Intrusive Emotional Memories: A Special Form of Memory?

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This dissertation is submitted for the degree of Doctor of Philosophy

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September 2016

Preface

The work described in this thesis was conducted at the Medical Research Council Cognition and Brain Sciences Unit (Cambridge, UK) under the supervision of Professor Emily Holmes & Professor Richard Henson (October 2013 – September 2016).

Declaration: this dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration except as specified in the text and Acknowledgements. It is not substantially the same as any that I have submitted, or, is being concurrently submitted for a degree or diploma or other qualification at the University of Cambridge or any other University or similar institution. I further state that no substantial part of my dissertation has already been submitted, or, is being concurrently submitted for any such degree, diploma or other qualification at the University of Cambridge or any other University of similar institution.

It does not exceed the prescribed word limit for the Degree Committee (Biology; word limit excluding references, tables, figures and appendices: 60 000 words; current word count = 41 611 words).

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September 2016

Acknowledgments

I would like to dedicate this thesis to my parents. From them I learned little about academia, but plenty about humility, curiosity and tenacity – all of which have helped me run towards the finishing line.

Thank you to:

Emily and Rik, whose combined supervision provided countless learning experiences over the last three years. Thank you Emily for showing how to navigate seamlessly between the lab and the clinic – your guidance will influence the way I cultivate, connect and communicate ideas within and beyond clinical science. Thank you Rik for sharing your theoretical and experimental thinking, and for the most timely and sharpest critical insights;

The CBU, for being a truly remarkable place to come to work daily, and for opening the door to many great minds and invaluable friendships;

My team (The Mental Imagery and Emotional Disorders Group), for your encouragement and camaraderie;

My fellow PhD's, who have accompanied me through this journey;

Selwyn College, for your community and the support to pursue many interests;

and The Cambridge Commonwealth, European and International Trust, whose generous award made possible the work in this thesis and, most importantly, the transformative experiences in Cambridge – which will lead to many rather positive intrusive memories.

Abstract

A key clinical target after psychological trauma is the mitigation of (involuntary) intrusive memories of the trauma without 'erasing' the content of the same memory for deliberate (voluntary) retrieval. Critical to this thesis, experimental psychopathology research has indicated that reductions in the frequency of intrusive memories could occur while leaving voluntary memory (e.g., recognition) apparently intact. However, such data challenge mainstream theories of episodic memory consolidation, which would expect a general involuntary/voluntary memory disruption. The work described in this thesis aimed to provide an experimental investigation to examine this puzzle, by focusing on the impact of an interference procedure (delivering reminder cues followed by Tetris game-play) during memory 'consolidation' of a trauma film (i.e., 30 min after viewing) on subsequent memory of the film.

Using a battery of involuntary and voluntary memory measures, four experiments aimed to a) replicate the intrusion/recognition experimental dissociation on existing measures, b) establish if the involuntary/voluntary memory dissociation holds with improved measures, and c) investigate candidate factors that could explain such dissociation. These experiments also investigated the relationship between two additional procedural features and this dissociation: the timing of intrusion measurement and the role of reminder cues prior interference. The pattern of findings revealed that a) the intrusion/recognition dissociation was consistently replicated (Experiment 1, 2 and 4); b) the involuntary/voluntary memory dissociation still held even with improved measures (Experiment 1, 2 and 4); and c) the novel measures ruled out several candidate factors as explanations for this dissociation, including task-relevant cues (Experiment 1), attention bias to task-irrelevant cues (Experiment 2), working memory load at retrieval (Experiment 3) and associations between scenes (Experiment 4). Additionally, the interference effect on intrusions appeared as non-time-dependent, i.e., emerged almost immediately after interference (Experiment 1, 2 and 3) but cue-dependent, i.e., interference was effective only with the delivery of reminder cues (Experiment 3). Finally, a meta-analysis across experiments showed that the interference effect on diary-based intrusion of the film was more pronounced for intrusions triggered by sensory-perceptual rather than abstract cues in daily life.

It is argued that none of the current theories on episodic memory consolidation can fully account for these findings, which suggest that the interference procedure spares memory content whilst targeting the involuntary (but not voluntary) access of the memory in the form of intrusion frequency only. These data highlight the clinical promise for translational work and call for methodological improvements better tailored to intrusive memory phenomena. Critically, current results prompt the need for revisions to the major memory theories, in order to accommodate such a highly consistent and selective effect on intrusive emotional memories while voluntary memory remains spared.

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1. Clinical, Theoretical, and Experimental Psychopathology Perspectives

Aim and Motivation

This thesis aims to provide an experimental investigation of intrusive emotional memories and their functional dissociation from the deliberate retrieval of the same event. The investigation is motivated by an apparent contradiction between data and theory. Data from experimental psychopathology research has consistently shown that intrusive/involuntary memory of an emotional event (i.e., a trauma film) can be independently manipulated alongside intact deliberate/voluntary memory. However, such a pattern of findings challenges mainstream theories of memory consolidation, which would instead predict a general involuntary/voluntary memory disruption. This paradox begs for resolution.

Clinical Perspectives: Intrusive Memories as Key Intervention Target Following Psychological Trauma

Initial Definition of Intrusive Memories

Intrusive memories are the conscious recollections of emotional events from the past which are brought to mind involuntarily, often accompanied by the phenomenological experience of such a memory 'popping up' and almost 'out of the blue'. These memories typically involve mental imagery, particularly in the visual domain, i.e., 'seeing in the mind's eye' (Brewin, Gregory, Lipton, & Burgess, 2010; Holmes & Mathews, 2005). In that sense, intrusive image-based memories mentally simulate the original perceptual experience (Ehlers, Hackmann, & Michael, 2004; J. Pearson, Naselaris, Holmes, & Kosslyn, 2015). Intrusive memories are widely discussed for negative events, but recurrent involuntary memories can also result from positive events (Brewin, Christodoulides, & Hutchins, 1996; Bywaters, Andrade, & Turpin, 2004). The 'intrusiveness' of a memory is in contrast to deliberate attempts to remember the same event, which instead involves voluntary retrieval (Berntsen, 2009; Brewin, 2013).

More recent conceptualizations on intrusive memories (Hyman et al., 2015; Kvavilashvili, 2014) have called for better delineating the 'fuzzy' boundary between *involuntary* and *intrusive*. These views argue that in addition to spontaneity of retrieval, the key distinctive feature of intrusive memories is their repetitive nature (e.g., frequency of occurrence), whereas (non-intrusive) involuntary memories can be one-off and never spring back again. Such repetitiveness can be outside of one's control, invite avoidance/suppression attempts, and may disrupt ongoing activities. For simplicity, the terms 'intrusive memories' and 'intrusions' would be used interchangeable throughout the thesis.

Across Daily Life and Psychological Disorders

In everyday life, involuntary retrieval occurs frequently (Berntsen, 2009; Conway & Pleydell-Pearce, 2000; Hyman et al., 2015; Kvavilashvili & Mandler, 2004). Within emotional psychopathology, intrusive memories have been theorised to play a critical role in the development and maintenance of various psychological disorders (Brewin et al., 2010; Dalgleish, 2004; Ehlers & Clark, 2000; Foa et al., 1986; Hackmann & Holmes, 2004), including depression (Meiser-Stedman, Dalgleish, Yule, & Smith, 2012; T. Patel et al., 2007), bipolar disorder (Gregory, Brewin, Mansell, & Donaldson, 2010), social anxiety (Wild, Hackmann, & Clark, 2008), agoraphobia (Day, Holmes, & Hackmann, 2004) and health anxiety (Muse, McManus, Hackmann, Williams, & Williams, 2010).

Table 1.1

Examples of Intrusive Memories from Patients Diagnosed with Post-Traumatic Stress Disorder

"The body between the tube and the platform"
"Being pushed to floor, them saying 'get down' and being tied up"
"Gun put to head"
"He runs off and I look back to my house to see my daughter crying and banging at door"
"His face above me, laughing, laughing, laughing"

Note. Examples taken from Holmes, Grey & Young (2005).

Perhaps the most striking illustration is in psychological trauma, where intrusive memories of the event(s) constitute the cardinal symptom of stress-related disorders, including Acute Stress Disorder (ASD) and Post-traumatic Stress Disorder (PTSD) (*DSM*-5; American Psychiatric Association, 2013). See Table 1.1 for examples of intrusive memories in patients with PTSD. Although repetition may be a unique feature of intrusive compared to (non-intrusive) involuntary memories, a patient can experience intrusions of several distinct moments of the wider traumatic event rather than of just a single moment (Ehlers, 2010; Holmes et al., 2005). A study reported that a given patient with PTSD could identify up to 7 hotspots of their trauma, i.e., moments that caused higher levels of distress, with the majority of these moments also popping back as intrusive memories (Grey & Holmes, 2008).

Intrusive memories are hypothesised to drive the remaining symptoms in clinical post-traumatic distress (Brewin, Dalgleish, & Joseph, 1996; Ehlers & Clark, 2000), such as avoidance, hyperarousal and negative cognitions, e.g., 'I am going to die'. In fact, some evidence points towards early re-experiencing symptoms, including intrusive memories, contributing to the subsequent development of PTSD (Creamer, O'Donnell, & Pattison, 2004; Hackmann, Ehlers, Speckens, & Clark, 2004; Michael, Ehlers, Halligan, & Clark, 2005; O 'Donnell, Elliott, Lau, & Creamer, 2007). Given the trandiagnostic nature of intrusive memories and their canonical status within psychological trauma, a major target for clinical innovation (prevention and treatment) is to mitigate their negative impact, particularly the repetitive occurrence of these memories.

Targeting Intrusive Memories While Sparing Deliberately-Retrieved Memories

What are the consequences of manipulating intrusive memories for other aspects of the same memory? This issue is little expanded in clinical studies. In the field of PTSD, several treatment development studies (e.g., pharmacology, electroconvulsive therapy) have been framed as seeking to 'erase' the trauma memory (Kroes et al., 2013; Schwabe, Nader, & Pruessner, 2014). While some have argued that it specifically refers to erasing the *affect* linked to the memory (e.g., Kindt, Soeter, & Vervliet, 2009), there is empirical evidence that some of those manipulations indeed also affect the capacity to deliberately retrieve the *content* of the memory (e.g., Lonergan, Olivera-Figueroa, Pitman, & Brunet, 2013). Note that psychological treatments for PTSD, such as Cognitive Behavioural Therapy (CBT; e.g., Ehlers & Clark, 2000) do not aim to 'erase' trauma memory.

Erasing or permanently altering a memory, even for traumatic event(s), can bring about profound legal, ethical and clinical consequences (Liao & Sandberg, 2008). In the legal context, for example, a trauma survivor may need to report the event in court, where even a minor detail (e.g., colour of a car or size of a weapon) can be critical for eyewitness testimony. In the professional context, a journalist repeatedly exposed to details of atrocities may need to deliberately conjure up mental images of the events to pitch a news story. Furthermore, it may be helpful to retrieve past events, even if negative, for the construction of one's autobiographical self and even to bring about post-traumatic psychological growth (Tedeschi & Calhoun, 2004). Hence, there are many occasions where deliberately retrieve details of the trauma can be important and the inability to remember can be counterproductive.

Alongside the complexities associated with full forgetting, it may be argued that it is the *intrusive* nature of the trauma memory, and not its content per se, that is critical in the psychopathology of ASD/PTSD (Holmes, Sandberg, & Iyadurai, 2010). This opens up a novel therapeutic proposal: a clinical intervention may seek to target the *intrusiveness* of the trauma memory, i.e., the repetitive occurrence, without compromising *deliberate* attempts to retrieve the same information. In other words, an intervention would seek to reduce *involuntary* but not *voluntary* retrieval of the event(s). Thus, the simultaneous consideration of intrusive memories and deliberate memory for the same event(s) are paramount for traumatic stress research.

Theoretical Perspectives: The Relation between Intrusive and Deliberately-Retrieved Memories of the Same Event

Prominent theories in memory research allow us to derive predictions regarding the relation between intrusive and deliberate memory. Despite theoretical and empirical differences, memory processes are broadly divided into three stages: information is initially registered to leave a memory trace (encoding), which may become stabilised over a time period (consolidation), ultimately allowing later access to the trace (retrieval). It is important to specify the relation between intrusive and deliberate memory across each of these stages, in order to understand at which point one could selectively target intrusions without affecting deliberate retrieval. Below, relevant accounts are reviewed from the fields of episodic memory, autobiographical memory, PTSD memory and fear memory.

Episodic Memory

The literature on episodic memory does not typically differentiate intrusive memories from other forms of episodic memory. Originally coined by Endel Tulving (1983, 2002), episodic memories are defined as memories referring to a specific event with a particular spatiotemporal context. Crucially, he emphasized the role of mental imagery (Tulving, 2002), which allows episodic memory to perform 'mental time travel' and bring about a subjective sense of re-experiencing. Tulving (2002, p. 6) stated that "episodic memory is oriented to the past in a way in which no other kind of memory, or memory system, is. It is the only memory system that allows people to consciously re-experience past experiences…Most people naturally associate all memory with the past and are astonished to learn that this is not so". Such a description is consistent with the phenomenological experience that can intrusive memory can take one back to the past (Grey & Holmes, 2008; Holmes et al., 2005).

