and case series (N= 3) [23] and further investigated the effects of a novel intervention to reduce intrusive memories of past trauma. The total number of intrusive memories (primary outcome) of trauma occurring years earlier were reduced from baseline to the intervention phase among six out of eight participants (25% to 93% reduction). For five out of eight participants the number of intrusive memories continued to reduce to follow-up phases. Two participants reported zero intrusions at follow-up. In general, the frequency of targeted intrusions reduced more than non-targeted intrusions.

The overall trend for secondary outcomes was that symptoms of PTSD, depression and anxiety reduced significantly for most participants from baseline to post-intervention and symptoms continued to reduce to follow-ups for most of them. Symptoms were reduced in a clinically significant way on the measure of anxiety, but not on measures of PTSD and depression. Functional impairment was improved for participants and continued to improve at follow-up phases. Participants reported less stress related to intrusive memories and their sleep was improved. The time intrusive memories interrupted concentration was lessened from approximately 30-minute disruption at baseline to approximately 5-10 minutes post-intervention and continued to reduce to at about 1–5-minute disruption at the 3-month follow-up. The effect intrusive memories had on participants' ability to function in daily life was also improved from baseline to post-intervention and this improvement was maintained at follow-up.

Findings for the primary outcome are similar to Kessler et al. 2018 [26] (reduction of 64% overall), and our previous case study [22] and case series [23] where the reduction in the number of intrusive memories ranged between 38% and 56%. This findings also follow the same trend as the results found in Kessler et al. 2018 [26] in which targeted intrusions reduced by 64% and non-

targeted intrusions by 11%. However, it should be noted that here the number of non-targeted intrusions was very low at baseline. Overall, the longer-term follow up results on symptoms reduction over time are in accordance with our previous case study [22] and case series [23]. These results suggest the potential longer-term effects on intrusions, which could be due to the simplicity of self-administered use of the intervention, giving participants the chance to use it independently if needed once they have been taught how to use it.

Future research should explore whether self-guided use that extends to all intrusive memories instead of just targeted ones would result in greater reductions in intrusive memories. It is not clear why two participants did not experience clear treatment gains. More research is needed with larger samples in order to determine predictors of treatment response and hopefully to adjust the intervention if needed to different groups.

Follow-up results may suggest that clinically targeting core symptoms like intrusive memories in PTSD can have effects on other symptoms in the symptom network [46,47].It should be highlighted that in the current study all sessions were carried out remotely and all participants found the intervention to be an acceptable way to reduce intrusive memories and that they would certainly recommend it to a friend, similar to previous research [22,23]. Delivery of the intervention in person does not seem to be essential and remote delivery appears acceptable and effective.

This intervention developed to target one symptom of PTSD does not include some of the barriers that current PTSD treatment entails, including patients' reluctance to recall the traumatic event in detail, high cost and geographical barriers [11]. In the current case series, the intervention was delivered completely remotely, removing geographical constraints, thus being able to reach people regardless of their location or situation (e.g., in quarantine during the COVID-19 pandemic; [28]). Results to date are promising. However, future research should move toward larger scale testing, and comparing the remotely delivered intervention to a credible control task.

Critically, taking one step further towards simplicity, the intervention was delivered to four

participants (half of participants) by a master level student and two bachelor degree graduates, i.e. not mental health professionals, after receiving training in the intervention. This did not affect the results, which indicates that non-specialists in trauma therapy could successfully deliver the intervention after appropriate training. Treating people post-trauma without the need for a mental health specialist (as only some of our researchers were clinically qualified) is a novel contribution of the current research study. And one that if tested further in an RCT could help improve the scalability of treatment delivery. It is important to test this intervention with case series involving other groups, such as men and more diverse populations, before moving on to an RCT which could help improve the scalability of treatment delivery. This could mean after RCT validation that the intervention could benefit other groups after trauma for example regarding ethnicity and gender.

Limitations

This case series included participants of one group (Icelandic women), as well as including a small sample size, therefore limiting the generalizability of results. Furthermore, we cannot estimate the effects of common factors of treatment as we did not include a credible control task.