Episodic memories are contrasted with semantic memories (Tulving, 2002), which refer to general, acontextual storage of knowledge generalized across events. Both episodic and semantic memories form part of a declarative memory system, dedicated to explicit/conscious forms of memory, in contrast to retrieval from a non-declarative (procedural) memory system (Squire, 1992), supporting the implicit/unconscious memories associated with priming and classical conditioning. Note that intrusive memories are consciously experienced, i.e., examples of explicit (declarative) memory rather than implicit memory, highlighting the important distinction between retrieval volition (voluntary vs involuntary) and retrieval awareness (explicit vs implicit) (Richardson-Klavehn, Gardiner, & Java, 1995).

While multiple memory systems have been proposed, most theories assume a single system for episodic memory. Based on neuropsychological and neuroimaging data, this system is believed to involve the hippocampus and connected regions in the medial temporal lobe (MTL) and broader neocortex (McKenzie & Eichenbaum, 2011; Winocur, Moscovitch, & Bontempi, 2010). One prominent view, the Standard Consolidation Theory (Squire & Zola-Morgan, 1991), is that episodic memories are initially encoded in the hippocampus, but then gradually consolidated into the neocortex (e.g., over days, weeks or months, perhaps during sleep), based primarily on evidence that hippocampal lesions impair recently-formed memories but not older memories.

Such standard view is challenged by the semantization theory (Rosenbaum, Winocur, & Moscovitch, 2001), which proposes that consolidation into the neocortex also involves a change in the nature of the memories, as they become more "semantic" (gist-like) than "episodic" (details). Another challenge is from the Multiple Trace Theory (Nadel & Moscovitch, 1997), which instead argues that the greater effect of hippocampal lesions on recent than remote memories reflects the formation of multiple memory traces over time in the hippocampus, such that older memories have more traces and are therefore more robust to (partial) lesions

The concepts of consolidation and reconsolidation are elaborated later, but the relevant point here is that these broad system-level theories say more about storage-related processes and less about retrieval-related processes, e.g., differences between voluntary and involuntary retrieval of episodic memories. Thus, both involuntary and voluntary memory are assumed to operate on this same system. One reason for this is that episodic memory research tends to draw evidence from memory tests that emphasize *voluntary* retrieval, also been referred to as retrieval mode or retrieval orientation (Tulving, 1983). Further, the most commonly used paradigms employ simple stimuli presented in the laboratory, such as static images and word lists. These experiments are quite different from those used to study autobiographical memory.

Autobiographical Memory

Autobiographical memory research concerns the study of memories about one's personal past (e.g., memories of events in daily lives). Intrusive memories, which typically arise from personally-meaningful events, have received a greater treatment within this literature. Although the term autobiographical memory and episodic memory have been used interchangeably, researchers have argued that autobiographical memory also includes semantic memories, i.e., is not limited to specific episodes.

Paradigms within this tradition depart from a typical episodic memory test by considering more naturalistic/real-life events and by also assessing phenomenological properties (e.g., vividness and emotionality of a memory) beyond accuracy. A commonly used method is the use of diaries or structured interviews, with some more recent developments in laboratory-based paradigms (e.g., Schlagman & Kvavilashvili, 2008; Staagard & Berntsen, 2014; Plimpton, Patel, & Kvavilashvili, 2015). Importantly, the use of real-life memories means that this field puts less emphasis on encoding and consolidation due to little control over these stages, and more emphasis on retrieval and reconstructive processes. Thus, this literature has more explicitly studied the involuntary/voluntary memory distinction. Here, intrusive memories are conceptualized as a specific form of involuntary access to the autobiographical memory system shared with voluntary memory. Two prominent accounts will be described below.

One account proposes that autobiographical memories are constructed within the Self-Memory System (Conway & Pleydell-Pearce, 2000). In this system, episodic memory is the storage of experiences containing rich sensory-perceptual details (Conway, 2001), in line with Tulving's description. However, episodic memories are integrated with the wider and higher-order autobiographical memory knowledge structures (general events, life periods, themes). This account provides a detailed articulation of the involuntary/voluntary distinction. Involuntary retrieval is explained as an automatic activation of episodic representations via a process of cue matching, with such cues sharing sensory-perceptual features with the original event. Importantly, episodic instances need to be activated enough to capture attention and appear into consciousness, such as when cues match one's current goal and concerns. This explanation of involuntary retrieval is used to account for the experience of intrusive memories in both daily life and psychopathology. In contrast, voluntary retrieval requires the semantic elaboration of an initial cue leading to a directed search. Such a search may start from a higher-order autobiographical memory structure such as life events, but eventually can also reach the episodic memory system. Moreover, involuntary retrieval is thought as less probable than voluntary retrieval because of a supposed low probability of one encountering closely-matched cues.

Berntsen (2009) has provided one of the most comprehensive accounts of involuntary retrieval. Contrary to Conway (2001), Berntsen (2009) views involuntary memory as a 'basic mode of remembering' and thus occurring as frequently as voluntary memory. This theorization also explicitly states that both involuntary and voluntary autobiographical memories operate on the same underlying memory system, sharing encoding and consolidation processes but differing in retrieval mechanisms (Rubin, Boals, & Berntsen, 2008). Voluntary retrieval is characterized as a goal-directed process requiring executive functions, whereas involuntary retrieval occurs via associative processes. Specifically, cue-triggered activation is thought to automatically spread across an associative network of memories, leading to involuntary memories. This process is aided by a diffused state of attention (such as during monotonous, low-attention demanding tasks) and by the presence of situational cues, typically matching in sensory-perceptual properties, in line with Conway's account.

Overall, both autobiographical memory theories (Berntsen, 2009; Conway, 2001) explain intrusive memories (even in PTSD) with the same principles governing involuntary retrieval of autobiographical memories, without needing to invoke 'special' mechanisms distinct from memories in daily life.

PTSD Memory

Clinical study of intrusive memories has occurred most often in the context of PTSD, given their status as hallmark symptoms. PTSD-specific theories were developed by clinical researchers, drawing on findings from clinical practice, patient studies and experimental work. A longstanding debate in this literature (Brewin, 2013; Kvavilashvili, 2014; Rubin et al., 2008) is whether (intrusive) trauma memory in people with and without PTSD (e.g., depression or other sub-threshold levels of posttraumatic distress) share qualitative or quantitative differences.

Several contemporary information-processing theories of PTSD propose qualitative differences in the re-experiencing of the traumatic event. For example, one clinical perspective is that intrusive memories in PTSD carry a sense of 'nowness' unlike those in depression (Brewin, 2013). Other forms of re-experiencing include dissociative flashbacks, i.e., when a person loses awareness of their surroundings, and affective responses without recollection (Ehlers & Clark, 2000), when a person displays emotions and behaviours without a conscious recall of the trauma. Thus, PTSD theories aim to explain a wider range of re-experiencing symptoms in addition to intrusive memories.

An influential account is the dual-representation theory (Brewin, Dalgleish, et al., 1996; Brewin, 2001, 2013). An early version (Brewin, Dalgleish, et al., 1996) proposed that two separate traces are formed at the time of trauma, governing voluntary and involuntary memory separately: *verbally-accessible memories* (VAM) containing the representations of trauma fully integrated with the wider autobiographical memory system, which can be voluntarily retrieved, and *situationally-accessible memories* (SAM) containing sensory and affective/emotional components, which can only be involuntarily retrieved. The latter is thought to be highly sensitive to cues that share sensory-perceptual properties or meaning with the event. Whereas this initial version was interpreted as a difference in modality/code between both involuntary vs. voluntary traces (e.g., visuospatial vs. verbal, Holmes, Brewin, & Hennessy, 2004), a revised version (Brewin et al., 2010) renamed both representations as *contextual representations* (or C-reps) vs. *sensory-bound representations* (S-reps). This new version proposes that the difference between traces reflects the processing performed on the same sensory input: C-reps contain information that has been recoded into an abstract structure and allocentric (contextual) viewpoint, whereas S-reps contain less-processed information that corresponds closer to a (self) egocentric viewpoint (intrusive memories result from the formation of weak C-reps and strong S-reps, together with an impaired connection between them). Brewin (2013) further argued for a separate and specialized long-term perceptual memory system underlying intrusive memories, which differs from that supporting ordinary episodic memory. Therefore, this theory proposes that involuntary and voluntary memories for the same trauma are subserved by distinct memory systems, diverging at all stages of encoding, consolidation and retrieval.

Another prominent account is the cognitive theory of PTSD (Ehlers & Clark, 2000), which unlike the dual-representation theory, does not assume a separate trace underlying intrusive memories. This theory proposes that enhanced data-driven processing (e.g., sensory impressions) and impaired conceptually-driven processing (e.g., making sense of the event) during encoding of the traumatic event leads in parallel to strong perceptual priming of stimuli during the trauma and poor integration with the wider autobiographical memory system. Enhanced perceptual priming facilitates subsequent cue-driven involuntary re-experiencing, driving intrusive memories, whereas poor memory integration leads to impaired voluntary retrieval (although it is not specified if this is for episodic or semantic details). To explain this involuntary/voluntary dissociation, Ehlers (2010) subsequently proposed that enhanced involuntary retrieval and impaired voluntary retrieval may apply to different moments, each of which constitutes a unique instance within the sequence of events. Therefore, it broadly appears that this theory explains involuntary and voluntary memory as two different access routes to the same underlying, albeit abnormal, memory trace for the trauma.

Holmes and Bourne (2008) synthesized testable predictions from the above models, highlighting that both models would assume that the relative balance between sensory and conceptual processing at the time of encoding determines the frequency of subsequent intrusive image-based memories. The synthesis made no differential prediction for deliberately-retrieved memory of the very same content.

Fear Memory

A final relevant literature concerns memory for fearful events, usually studied with conditioning paradigms (Kindt et al., 2009; VanElzakker, Dahlgren, Davis, Dubois, & Shin, 2014). Within this perspective, a neutral stimulus (conditioned stimulus) presented during the traumatic situation subsequently acquires fear-eliciting properties via association with an unconditioned stimulus. Later, exposure to such a neutral stimulus automatically elicits fear. Although this literature has not focused on intrusive memories as such, it has sought to provide mechanistic models to explain core PTSD symptomatology.

This literature highlights the dissociation between different levels of emotional responding that warrant consideration. Experimental work has demonstrated the possibility of selectively targeting the startle fear response, but not skin conductance nor expected contingencies (Soeter & Kindt, 2011). An explanation is that the latter two reflect knowledge subserved by the hippocampally-based declarative memory system (Squire, 1992), whereas startle responses originate from an amygdala-based non-declarative fear system (Hamm & Weike, 2005). The 'erasure' of such a fear response without compromising the actual knowledge of the contingencies is indeed clinically promising.

Although related, such a fear/knowledge dissociation is distinct from the involuntary/voluntary dissociation. Involuntary retrieval of an intrusive memory is not just 'fear', but it also involves consciously retrieving a memory, i.e., drawing from the declarative memory system. Relatedly, physiological responses to trauma reminders are listed as a separate symptom from intrusive memories in the DSM-5. Although a fear response may very well be part of an intrusive memory, it does not account for its image-based episodic nature. Surprisingly, prominent neural circuitry models of PTSD based on fear-conditioning findings do not include mental imagery (Liberzon & Martins, 2006). This conditioning literature, therefore, does not directly speak to dissociation between involuntary and voluntary memory, both within the episodic memory system.

A related concept widely discussed in this literature is *reconsolidation* (Hardt, Einarsson, & Nader, 2010). Challenging the traditional division between encoding, consolidation and retrieval, reconsolidation refers to the hypothesised process whereby retrieval of an already-consolidated memory can destabilize the memory trace, allowing for manipulations to influence the memory before its re-storage (Merlo, Milton, Goozee, Theobald, & Everitt, 2014; Walker, Brakefield, Hobson, & Stickgold, 2003). It has been proposed that certain properties of retrieval cues make them more likely to initiate reconsolidation to allow for memory modification, including the idea that such cues need to trigger a 'prediction error' (Henson & Gagnepain, 2010; Sevenster, Beckers, & Kindt, 2014). Unlike for fear memory, the idea that reconsolidation occurs is highly contested for human declarative memory systems (Chan & LaPaglia, 2013; Hardwicke, Taqi, & Shanks, 2016; Sederberg, Gershman, Polyn, & Norman, 2011). Nevertheless, the idea of reactivation points to the possibility that one may be able to selectively reactivate memory traces and subsequently implement targeted interference (whether for involuntary or voluntary memory).

Summary of Theories

Mainstream theories of episodic memory are surprisingly silent regarding the nature of intrusive memories. Therefore, the default assumption would appear to be that they are not a special form of memory, and can be accommodated by the assumption that both involuntary and voluntary memories represent two access routes to a shared episodic trace (Tulving, 2002). Such an assumption is explicitly articulated by accounts of autobiographical memory. Two prominent theories (Berntsen, 2009; Conway, 2001) explain intrusive memories within the mechanisms of involuntary retrieval, which is then contrasted with voluntary retrieval. Despite differences in the specific mechanisms, they converge on at least three central ideas: first, that involuntary and voluntary retrieval differ only at the retrieval stage; second, that involuntary memory is highly sensitive to the retrieval cue, particularly cues with sensory-perceptual properties matching the episodic memory; third, that voluntary memory for the same event typically occurs via a different retrieval mechanism involving goal-directed search, although it can eventually reach the same episodic trace.

In contrast to theories on episodic/autobiographical memories, PTSD theories (Brewin, 2013; Ehlers & Clark, 2000) have explicitly aimed to explain the intrusive emotional memories. Brewin proposes a separate trace underlying intrusive memories, distinct from voluntary retrieval for the same trauma event. Ehler's theory discusses mechanisms that highlight the sensory-perceptual and cue-driven nature of intrusive memories, but does not propose a different store for involuntary and voluntary memory for the same content. Finally, the fear memory (conditioning) literature implies links between fear responses and intrusive memories, but is silent regarding their image-based nature.

Theoretical Predictions Regarding an (Involuntary) Intrusive/Voluntary Dissociation

A satisfying theoretical account of intrusive memories needs to explain their episodic image-based and their transdiagnostic relevance. The possibility of targeting intrusive memories, without 'erasing' the memory itself, has the wider theoretical and practical applicability beyond PTSD. Therefore, this thesis derives predictions for intrusive memories from nonclinical episodic and autobiographical memory theories (collectively referred to as "mainstream theories" within this thesis).

These mainstream memory theories converge to predict that manipulations of memory retrieval (i.e., of the memory accessibility) could dissociate involuntary from voluntary memory, therefore opening the possibility of disrupting (involuntary) intrusive memories without affecting their (voluntary) deliberate access. However, manipulations of memory encoding and/or consolidation (storage), which putatively affects the underlying trace (i.e., memory availability), should produce equivalent effects on both involuntary and voluntary memory. That is, encoding/consolidation effects would not dissociate involuntary from voluntary memory.

An Experimental Psychopathology Perspective: Intrusive Memories Versus Deliberately-Retrieved Memories of the Same Emotional Event

Empirical data addressing the relation between intrusive and deliberately-retrieved memories are scarce, given the historical focus on voluntary memory and on the use of simple non-emotional stimuli. Additionally, while the involuntary/voluntary distinction has been better studied for autobiographical memories, the focus has been on paradigms that examine retrieval, ignoring the role of encoding and consolidation. The same difficulty applies to research with patients.

The Trauma Film Paradigm

In the field of experimental psychopathology, the trauma film paradigm (Holmes & Bourne, 2008; Horowitz, 1975; James et al., 2016; Lazarus, 1963) has emerged as a well-established methodology to study involuntary and intrusive memories. It uses film stimuli in the laboratory, which contain traumatic content that can bring about intrusive memories subsequently in daily life. These memories are typically recorded in a diary, allowing for a frequency count of intrusive memories (see Figure 1.1). Such a paradigm enables the study of memory for more ecologically-valid stimuli, but still within a laboratory setting, conferring additional experimental control.

However, this paradigm has focused on intrusive/involuntary but not deliberate/voluntary memories, hampering the study of their relationship. While the paradigm was first used in the 1960s, it appears that a voluntary memory measure was not considered until more recently (Brewin & Saunders, 2001; Holmes et al., 2004). Further, measures of voluntary memory have rarely been integrated in this paradigm; and when they have, they have been used mainly as manipulation checks (e.g., checking that attention was paid to the film), or have not been properly discussed along with the findings on intrusive memories. Inadvertently, this field has diverged from mainstream research on episodic memory, creating two literatures with little shared continuity. In the last decade, however, the proliferation of studies using the trauma film paradigm (James et al., 2016) provides a unique and timely opportunity to examine relations between involuntary and voluntary memory using this paradigm. This could then inform treatment-related research that aims to target intrusive but not deliberate memory, as well as feeding back to inform mainstream memory theories.

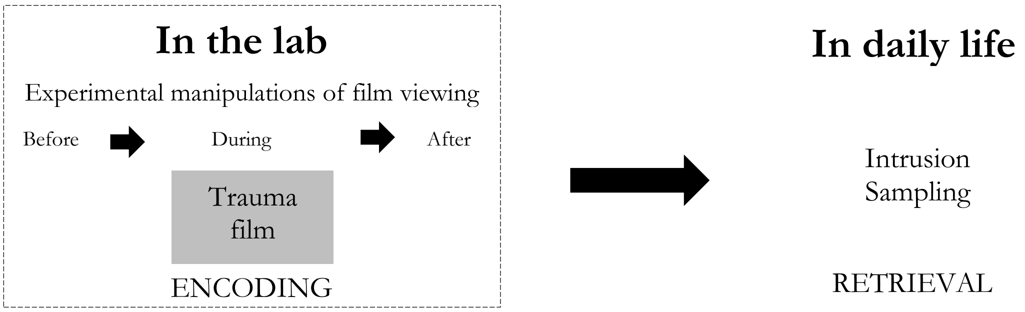


Figure 1.1. Schematic view of the trauma film paradigm (James et al., 2016). In a typical study using the paradigm, participants attend an initial laboratory session in which they watch the trauma film. Experimental manipulations can be administered before, during or after film viewing. Thus, this laboratory-based session allows for exposure to the initial event under controlled settings. Subsequently, intrusive memories are typically sampled in daily life and recorded in a diary (e.g., for a one-week period). A main outcome assessed is the frequency of intrusive memories. The diary methodology confers high ecological validity but lacks experimental control.

Mini-Review: Experimental Dissociations of Intrusive and Deliberate Memory Using the Trauma Film Paradigm (*N* = 21 studies)

The current review is constrained by considering a selective number of studies from a broader review of the trauma film paradigm by James et al. (2016). Twenty-one studies were included meeting the following criteria: the frequency of intrusive memories was assessed with the diary methodology, the most common outcome across studies; voluntary memory for the film was tested; the design was experimental. This mini-review is then structured according to variations of voluntary measures used (free recall, cued recall and recognition). As more than one test of voluntary memory was administered in some studies, each of these was compared against intrusion frequency within the same study, yielding 31 comparisons. Table 1.2 provides a summary of the studies, reporting the following information: timing of the experimental manipulation in relation to film viewing, timing of delivery of the voluntary memory test and its order in relation to intrusion sampling, the impact of experimental manipulations on both intrusion frequency and voluntary memory, and whether a functional dissociation between these measures was obtained.

Previous reviews considering the trauma film paradigm have not examined the relation between intrusive memories and voluntary memory (Holmes & Bourne, 2008; James et al., 2016; Krans, Becker, & Holmes, 2009), or did not differentiate between different types of tasks used to measure voluntary memory (Brewin, 2013; Clark, Mackay, & Holmes, 2014). Here, a more nuanced task-analysis approach is taken – to examine the relevance of such data to current theories by first considering the available methods carefully.

Free Recall.

In free recall tests, participants generate information from previously encountered stimuli without being exposed to retrieval cues. Only one study compared the effect of a manipulation on intrusion frequency vs. free recall. In this study (Hawkins & Cougle, 2013), participants were asked to view a film either after taking a nicotine or a placebo lozenge. Soon after, they were asked to perform a 10-min free recall test (day 1), in which they had to describe everything they could recall from the film. They were subsequently asked to carry an intrusion diary and return for a follow-up session (day 8) to perform free recall again. The nicotine manipulation had no apparent impact on diary intrusions or free recall. As this is the only experimental study comparing free recall with intrusions, it would be premature to make conclusions based on such data.

Table 1.2

Summary of Studies Using the Trauma Film Paradigm from 2008 Using an Experimental Design and Measuring both Intrusion Frequency (Diary) and Voluntary Memory (Free Recall, Cued Recall or Recognition)

Reference	Timing of manipulation	Timing of voluntary test	Order of voluntary test in relation to intrusions	Impact of on *involuntary* memory	Impact of variable on *voluntary* memory	Dissociation
Free recall						
Hawkin & Cougle (2013)	After	Day 1 & 8	Before & after	Spared	Spared	N
Cued recall						
Krans, Naring, Holmes et al. (2010)	During	Day 8	After	Attenuated by visuospatial movement	Attenuated by visuospatial movement	N
Krans, Naring & Becker (2010)	During	Day 8	After	Attenuated by verbal interference	Attenuated by verbal interference	N
Pearson (2012)	Before	Day 8	After	Amplified by contextual information	Spared	Y
Nixon et al. (2009b)	After	Day 1 & 8	Before & after	Amplified by suppression+load	Spared	Y
Nixon et al. (2009a)	After	Day 1 & 8	Before & after	Spared	Spared	N
Brown et al. (2012)	Before	Day 2	After	Attenuated by high-efficacy	Attenuated by high-efficacy (central details only)	N
Bourne et al. (2010; Exp 1)	During	Day 8	After	Attenuated by visuospatial interference	Attenuated by verbal interference	Y
Jobson & Dalgleish (2014; Exp 2)	After	Day 8	After	Attenuated by narrative task	Amplified by narrative task	Y
Krans et al. (2009)	After	Day 8	After	Attenuated by recognition task	Amplified by recognition task	Y
Hagenaars & Arntz (2012)	After	Day 8	After	Attenuated by imagery rescripting	Amplified by imagery rescripting & exposure	Y
Bisby et al. (2009)	Before	Day 8	After	Amplified by low dose; attenuated by high dose	Attenuated by high alcohol dose	Y
Recognition						
Bourne et al. (2010; Exp 1)	During	Day 8	After	Attenuated by visuospatial interference	Spared	Y
Bourne et al. (2010; Exp 2)	During	Day 8	After	Amplified by verbal interference	Attenuated by verbal interference	Y
Jobson & Dalgleish (2014; Exp 2)	After	Day 8	After	Attenuated by narrative task	Amplified by narrative task	Y
Krans, Naring & Becker (2010)	During	Day 8	After	Attenuated by verbal interference	Spared	Y
Krans, Naring, Holmes et al. (2010)	During	Day 8	After	Attenuated by visuospatial interference	Spared	Y
Pearson et al. (2012)	Before	Day 8	After	Amplified by contextual information	Spared	Y
Deeprose et al. (2012; Exp 2)	During	Day 8	After	Attenuated by visuospatial interference	Spared	Y
Holmes et al. (2009)	After	Day 8	After	Attenuated by Tetris	Spared	Y
Holmes et al. (2010; Exp 1)	After	Day 8	After	Attenuated by Tetris; amplified by Pub Quiz	Spared	Y
Holmes et al. (2010; Exp 2)	After	Day 8	After	Attenuated by Tetris	Spared	Y
James et al. (2016)	Before	Day 8	After	Spared	Spared	N
James et al. (2015; Exp 1)	After	Day 8	After	Attenuated by reactivation+Tetris	Spared	Y
James et al. (2015; Exp 2) – verbal	After	Day 8	After	Attenuated by reactivation+Tetris	Spared	Y
James et al. (2015; Exp 2) – visual	After	Day 8	After	Attenuated by reactivation+Tetris	Spared	Y
Nixon et al. (2009b)	After	Day 1 & 8	Before & after	Amplified by suppression+load	Amplified by suppression+load & suppression-only	Y
Nixon et al. (2009a)	After	Day 1 & 8	Before & after	Spared	Spared	N
Hawkins & Cougle (2013)	Before	Day 1 & 8	Before & after	Spared	Spared	N
Bisby et al. (2009)	Before	Day 8	After	Amplified by low dose; attenuated by high dose	Attenuated by low (gist) and high dose (gist & detail)	Y
Segovia et al. (2016)	During	Day 8	After	Spared	Spared	N

Note. N = No; there was not an experimental dissociation; Y = Yes; there was indeed an experimental dissociation.

Cued Recall[1].

To test cued recall, all studies used open-ended questions probing specific film content. Such questions were typically designed by individual research groups and tailored to their specific films, making cross-comparisons difficult. Examples of such questions include: *what colour was the car that was on fire in scene 1?* and *what body parts were wounded and bleeding when the woman was freed from the minivan and was lying down on the stretcher?* (e.g., Holmes et al., 2004).

Using this test, a few studies assessed cued recall *after* intrusions, three of which showed that modulation of intrusion frequency was accompanied by modulation of performance on cued recall in the *same* direction. Both visuospatial interference (Krans, Näring, Holmes, & Becker, 2010) and verbal interference (Krans, Naring, & Becker, 2009) during film viewing led to fewer intrusions in tandem with worse cued recall, while a high self-efficacy induction procedure prior the film (Brown, Joscelyne, Dorfman, Marmar, & Bryant, 2012) led to fewer intrusions (with retrospective estimates instead a of diary) together with worse cued recall, albeit only for central but not peripheral details. However, providing context to the film prior to viewing (D. G. Pearson, Ross, & Webster, 2012) led to more intrusions – but not better cued recall.

Other studies have assessed cued recall *prior* to intrusions, followed by a re-assessment of cued recall. One study found that after film viewing, performing thought suppression while maintaining a cognitive load led to more intrusions but not better cued recall (Nixon, Cain, Nehmy, & Seymour, 2009a), although a similar manipulation in another study (Nixon, Cain, Nehmy, & Seymour, 2009b) led to negligible impact on either intrusions or cued recall. It is possible that measuring cued recall prior to diary recording could have in itself affected subsequent intrusion frequency. Relevant to this possibility, two studies showed that voluntarily retrieving film content soon after film, such as with a narrative task (Jobson & Dalgleish, 2014; Experiment 2) or a recognition memory test (Krans, Näring, Holmes, & Becker, 2009), led to fewer intrusions but better cued recall. The latter two studies showed that the same manipulation led to differential effects on intrusions vs. cued recall.