Conclusions

When delivered remotely, and by non-mental health professionals, this imagery competing task intervention (including a brief memory reminder cue + Tetris gameplay with mental rotation) showed promising results in reducing the frequency of intrusive memories for women with trauma that could be from many years back. Results confirm and extend previous studies involving older trauma memories. Targeting intrusive memories of trauma appeared to impact PTSD, depression and anxiety symptoms (secondary outcomes), which may suggest that such targeted efforts can have effects on other symptoms in the symptom network. Delivering the intervention remotely was feasible and acceptable to all participants. Participants opted for varying numbers of intervention sessions (ranging from three to six sessions). It would be interesting to explore whether similar gains

could be achieved with fewer sessions. Furthermore, it should be explored how psychoeducation could be added to the intervention package in the form of simple videos explaining how intrusive memories are formed and how the intervention works and why it can be effective – further moving the intervention delivery towards self-guided delivery. The next steps in developing the intervention and assessing its effectiveness could include fewer sessions, less researcher support, and having non-mental health professionals deliver the intervention. Although the results are promising these findings are preliminary since the efficacy of the intervention needs to be validated with a larger scale RCT comparing the intervention to a credible control task.

Conflict of interest

EAH also received salary partly funded by the Welcome Trust (223016/Z/21/Z) via consultancy to P1vital Products Ltd; EAH developed the imagery-competing task intervention and know-how in using it over the last 20 years (ANEMONE ™); is on the Board of Trustees of the MQ Foundation; reports book royalties from Guildford Press and Oxford University Press, occasional honoraria for conference keynotes and clinical workshops, and occasional consultancy fees from the Swedish agency for health technology assessment and assessment of social services. Other authors declare no conflicts of interest.

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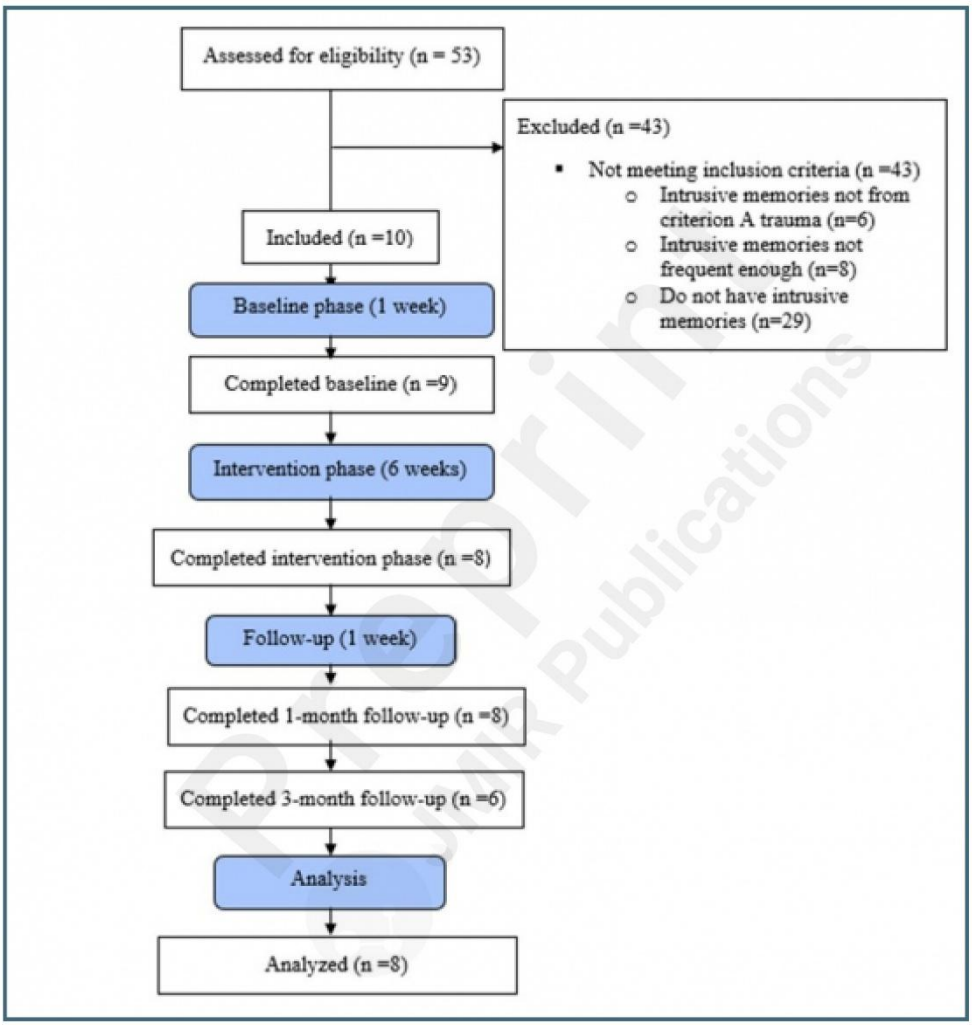
Supplementary Files

Figures

Adapted CONSORT Flow Diagram for the study.



Total number of intrusive memories per day for each participant across phases; baseline, intervention, and follow-ups.