Three additional studies also demonstrated differential modulation of both intrusion frequency and cued recall, albeit by different experimental manipulations within the same study. For example, visuospatial interference during film viewing led to fewer intrusions only, whereas

[1] A review by Brewin (2013) identified four additional relevant experiments conducted before 2008 (Brewin & Saunders, 2001; Exp 1, 2 & 3, Holmes et al., 2004,) all of which found a modulation on intrusion frequency sparing cued recall.

verbal interference led to worse cued recall only (Bourne, Frasquilho, Roth, & Holmes, 2010; Experiment 1). An imagery rescripting procedure (changing the content of a negative image) after film viewing led to fewer intrusions, but a positive imagery procedure (creating a separate positive image) led to worse cued recall (Hagenaars & Arntz, 2012). Finally, while a low alcohol dose before film viewing led to more intrusions and a high alcohol dose led to fewer intrusions, only a high alcohol dose led to worst cued recall (Bisby, Brewin, Leitz, & Curran, 2009).

It is clear that the pattern of findings for cued recall relative to intrusions is mixed. One explanation may relate to the inconsistent order of the tests, whereby testing cued recall prior intrusions can contaminate the original effects of the experimental manipulation on intrusions. Another explanation may relate to the specific nature of each test which were designed by individual research groups and may provide variable amount of retrieval cues, which differentially tap into different aspects of the memory.

Recognition[2].

Voluntary memory for trauma films has mostly been measured with recognition tests. Here, participants typically make true/false judgments to written statements (verbal recognition; e.g., *the paramedics covered the students' head with a bandage*) or yes/no decisions to pictorial stimuli (visual recognition).

A minority of studies tested recognition both *before* and *after* assessing intrusions (in a one-week diary), with a mixed pattern of results. Performing thought suppression while simultaneously maintaining a cognitive load led to more intrusions and better verbal recognition, while thought suppression without load also led to better verbal recognition but not more intrusions (Nixon et al., 2009a), although neither effect was replicated in a subsequent study (Nixon et al., 2009b). Another study also failed to find modulation effects on either intrusions or visual recognition, using a nicotine manipulation prior film viewing (Hawkins & Cougle, 2013). Focusing more specifically on the impact of performing voluntary retrieval of the film on subsequent recognition, one study found that performing a narrative task post-film led to fewer intrusions but better recognition (Jobson & Dalgleish, 2014; Experiment 2).

[2] A review by Brewin (2013) identified two relevant additional experiments conducted before 2008. One of them found a modulation on intrusion frequency sparing recognition (Exp 3; Holmes et al., 2004) whereas another one found that reduced intrusion frequency was also accompanied by worse recognition (Exp 2; Holmes et al., 2004).

The majority of studies assessed intrusions only *prior* to testing recognition. One study failed to find a modulation by film type (films with or without correct temporal sequences) or instructed focus (data-driven or conceptually-driven processing) on subsequent intrusions or visual recognition test (Segovia, Strange, & Takarangi, 2016). Another showed that intrusions and recognition were differentially modulated within the same study, with a low alcohol dose prior to film viewing leading to more intrusions but worst recognition of gist information, but a high dose leading to worse recognition of both gist and detail information (Bisby et al., 2009).

Nevertheless, critical to this thesis, most of the studies testing recognition *after* intrusions (thus avoiding 'contamination' of recognition on intrusions) have found a modulation on intrusions while apparently leaving recognition intact. For example, watching a film with additional contextual information led to more intrusions without better verbal recognition (D. G. Pearson et al., 2012). Furthermore, visuospatial interference during film viewing led to fewer intrusions but left verbal recognition intact (Bourne et al., 2010, Experiment 1; Krans et al., 2010). There is one exception, where a verbal interference during film viewing led to more intrusions but worse verbal recognition (Bourne et al., 2010; Experiment 2), although this effect on recognition was not replicated in a different study (Krans, Naring, et al., 2009).

A series of experiments have investigated the impact of administering a visuospatial-interference procedure after film viewing. These experiments aimed to target the hypothesised process of memory consolidation – during which a memory undergoes stabilisation while still remaining labile (six hours; Nader, Schafe, & Le Doux, 2000) – by providing memory interference after film viewing (i.e., post-encoding). Such an interference procedure consists of two components: first, reminder cues using stills from the film; and second, a cognitive task designed to tax visuospatial working memory (WM) resources which are thought to be needed to form intrusive memories with strong visual components (Holmes, James, Coode-Bate, & Deeprose, 2009). Such experiments have demonstrated a well-replicated pattern of results, with such interference procedure resulting in fewer intrusions while preserving recognition performance. For instance, a procedure involving a complex visuospatial tapping 30-min after film viewing led to fewer intrusions without affecting verbal recognition (Deeprose, Zhang, Dejong, Dalgleish, & Holmes, 2012; Experiment 2), compared to counting backwards in 7's (designed to tax verbal rather than visuospatial WM) or no task. The same pattern of results emerged with subsequent studies using the computer game *Tetris* as the interference task. Such studies have further characterised the nature of the interference effect on intrusions, demonstrating that the effect is also observed when the procedure is applied at various time periods following film viewing, both within an estimated consolidation window within 6 hours of the event (30 min, Holmes, James, Coode-Bate, & Deeprose, 2009; 4 hrs, Holmes, James, Kilford, & Deeprose, 2010, Experiment 2) and reconsolidation window 24 hrs after the event (James, Bonsall, et al., 2015), but not when applied before film viewing (James, Lau-Zhu, Tickle, Horsch, & Holmes, 2015). The visuospatial nature of Tetris appears to be critical, because a less visuospatially demanding Pub Quiz game did not show the same effects on intrusions (Holmes, James, et al., 2010). Importantly, across all such studies, recognition is not affected by the interference procedure using Tetris, whether tested via verbal (Holmes et al., 2009; Holmes, James, et al., 2010; James, Bonsall, et al., 2015) or visual stimuli (James, Bonsall, et al., 2015).

Overall, with a few exceptions, several manipulations (particularly those involving visuospatial interference) appeared to modulate intrusion frequency, critically without affecting recognition memory.

Discussion of Studies Reviewed

Summary of findings

An overview of the 21 studies and 31 comparisons set the scene for the functional relation between intrusive memories and their voluntary counterparts. It would be premature to draw any conclusions regarding intrusive memories and free recall based on only one study conducted. The patterns emerging between intrusive memories and cued recall were mixed, prompting the need for replication to establish the reliability of the effects. Finally, most studies compared intrusive memories with recognition, with a consistent and well-replicated pattern of single dissociation (i.e., selective impact on intrusion frequency sparing recognition).

Theoretical implications

It is certainly tempting to interpret such intrusion/recognition or involuntary/voluntary dissociations as evidence for two separate traces, i.e., a storage-based account (e.g., Brewin, 2013). The same pattern, however, can be easily accommodated within mainstream memory theories based on a single memory system by alluding to retrieval-based accounts (Berntsen, 2009; Conway & Pleydell-Pearce, 2000; Tulving, 2002), which tend to be overlooked in contemporary memory research (Miller & Matzel, 2007).

Such a retrieval-based account would argue that there are methodological differences between measures for intrusive memories vs. voluntary memory which in turn can explain their dissociation. An important difference between measures, among others, relates to the nature of the retrieval cues. Recognition tests in laboratory settings involve strong retrieval cues that aid memory recovery, i.e., strong clues, which are not typical for measures of intrusive memories in daily life (e.g., diary) where such cues could be assumed as either non-existent or weak (at least not as strong as in recognition tests). In other words, intrusive memories within the trauma film paradigm have generally been measured in conditions with little retrieval support.

By taking into account retrieval processes, one could argue that the selective effect on intrusive memories is apparent only with measures that provide relatively less retrieval support (weak cues), but such an effect is minimized or overridden when stronger retrieval support is present (strong cues), i.e., the test becomes easier. Such an interpretation also explains the differential pattern of results across tests of voluntary memory: tests of recognition tend to provide the strongest cues, whereas tests of cued recall are variable regarding the strength of the cues.

In stark contrast to the retrieval-based account, several studies using the trauma film paradigm have found such an intrusion/recognition dissociation even with procedures that aimed to experimentally manipulate either encoding or (re)consolidation. From a mainstream memory perspective, such procedures would in fact affect the underlying memory. However, it is still possible that the locus of the effect has been misattributed - manipulations that are administered during the time window of encoding or consolidation can still exert their effects later at retrieval.

Methodological considerations

There is a clear need to improve existing memory measures within the trauma film paradigm to conduct a proper test of the apparent involuntary/voluntary dissociation. Among several issues, the critical one is the *retrieval intentionality criterion* (Richardson-Klavehn & Bjork, 1988), which states that robust evidence for dissociation between involuntary and voluntary memory should use tests that are appropriate matched in as many features as possible, particularly those known to influence retrieval, including the presence and nature of retrieval cues. Several of these features are investigated in this thesis.

Another key issue is the order of different measures, particularly when multiple testing is involved. For example, a test of voluntary memory can subsequently affect a later test of involuntary (intrusive) memory, as demonstrated in some of the studies reviewed (Jobson &

Dalgleish, 2014; Krans, Näring, et al., 2009). Retrieval demands of one test may also carry over to the next test close in time (i.e., participants may continue to adopt an intentional "retrieval mode" even if they are not supposed to). Steps should be taken to minimise such contamination, such as considering between-subject designs, counterbalancing the right order of tests when using within-group designs, or attempting to minimise capacity for voluntary retrieval during tests probing for involuntary memory, e.g., by introducing a concurrent load that can disrupt resources necessary for effortful retrieval. Finally, it is important to consider the validity and reliability of each test. Key issues to consider include floor/ceiling effects and ruling out non-memory explanations for successful test performance.

The current thesis will attempt to address these methodological issues by making comparisons between involuntary and voluntary retrieval with better matched tests, carefully considering the order of various measures as to avoid memory 'contamination', and designing memory tests that can rule out non-memory processes for successful performance.

Thesis Overview

The central aim of this thesis is to reconcile the contradiction between findings from experimental psychopathology – where there is an apparent functional dissociation between the frequency of intrusive memories and performance on tests of voluntary memory for the same emotional event (trauma film) – and mainstream memory theories, which would not predict such a dissociation. More specifically, how can manipulations of memory *consolidation* (which theoretically should affect the underlying trace) influence intrusive memories but not voluntary memory for the same event, if both manifestations of memory are derived from the same trace?

Using a battery of involuntary and voluntary memory measures, four experiments aimed to a) replicate the intrusion/recognition dissociation on existing measures, b) establish if the involuntary/voluntary memory dissociation holds with improved measures, and c) investigate candidate factors that could explain such dissociation. These experiments also investigated the relation between two additional procedural features and this dissociation: the timing of intrusion measurement and the role of reminder cues prior interference.

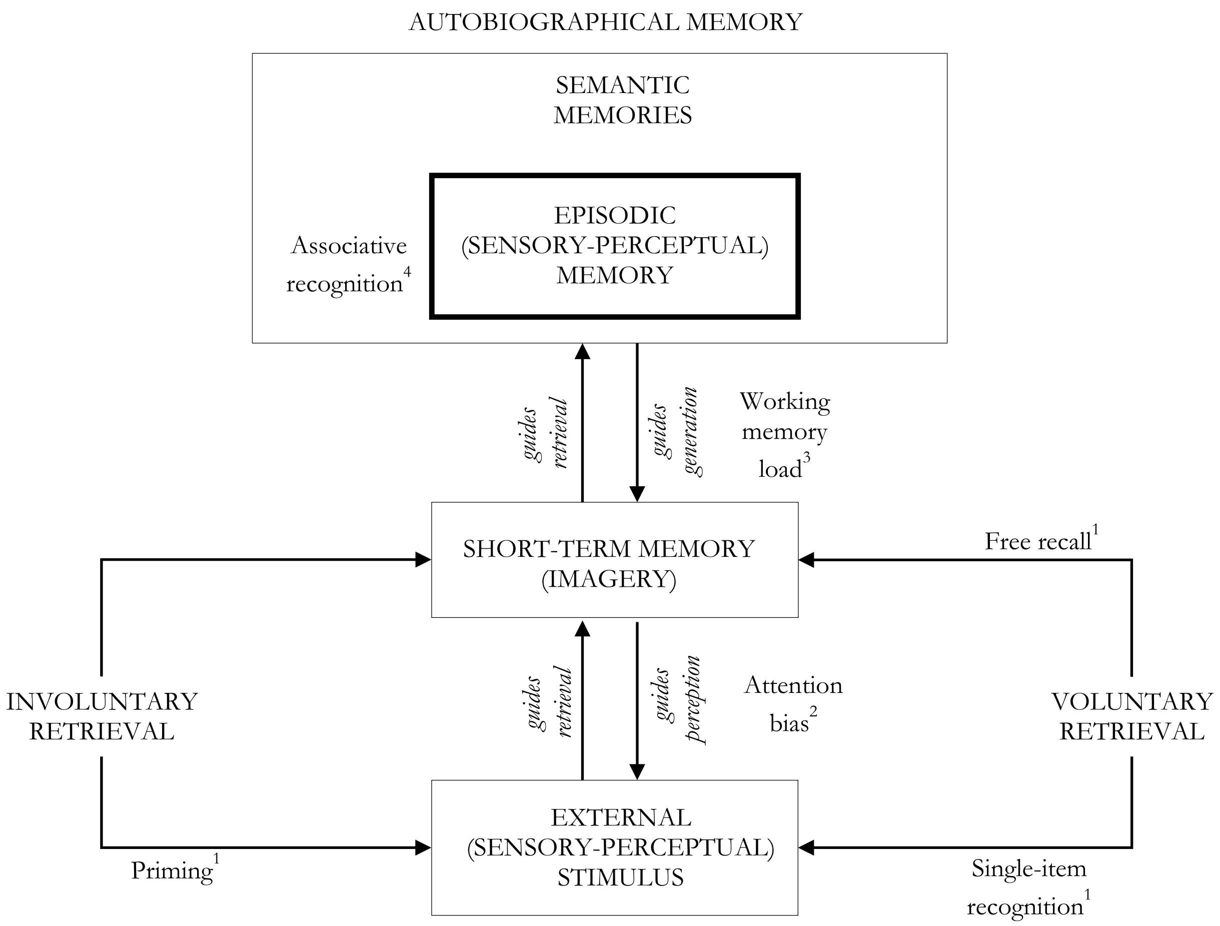


Figure 1.2. Schematic of the framework used to generate hypotheses regarding the memory mechanisms that modulate the frequency of intrusive memories of the trauma film. The numbers represent the experiments in which the corresponding memory measure was used.

Theoretical Framework Informing Experimental Studies

A framework was derived based on theories of episodic and autobiographical memory reviewed in this chapter. This framework guided the design of the four experiments pursued within this thesis, each aiming to examine a component within the framework (see Figure 1.2).

The top box represents the autobiographical memory system, which contains both semantic and episodic memories. More specifically, memories for emotional events, e.g., psychological trauma (trauma film), are represented within this episodic memory store, retaining their sensory-perceptual traces. The activation of this episodic trace produces the experience of mental imagery, i.e., 'seeing in the mind's eye'. This activation is initiated internally (i.e., WM) or externally (i.e., perception of an external stimulus), both of these routes represented by arrows that ultimately feed into the episodic store. More specifically, whereas retrieval beginning in WM involves the elaboration of internally-generated cues that are used to guide retrieval, retrieval beginning externally involves the initial perception of stimulus cues being processed in WM and subsequently used as cues to guide retrieval (e.g., by sensory-perceptual similarity). The important point here is that retrieval initiated from either activation source can be accompanied by either involuntary or voluntary retrieval intention.

It is possible that single-item (voluntary) recognition rely on external cues but (involuntary) intrusive memories do not, and thus are more prone to interference. In other words, these measures of voluntary and involuntary memory are not properly matched in terms of the retrieval cues, rendering questionable the possible involuntary/voluntary dissociation based on these existing measures. Thus, Experiment 1 (Chapter 2) aimed make a better involuntary/voluntary memory comparison. It was hypothesised that alongside intrusion frequency reduction, voluntary retrieval *without* external task-relevant cues (i.e., tested using free recall) would also be affected. Additionally, it was examined whether or not involuntary retrieval in response to external laboratory cues (i.e., tested using priming) would also be affected.

In addition to different activation sources (external/internal), an activated episodic trace can in turn affect other ongoing cognitive processes (represented by arrows emanating from the episodic store). For example, episodic retrieval can guide external perception by biasing selective attention towards specific external stimuli. Experiment 2 (Chapter 3) hypothesised that intrusion frequency reduction occurs in tandem with reduction in an early orienting of attention towards external film cues (tested with an attention bias task). Furthermore, episodic retrieval may also depend on WM processes, for instance, by competing for capacity-limited WM resources.

Experiment 3 (Chapter 4) hypothesised that the intrusion frequency reduction is more pronounced for intrusions occurring while (modality-specific) WM resources are available (i.e., tested using a low vs. high WM load manipulation at retrieval).

Finally, the nature of the episodic memory representation was investigated as a form of associative memory, i.e., consisting of binding among different 'snapshots' of the unfolding episode, some of which serve as memory cues and others which reflect content of the intrusive memory. In other words, intrusive memories depend on reactivating details that are bound to each other within a complex episode. Experiment 4 (Chapter 5) hypothesised that intrusion frequency reduction occurs due to a reduced advantage of cueing memories using the same film cues (i.e., tested using associative recognition, and a comparison between intrusions induced with and without film cues).

Methodological Approach

This thesis combined several methodological approaches across four experiments. First, it uses the trauma film paradigm (James et al., 2016) to study intrusive memories and their neglected relationship to voluntary memory. Hence, the emotional episodic event within this thesis refers to memory for scenes of a film with traumatic content (i.e., film memory).

Second, the thesis focuses on one specific manipulation stemming from the field of experimental psychopathology with translational relevance, namely the interference procedure involving Tetris game-play as a competing (visuospatial) cognitive task (Holmes et al., 2009; Holmes, James, et al., 2010; James, Bonsall, et al., 2015). The term 'interference procedure' would be used throughout this thesis to refer to the behavioural procedure involving 1) presentation of reminder (trauma film) cues followed by 2) Tetris game-play. Since this interference procedure has shown to produce an intrusion/recognition dissociation, hence involuntary/voluntary dissociation (See Table 1.2), understanding its mechanisms of action serves as a springboard to study intrusive memories and their relation to involuntary/voluntary memory more broadly. The same groups were used throughout the thesis: 'Cues+Interference' vs. 'Cues+No-Interference' (except for the additional 'Interference-only' group in Experiment 3).

The experiments used various novel measures of intrusive, involuntary and voluntary memory, which were adapted to test the contents of a film, and bridged the basic and clinical literatures on memory. These measures considered various factors linked to the diary methodology that might account for intrusive memories and their modulation, as depicted in the theoretical framework in Figure 1.2. For a schematic overview of the different memory measures used in the four experiments, see Figure 1.3 now depicted in temporal order within the experiments (from top to bottom).

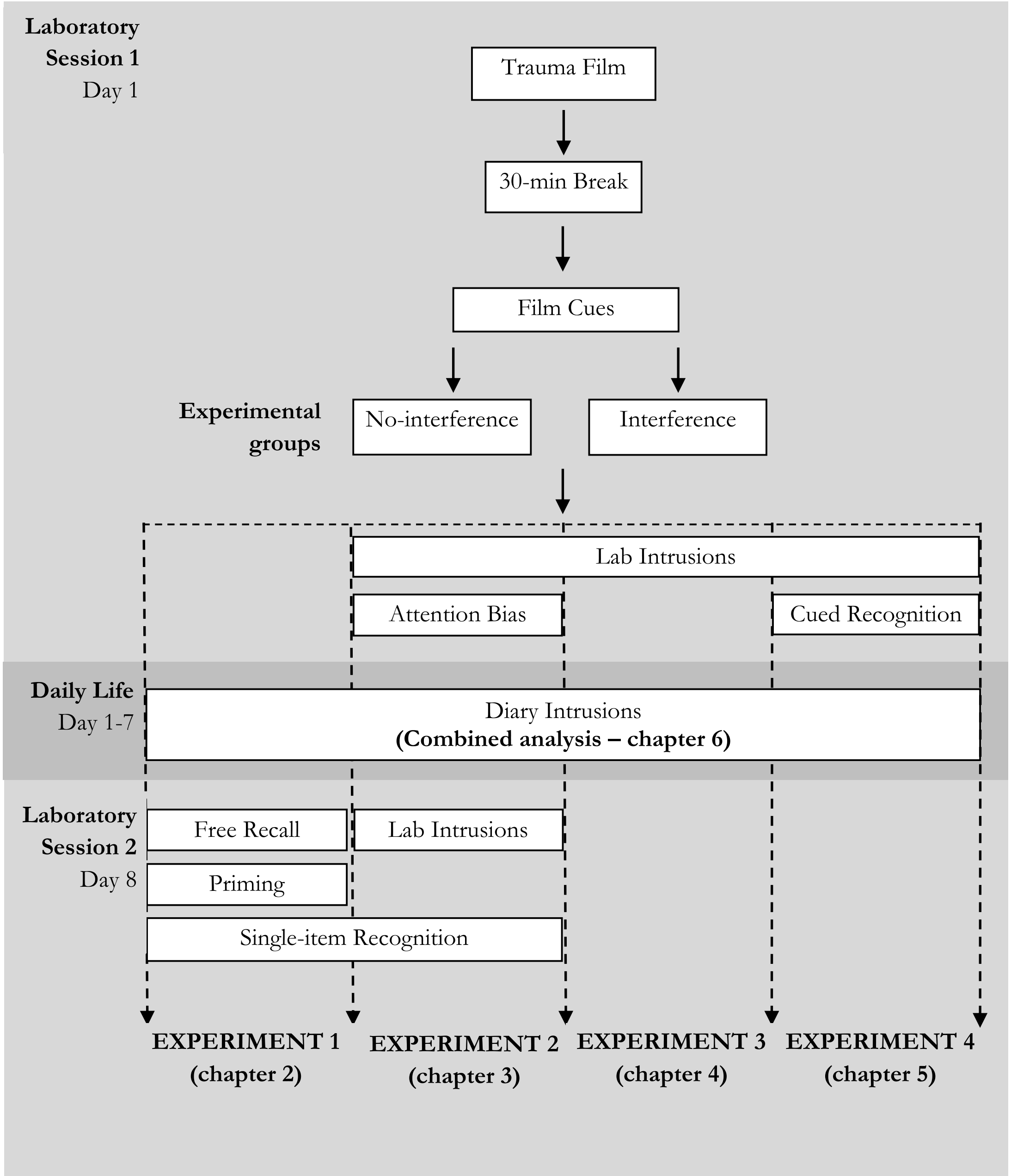
Finally, the experiments also investigated the relation between two additional procedural features of the paradigm and intrusive memories, namely the timing of intrusion measurement (Experiment 2, 3 and 4) and the role of reminder cues prior interference (Experiment 3).

Statistical Approach

The data within each experiment were examined for potential univariate outliers. If a score was more than 3 *SD* from the mean, it was changed to one unit larger (if the score was below the mean) or smaller (if the score was above the mean) than the next most extreme score in the distribution (Tabachnick & Fidell, 1996). See Appendices 3.4, 4.3 and 6.3 for details of outlier treatment where applicable.

Between-group comparisons were conducted using independent sample t-tests, unless indicated otherwise, with homogeneity of variance assessed using Levene's statistic. When this was violated, the corresponding non-parametric tests were applied. As patterns of results converged across tests, only results from the parametric tests were reported. Analyses of variance (ANOVA) with repeated measures were used when within-group variables were included as well as between-group variables, with sphericity assessed using the Mauchly's test statistic. When this was violated, Greenhouse Geisser corrections were applied. Furthermore, repeated-measures data with missing values were analysed with mixed effects models where applicable, adapting a script from P. Watson (Chapter 4). An alpha level of .05 was used for all statistical tests. These statistical analyses were performed using SPSS 22.0.

When relevant, a Bayesian approach was also used for the main outcomes to assess the relative evidence for the null hypothesis vs. the alternative hypothesis (Dienes, 2011). These analyses were conducted using code from R. Henson in MATLAB 2009.



Note. Experiment 3 included an additional group (Interference-only without prior film cues)

Figure 1.3. Schematic overview of the procedure across four experiments in this thesis, indicating the overlap on memory measures.

2. Task-Relevant Cues

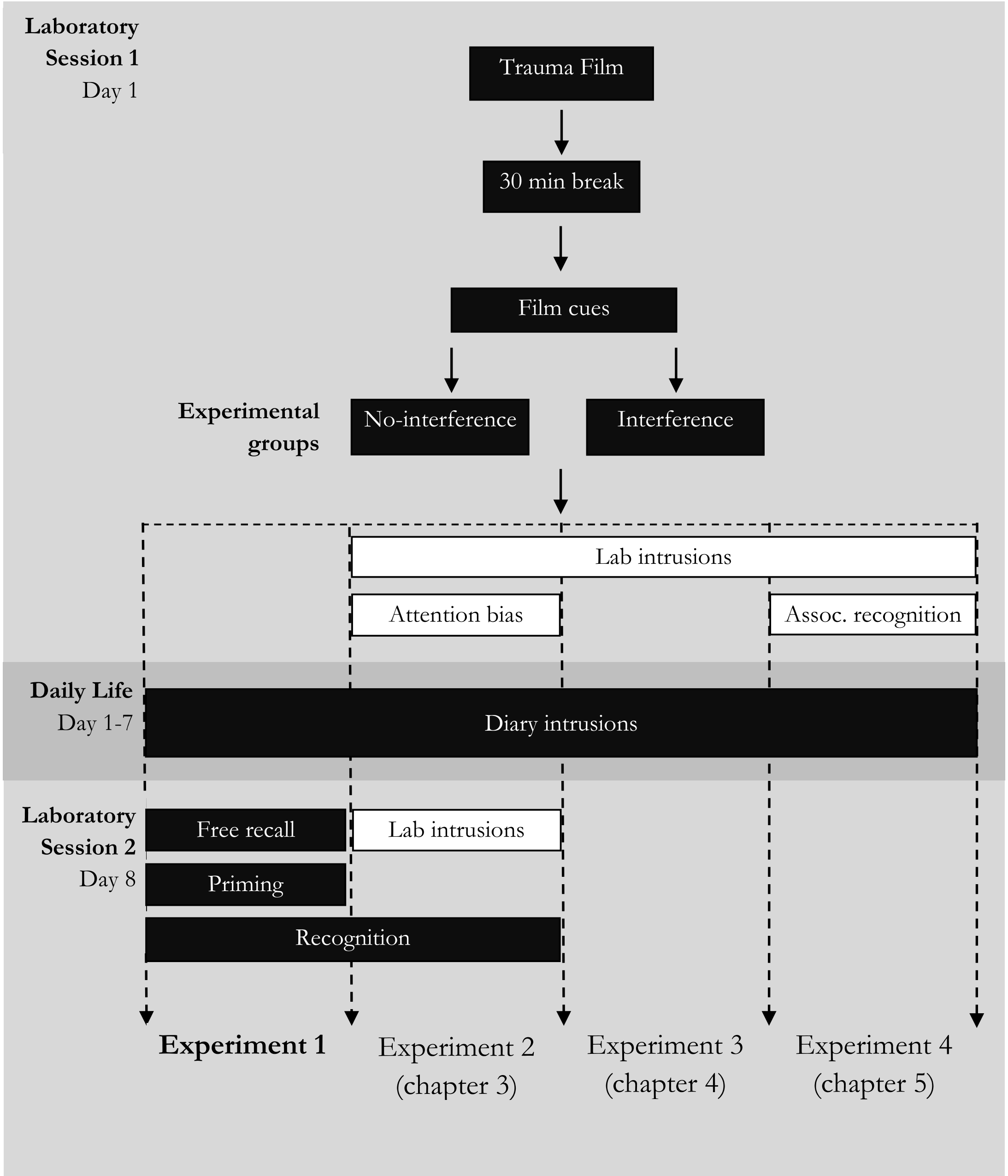


Figure 2.1. Experiment 1: procedural diagram relative to other experiments. Black boxes highlight procedural components specific to this experiment. White boxes highlight procedural components included in other experiments only. Dotted lines separate the memory measures administered across experiments, indicating that *free recall* and *priming* were specific to Experiment 1; *recognition* was also examined in Experiment 2 and *diary intrusions* (daily life) were examined across all experiments.

Introduction

Fifteen studies using the trauma film paradigm since the earliest review (Holmes & Bourne, 2008) have found a consistent pattern of experimental dissociation between diary intrusion frequency and recognition performance accuracy (James et al., 2016; also see Table 1.2). Does such intrusion/recognition dissociation genuinely reflect discrepant effects on involuntary vs. voluntary retrieval? Or can it be explained instead by additional differences between the existing measures?

In the autobiographical memory literature, voluntary and involuntary retrieval constitute two forms of retrieval intention that differ with regards to whether or not one deliberately brings a memory back into mind (Berntsen, 2009; Conway & Pleydell-Pearce, 2000). An equivalent distinction is between intentional and incidental retrieval (Richardson-Klavehn & Bjork, 1988), which refers more specifically to whether or not a memory measure has instructions referring to a previous learning episode. By definition, intrusive memories reported in the diary are involuntary/incidental, whereas a recognition test has instructions to think about the past (i.e., the film) and therefore putatively engages retrieval that is voluntary/intentional.

However, the intrusion diary and the recognition test also have additional differences beyond the involuntary/voluntary distinction. A closer inspection suggests that there is a critical difference regarding the availability of retrieval cues. Cues are defined here as task-relevant and as provided within an experimental context. Thus, there are task-relevant cues in a recognition test but not in the intrusion diary. As retrieval cues can facilitate memory retrieval (Tulving & Pearlstone, 1966), it is possible the interference-task effect on reducing intrusion frequency does not reflect a selective effect on involuntary memory but instead on all forms of uncued retrieval, i.e., when retrieval is not supported by task-relevant cues (involuntary and voluntary). Thus, establishing a robust experimental involuntary/voluntary dissociation demands that their respective measures are better matched, especially with regards to the contributions of task-relevant cues.

Experiment 1

The first aim of the experiment was to replicate the findings by Holmes et al. (2009), i.e., whereby the interference procedure administered 30 min after trauma film viewing reduces the frequency of intrusive memories experienced subsequently in daily life as reported in a diary compared to a no-interference control condition, but spares performance on a test of recognition memory delivered at post-diary follow-up.

Given at least these two crucial methodological differences between diary and recognition, the second aim was to test if such an intrusion/recognition dissociation can be explained by differences with regard to the availability of task-relevant cues, or genuinely by the involuntary/voluntary retrieval distinction.

Overview of Measures of Film Memory

The experiment followed the same procedure used by Holmes et al. (2009) and added three new memory measures in the second laboratory session (day 8). Together, these different measures differed in two independent dimensions (see Figure 2.2). First, they differed in retrieval intention, which referred to a difference in whether memory retrieval occurred by deliberate intention (i.e., voluntary) or not (i.e., involuntary). Second, they differed in the availability of task-relevant cues, which referred to the cues that a) were provided externally, b) in an experimental context, c) contained information about film content, and d) whose relevance to the task was made explicit by the experimental instructions. Holmes et al. (2009) used a diary to record the frequency of intrusive memories experienced in daily life (Figure 2.2, A). This was considered a measure of involuntary memory without task-relevant cues.

A novel recognition memory test was used (Figure 2.2, D) as a measure of voluntary memory with task-relevant cues. Initially, Holmes et al. (2009) used a recognition test with written verbal statements. Later, James, Bonsall et al. (2015) introduced a recognition test with visual film stills and continued to find that recognition performance was spared. However, James, Bonsall et al. (2015) only used 22 trials which may have led to a ceiling effect. The current recognition test used 180 trials with visual film stills and introduced confidence ratings per trial, as accuracy and confidence have shown to dissociate (Simons, Peers, Mazuz, Berryhill, & Olson, 2010). Based on the results by Holmes et al. (2009) and also James, Bonsall et al. (2015), recognition memory is expected to be spared by the interference procedure.

	Without task-relevant cues	With task-relevant cues
Involuntary	A. Diary	C. Priming
Voluntary	B. Free recall	D. Recognition

Figure 2.2. Memory measures for the trauma film used in Experiment 1, varying in retrieval intention (involuntary vs. voluntary retrieval) and availability of task-relevant cues (with vs. without).

A free recall test (Figure 2.2, B) was devised as a measure of voluntary memory without task-relevant cues. Although there were still instructions prompting to recall, task-relevant cues (as defined for the recognition test) were absent, therefore matching cueing conditions of the diary. Unlike with word-based stimuli, testing free recall for complex visual stimuli is inherently challenging. Thus, a protocol assessing recall of film content was adapted from the standardised Autobiographical Interview (AI; Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002) typically used to study real-life memories.

Finally, a test of perceptual priming (Figure 2.2, C) was devised as a measure of involuntary memory with task-relevant cues. Perceptual priming capitalises on the phenomenon of repetition priming, in which prior exposure to a stimulus facilitates its later identification even when such a stimulus is presented under non-optimal conditions. Priming can be considered a form of involuntary memory because testing instructions make no reference to film content, and therefore any contribution from film memory can be considered involuntary. Although priming is typically studied as a form of unconscious memory, contributions from the declarative memory system are hard to rule out (Henson, 2003). For the present experiment, the use of a perceptual priming paradigm to assess memory for a visual film is pertinent given the predominantly visual nature of intrusive memories (Brewin et al., 2010; Holmes et al., 2004; Ehlers & Clark, 2000; Michael et al., 2005).

The order of administering these memory measures was carefully considered to avoid potential contamination across tests as studies described in Chapter 1. The assumption was that the effects of both instructions to voluntarily retrieve and task-relevant cues are more likely to carry over into subsequent measures. Thus, efforts were made to first test measures of involuntary memory and/or those without task-relevant cues. The final order was as follows: intrusion diary on day 1-7, and free recall, priming and recognition on day 8.

Hypotheses

Replication of findings by Holmes et al. (2009)

Hypothesis A: Compared to no-interference, the interference procedure would reduce the frequency of intrusive memories in the diary, but lead to comparable performance on recognition memory (i.e., an intrusion/recognition dissociation).

Extension to test new measures of memory

Hypothesis B1: The intrusion/recognition dissociation reflects unmatched methodological features, i.e., differential availability of task-relevant cues. Therefore, compared to no-interference, the interference procedure would also disrupt voluntary memory without task-relevant cues (i.e., free recall).

Hypothesis B2: Such an intrusion/recognition dissociation reflects a genuine dissociation between involuntary and voluntary memory. Therefore, compared to no-interference, the interference procedure would also disrupt performance on involuntary memory even with task-relevant cues (i.e., priming).

Method

Participants

Sample size estimation. The effect of the interference task on diary intrusion frequency by Holmes et al. (2009) had an effect size of $d = .91$. On this basis, a sample size of at least 20 participants per group was required to ensure 80% power to replicate this effect at 5% significance level (two-tailed hypothesis testing). The final sample consisted of 23 participants per group.

The 46 volunteers (28 females, age range = 19-49) were recruited from the Medical Research Council Cognition and Brain Sciences Unit Volunteers Panel and reimbursed for their participation. Due to ethical considerations, they were informed prior to the study that they would watch a film containing scenes of a potentially distressing nature. Participants were eligible to take part if they a) were between 18 to 65 years old, b) reported no history of mental health, neurological or psychiatric illness, c) had not been involved in related studies, d) were able to attend two experimental sessions, and e) were willing to carry a pen-and-paper diary between sessions. All participants provided written consent prior to the start of the study and were told that they could interrupt the study at any point without giving any explanations.

Approval for this study, and all consequent studies within this thesis, were obtained from the University of Cambridge Psychology Research Ethics Committee [2014/3214; see Appendix 2.1 for full ethics approval].

Table 2.1

Description of each Film Clip in the 12-min Trauma Film

Order	Title	Duration	Footage Type	Brief Description
1	30 for a Reason	20 sec	Car crash	A reverse clip of a young girl after being hit by a car
2	The Big Shave	2 min	Self-harm	A man is shown cutting himself while shaving
3	Never, Ever Drink and Drive	50 sec	Car crash	A drunken driver loses control of his car, crashes through a fence and kills a young boy
4	Eye Surgery	1 min	Medical procedure	A graphic close-up of a laser eye surgery
5	No Seatbelt, No Excuse	1 min 4 sec	Car crash	During a car accident, one passenger hits into the head of another passenger because they were not not wearing seatbelt
6	Ghosts of Rwanda	57 sec	Genocide	A documentary featuring graphic images of the Rwanda Genocide
7	Drink & Drowning	19 sec	Drowning	A man is shown drowning after consuming alcohol
8	The Faster the Speed	40 sec	Car crash	A young couple is pinned against the wall by a car after the driver loses control of the vehicle
9	Orthopaedic Surgery	1 min 32 sec	Medical procedure	A graphic close-up of a knee surgery with voiceover of the surgeon
10	Texting and Road Cross	41 sec	Car crash	A boy and a girl are flirting; the boy is hit by a van while texting on the road and the girl witnesses this accident
11	Elephant Rampage	1 min 39 sec	Animal attack	An elephant in a circus attacks the performers and rampages into the streets.

Note. These films have also been used previously in several studies using the paradigm (e.g., Bourne, Mackay, & Holmes, 2013; Deeprose et al., 2012; Holmes et al., 2009; Holmes, James, et al., 2010; James, Bonsall, et al., 2015).

Materials and stimuli

Trauma film.

A 12-minute video depicting 11 different scenes of injuries, violence and death (same as Holmes et al., 2009, see Table 2.1 for details) was used as the emotional event, serving as an experimental trauma analogous to indirect exposure to traumatic event(s) in real life (American Psychiatric Association, 2013), e.g., viewing details of traumatic events (James et al., 2016). All clips were available from the public domain, such as government road traffic safety adverts, documentary footage and news footage. This video has successfully induced subsequent intrusive memories in daily life in previous studies (e.g., Holmes et al., 2009, 2010, Deeprose et al., 2012, James et al., 2015). The viewing distance was of approximately 100 cm. The video was played using E-Prime version 2.0 and the audio was played from headphones. See Appendix 2.3 for more comprehensive details on film sources.

Reminder cues task.

Static pictures, one from each of the 11 clips, were used as film cues. These pictures typically depicted the instance before the 'worst moment'. These included, for example, the face of a smiley teenager (just before he was hit by a van while being distracted by texting) or the picture of the circus (right before the elephant escapes and goes on a rampage). These pictures were presented for 3 sec each, and in a different fixed order to the order of their corresponding clips during the film. Participants were instructed to imagine themselves as real bystanders in the scenes. See Appendix 2.4.

Cognitive tasks for the interference manipulation.

Interference task. Participants in the interference group played a desktop-based Tetris game (Blue Planet Software, 2007), a computer game requiring the mental rotation of seven different coloured 2D geometric blocks known as 'tetrominoes'. These blocks fell from the top of the screen (one at a time) and could be rotated 90 degrees each time. The objective of the game was to form full horizontal lines without leaving any gaps. The game was set on Marathon Mode. Critically, participants were instructed to focus on the three blocks at the top right of the screen which were due to fall after the one being played. They were told to work out using their 'mind's eye' how to best manipulate and place these shapes in order to maximize their performance. It was emphasised that their effort in trying and game enjoyment were more important than performance.

The game was adaptive and became harder as one's score increased. If all blocks were stacked and reached the top of the screen, the game was over and had to be manually restarted. See Figure 2.3 for a screenshot of the game.

No-interference. Participants sat quietly for 10 min, during which they were told they should remain seated and quiet, but that they could think about anything without restriction.

Procedure

The experiment consisted of two separate laboratory sessions (See Appendix 2.2 for the protocol). The trauma film, the reminder cues task and all computer-based memory measures were presented on the same desktop screen (size: 32 cm × 40 cm; resolution of 1280 × 1024 pixels).

Laboratory session 1 (day 1). Participants came into the laboratory, gave consent to be part of the study and completed baseline measures. They practised playing Tetris for 3 min. Then, they watched the film as if they were bystanders witnessing the scenes. Pre- and post-film mood ratings were also recorded, as well as self-reported ratings on film distress and attention paid to the film (See Appendix 2.5 for details of all baseline and mood measures). After the film, participants completed a structured 30-min break (See Appendix 2.6 for details of the filler tasks). Following this break, participants were presented with the reminder cues task, and then randomly allocated to one of the interference groups, i.e., play Tetris or sit quietly for 10 min. At the end of the session, participants were given detailed verbal and written instructions on filling in the diary to record subsequent intrusive memories in daily life. This session lasted for 1 hr and 30 min approximately.

Laboratory session 2 (day 8). One week later, participants returned to complete surprise computer-based memory tests in the following order: free recall, priming and recognition. Finally, they went through the diary with the experimenter if unclear intrusion entries were identified. This session also lasted for 1 hr and 30 min approximately.

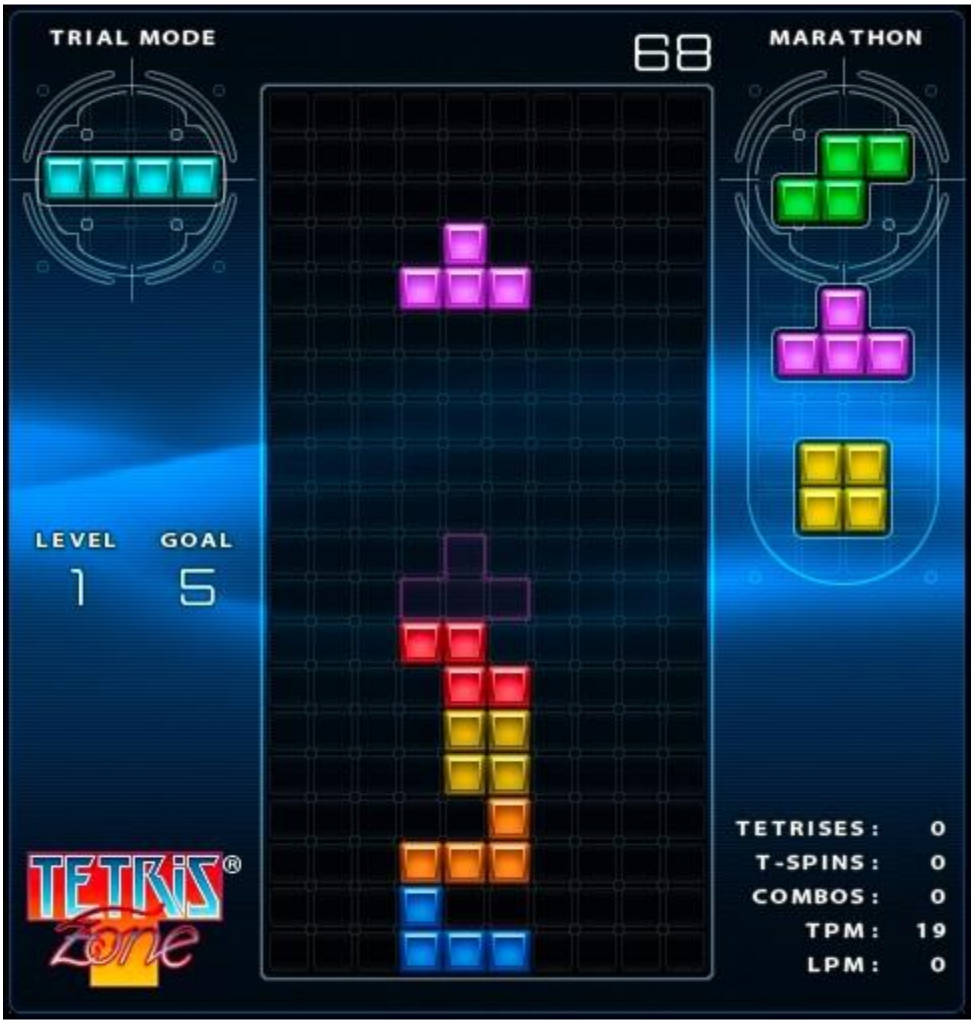


Figure 2.3. A screenshot of Tetris Zone (Blue Planet Software., 2007) used as the interference task in this thesis. Three blocks on the right corner pre-empted the subsequent blocks.

Measures of Film Memory

The tasks devised to measure memory for the film (see Figure 2.2) varied in retrieval intention (involuntary vs. voluntary retrieval) and the availability of task-relevant cues (with vs. without). All memory tests (i.e., except the diary) were presented using Matlab 2009 and Psychtoolbox.

Intrusion diary (Figure 2.2, A; involuntary retrieval without task-relevant cues)

Participants were asked to carry a pen-and-paper diary over a week following the film and to return it at follow-up. They were told to note down their intrusions related to the film, defined as 'image or thought from the film that pops into mind without one expecting it'. Participants were further instructed to distinguish between mental images and verbal thoughts. As such, an intrusive image-based memory was defined as 'visual images, sounds and bodily sensations related to the film' which can range from 'fuzzy and fragmented to vivid and as clear as normal vision'. These were contrasted with verbal thoughts involving 'words and phrases', 'like your internal dialogue'. Only image-based intrusions were counted for later analysis. For each intrusion, they also wrote down a description to show that the intrusion was indeed of the film. The main outcome was the total count of intrusive image-based memories across the week. See Appendix 6.1 for depiction of the diary used.

Recognition (Figure 2.2, D; voluntary retrieval with task-relevant cues)

The stimuli consisted of two sets of 90 still images, each drawn from either the trauma film or foil sources. For film stills, efforts were made to select stills that represented unique moments in the film. For foil stills, selection was based on similarity to film stills in content and themes (i.e., death and injury) and were obtained from a variety of sources, including footage of the same films what were edited out, footage from other films and stills from online sources (see Appendix 3.2 for examples of stills – also used for an attention bias task in Experiment 2). An independent norming study (see Appendix 2.8) was conducted to obtain ratings of negative emotionality inherent to both film and foil stills when these were not presented in the context of a moving film. Higher ratings indicated more negative emotions. Such emotionality ratings were matched between both stimuli set [film: $M = 5.29$, $SD = 1.36$; foil: $M = 5.21$, $SD = 1.34$; $t(178) = .40$, $p = .688$].

In each trial, a still was presented for 5 sec and participants judged whether or not each still belonged to the film (YES/NO response) as fast and as accurately as possible. Participants then provided a confidence rating for each decision using a scale from 1 (pure guess) to 4 (extremely confident) also within 5 sec. The order of each trial was randomised across participants.

For each participant, each trial was then classified as a hit, miss, false alarm or correct rejection. The main outcome was recognition accuracy calculated by subtracting the false alarm rate ([false alarm - correct rejection] / [false alarm + correct rejection]) from the hit rate ([hit - miss] / [hit + miss]).

Priming (Figure 2.2, B; involuntary retrieval with task-relevant cues)

This task used the same two sets of film and foil still images as in the recognition test (see Figure 2.4 for depiction of a sample trial). Each still was 'split' down the midline, each producing two 'still-halves'. Each trial started with a fixation cross in the middle of a grey screen for 2 sec, followed by two still-halves simultaneously presented, with one to the left and the other one to the right of the screen centre. The still-halves representing the left-half of the original still could only be presented on the right side of the screen, and those representing the right-half could only be presented on the left side of the screen. Each still (regardless of whether both or only one of the still-halves were presented) was used in one trial only.

There were 144 trials in total. In each trial, participants judged whether the two still-halves were a 'match' or a 'mismatch'. Both still-halves put together could either recompose into the same original still (75% of trials – 'match' response) or be from separate original stills (25% of trials – 'mismatch' response). A 'mismatch' trial would never contain two still-halves from the same film clip (e.g., a still depicting the elephant attacking the trainer would not be combined in a 'mismatch' trial with a still depicting the elephant running down the street which is from the same clip). However, both still-halves were always from the same set (film vs. foil).

Critically, both still-halves were initially fully covered by salt-and-pepper noise and then became clearer over the 6 sec following presentation by removing 20% of the noise pixels every 1250 msec (Berry, Shanks, & Henson, 2008). The fully revealed still-halves then stayed for 2 sec further on screen. Participants could have made a response at any point in these 8 secs, with the trial ending upon a response. Pairing of stills for each trial was fixed, whereas the order of the trials was randomised across participants. There was a practice stage consisting of 12 trials with separate foil stills not reinstated in the main experimental stage. The main outcome for this test was RT for accurate trials (match or mismatch).

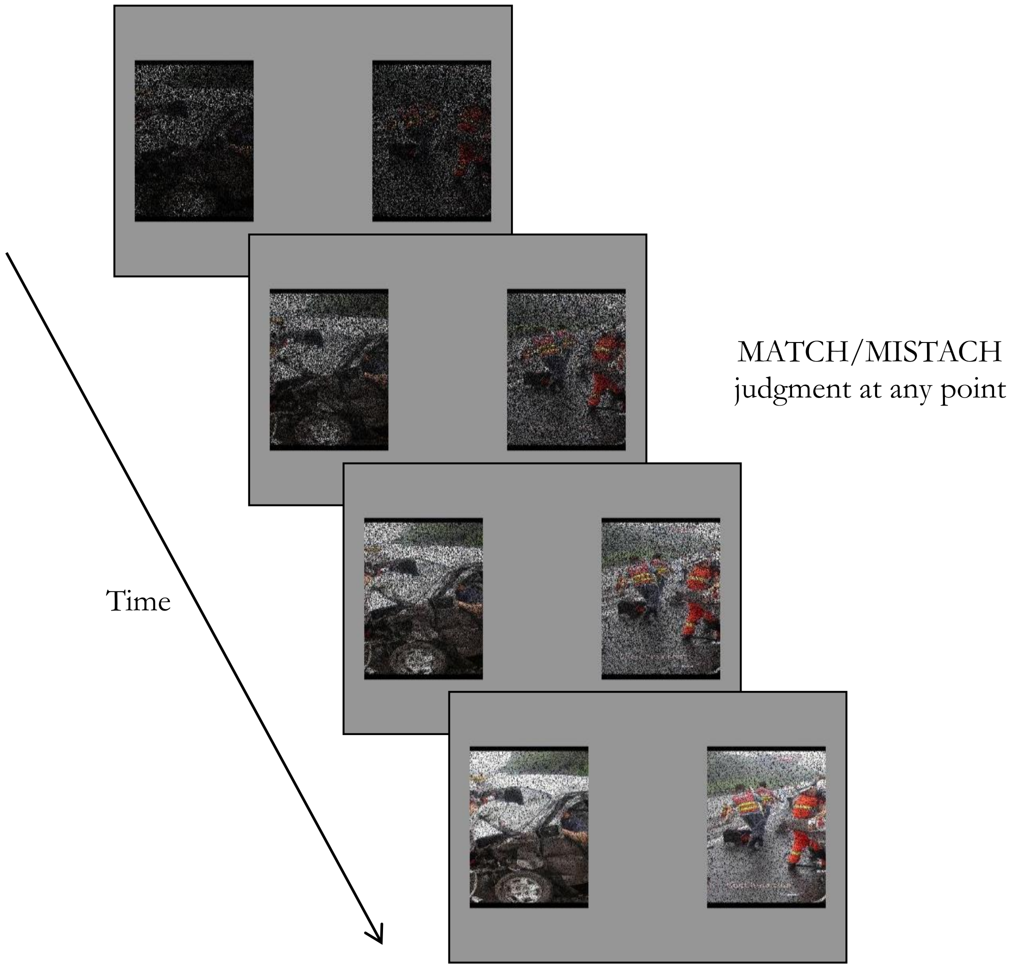


Figure 2.4. Schematic of an experimental trial in the priming task used in Experiment 1. In each trial, participants were presented with still-halves and were asked to judge whether or not both halves 'matched', i.e., belonged to the same original still image. These still-halves were initially covered by salt-and-pepper noise which were then continuously revealed over 6 sec, remaining fully clear on screen for 2 sec if a response had still not been made up to that point.

Free Recall (Figure 2.2, C; voluntary retrieval without task-relevant cues)

The task instructions and the scoring system from the AI (Levine et al., 2002) were adapted to devise a free recall test for the film content. AI has shown high inter-rater reliability (0.88 to 0.96) for scoring autobiographical memories and has been recently adapted to score traumatic memories in PTSD (McKinnon et al., 2014) and memories for film footage (St-Laurent, Moscovitch, Jadd, & McAndrews, 2014), the latter also achieving high inter-rater reliability (0.83 to 0.85).

For this experiment, various changes were made to the original AI at both interview and scoring stage. In contrast to the standard AI, participants self-administered the interview stage in this experiment. Detailed written instructions were presented on the screen and participants were given a tape recorder to use throughout recall while they verbalised their responses.

Interview. The interview stage entailed free recall and specific probing from the AI, but not the general probing stage. Throughout this task, participants could self-pace depending on how much information they could retrieve, unless they went over the maximum time allowed. The first stage was free recall which was of main interest to this experiment. Here, participants were instructed to retrieve as many details as possible from the film without being given any task-relevant cues or clues (i.e., free recall). They were told they could start with any of the clips, in any order, and not skip to the next stage until they had finished recalling all possible details. The maximum duration allowed for free recall was 10 min (based on typical durations during piloting) after which participants heard a beep signalling the next stage.

The second stage was specific probing. Here, they were presented with a list of written labels referring to each clip serving as clues (determined during piloting as distinct enough from each other), and were asked to retrieve additional details that were not already mentioned during free recall. The order of the labels was fixed for all participants, but differed from their original order during film viewing. They were also specifically encouraged to retrieve as many perceptual (e.g., objects, colours and sounds) details as they could. The maximum duration for each clip was 2 min with a beep sound signalling the next label (see Appendix 2.9 for details of the self-administered interview protocol).

Scoring. The tape-recorded verbalizations were transcribed and followed a process of text segmentation into meaningful units of information, or details, in line with the original AI.

A first categorization procedure was adapted from the original AI to score the details that referred to what took place in the film, i.e., details which pertained directly the episodic content of the film. Non-episodic content such as general opinions and comments in relation to other events (i.e., semantic: 'These things shouldn't happen to people') were ignored. As the veracity of the free recall of a film can be verified (unlike for an autobiographical memory), only accurate details were scored (similar to St-Lauren et al., 2014).

Episodic details that were identified were further categorised into two types of details directly linked to film content, i.e., *event* and *perceptual* details. Therefore, details referring to the participants' experience of place and time and their own emotion/thought at the time of film viewing were not scored. Event details referred to what had happened, such as the people that were present, their behaviours and their actions. These also included emotions and thoughts of the people involved in the film. Second, perceptual details referred to information experienced through different sensory modalities, and for a film stimulus these would include visual (e.g., objects and colours) and auditory details (e.g., sounds). When a detail could be scored as either event or perceptual detail, preference was given to the more specific category (i.e., perceptual). The categorisation into event or perceptual events was done separately for free recall and specific probing (see Appendix 2.9 for the full adapted scoring protocol). The main outcome was the number of accurate details, i.e., event and perceptual during free recall.

A further exploratory analysis used the Linguistic Inquiry and Word Count software (LIWC2015). Each individual transcript was split into free recall and specific probing and then saved into separate Microsoft Word documents. Each file underwent an automated text analysis using the LIWC2015, which provided a *word count* and also the number of words falling into *perceptual processes* word category referring to perceiving (e.g., 'see', 'hear' or 'feel') defined by the 2007 English dictionary (Pennebaker, Chung, Ireland, Gonzales, & Booth, 2007). A perceptual *detail* as defined by the AI scoring procedure refers to specific content of what was perceived (e.g., I saw the girl lying next to a <u>tree</u>), whereas a perceptual *process* word in the LIWC refers to the experience of the perceiver (e.g., I <u>saw</u> the girl lying next to a tree). This procedure has been used previously to study film memory (St-Laurent et al., 2014).

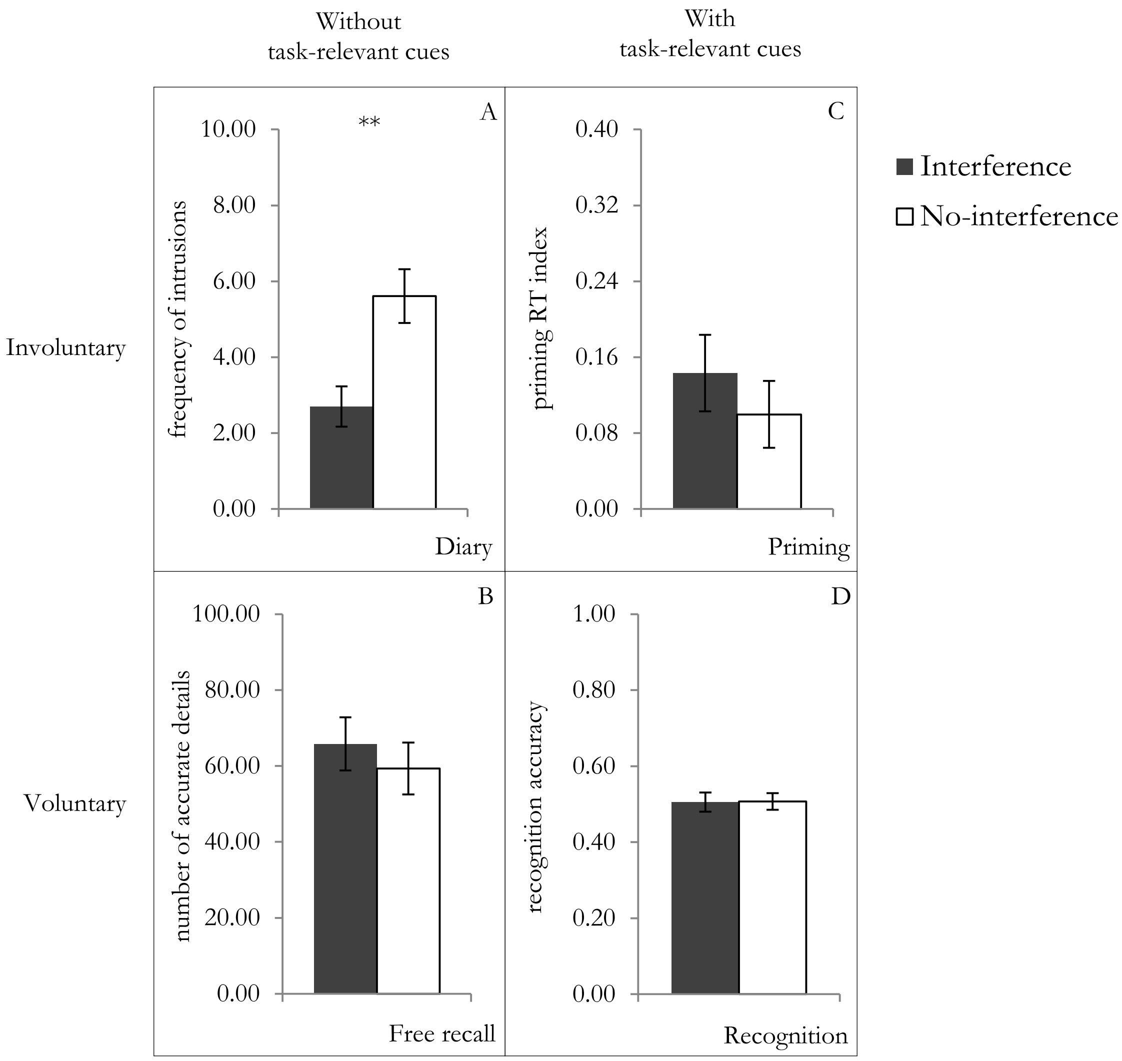


Figure 2.5. 'Retrieval strength' on each memory measure by groups on Experiment 1. These four measures differed in retrieval intention (involuntary vs. voluntary) and the availability of task-relevant cues (with vs. without). The main outcome for each memory measure was: for the diary, the frequency of intrusive memories across a one-week period; for free recall, the total number of accurate (event and perceptual) details; for priming, an index was derived by subtracting RT to trials with foil stills from RT to trials with film stills, with positive scores indicating the presence of priming; and for recognition, accuracy was determined by obtaining the difference between the rates of hits and rates of false alarms. Error bars represent standard errors. Significant two-tailed group comparisons within each memory measure were flagged, i.e., only the diary measure (**: alpha < .01).

Results

Randomization and manipulation checks

Both groups were matched at baseline in terms of gender, age, depressive symptoms, trait anxiety, number of previous traumatic events and general use of imagery. Viewing the film also resulted in predicted increases in negative mood, which was matched between both groups. Ratings for attention paid to the film, personal relevance of the film, and diary accuracy were also matched between groups (See Appendix 2.7 for details).

Interference-task effects on each of the measures of film memory

Intrusion diary (involuntary retrieval without task-relevant cues).

Frequency of intrusions. Participants in the interference group reported significantly fewer image-based intrusions in the diary compared to the no-interference group [$t(44) = 3.29$, $p = .002$, $d = .97$]. Results are depicted in Figure 2.5, A.

Number of distinct film clips. Participants in the interference group had a higher number of distinct film clips becoming intrusions ($M = 3.22$, $SD = 1.45$) than those in the no-interference group ($M = 1.91$, $SD = 1.54$) [$t(44) = 2.97$, $p < .005$, $d = .88$].

Recognition (voluntary retrieval with task-relevant cues).

Accuracy. Positive scores indicate memory performance above chance. Results are depicted in Figure 2.5, D. One-sample t-tests revealed that recognition accuracy was above chance in each group [$t(22)$'s > 20.03, *p's* < .001]. However, an independent sample t-test revealed that accuracy was not significantly different between groups [$t(44) = 0.05$, $p = .959$, $d = .00$]. Using the effect size of the interference effect on diary intrusions as the baseline ($d = .97$), the Bayes factor for the group difference in recognition accuracy was 0.0073, suggesting substantial evidence to accept the null relative to the alternative hypothesis (Dienes, 2011).

Confidence ratings. An additional analysis was also performed to compare the number of hits (correct identification of film pictures) that were endorsed with high confidence ratings (i.e., a score of 3 or 4 with 4 being extremely confident), but revealed that it did not significantly differ between groups [$t(44) = 1.31$, $p = .198$, $d = .39$].

Table 2.2

Means and Standard Deviations for Performance on Recognition Memory by Groups in Experiment 1

	Interference (n = 23)		No-interference (n = 23)	
	M	*(SD)*	*M*	*(SD)*
Hits	69.17	(9.79)	70.83	(7.66)
with high confidence	58.30	(16.22)	63.39	(9.20)
False alarms	24.17	(14.27)	25.43	(8.18)

Free Recall (voluntary retrieval without task-relevant cues).

Inter-rater reliability. The main researcher (A. Lau-Zhu) scored all individual scripts based on the procedure adapted from the original AI (See Figure 2.6 for an example of a coded transcript), while being blinded to the group condition during coding. A subsample of 22% of the scripts (10/46) selected at random were also scored by an independent researcher who did not run the study and was also blinded to the group conditions. Interclass correlations (two-way mixed effects model, consistency, single measures; McGraw & Wong, 1996) for the free recall stage were as follows: 0.96 for event, 0.69 for perceptual and 0.97 when both were combined; for the specific probing stage, 0.90 for event, 0.90 for perceptual and 0.88 when both were combined. Therefore, all outcomes had from strong to almost perfect agreement.

Number of distinct film clips. The number of film clips retrieved during free recall was not significantly different [$t(44) = 0.35, p = .725, d = .11$] between the interference ($M = 5.87$, $SD = 1.89$) and the no-interference group ($M = 6.09$, $SD = 2.25$).

Yeah that was the most [E]disturbing. Something that I haven't mentioned before is that his hair is [P]black. I kinda had a mental image of him but I didn't explain it previously. So his hair was black. He looks like in his late 20s [P]or 30s maximum. [P]Skin white, tall, not too tall though, [P]average. He was in a bathroom [E]looking to a mirror. Think he was wearing a [E]sleeveless [P]white shirt. Oh was it light blue, I think. Maybe the bathroom was [P]light blue. Something was light blue, think it was the [E]bathroom. The blood [P]was dark. And very disturbing image before. It went all the [E]way. Oh his neck, from the [P]front. What else. Yeah that's all I can remember about this. And he looks like he was [E]alone, the only character. There was music in the [P]background as I mentioned. Looked like he was at [E]home or something. Yeah more description about the man. He was a jock I think, like he wasn't your average like he wasn't [P]very slim. That's all. Yeah that's all.

Figure 2.6. Example of a verbatim transcript scored by the researcher according to a procedure based on the Autobiographical Interview. In this transcript, there are 17 accurately retrieved details, including 7 event details (E) and 10 perceptual details (P).

Yeah that was the most disturbing. Something that I haven't mentioned before is that his hair is black. I kinda had a mental image of him but I didn't explain it previously. So his hair was black. He looks like in his late 20s or 30s maximum. Skin white, tall, not too tall though, average. He was in a bathroom looking to a mirror. Think he was wearing a sleeveless white shirt. Oh was it light blue, I think. Maybe the bathroom was light blue. Something was light blue, think it was the bathroom. The blood was dark. And very disturbing image before. It went all the way. Oh his neck, from the front. What else. Yeah that's all I can remember about this. And he looks like he was alone, the only character. There was music in the background as I mentioned. Looked like he was at home or something. Yeah more description about the man. He was a jock I think, like he wasn't your average like he wasn't very slim. That's all. Yeah that's all.

Figure 2.7. Example of the automated text analysis by the Linguistic Inquire and Word Count software to count words falling in the perceptual processes category. In this transcript, there are 13 perceptual process words which are underlined.

Table 2.3

Means, Standard Deviation, and Independent Group Comparisons for Scoring Outcomes of the Recall Interview by Retrieval Stage (Free Recall vs. Specific Probing), Scoring Method (AI and LIWC) and Groups in Experiment 1

	Interference (n = 23)		No-interference (n = 23)		Independent Group Comparisons		
	M	*(SD)*	*M*	*(SD)*	*t*	*df*	*p*
Scoring based on AI							
Free recall							
event details	57.91	(29.24)	50.39	(24.98)	0.94	44	.353
perceptual details	7.91	(6.40)	8.96	(8.88)	0.46	44	.650
Specific probing							
event details	96.78	(34.78)	94.30	(35.62)	0.24	44	.812
perceptual details	20.04	(14.96)	24.70	(17.07)	0.98	44	.331
Scoring based on LIWC							
Free recall							
perceptual process words	30.91	(14.82)	30.04	(21.65)	0.16	44	.874
total word count	764.70	(288.20)	721.83	(366.07)	0.45	44	.658
Specific probing							
perceptual process words	74.87	(33.40)	85.91	(49.65)	0.89	44	.381
total word count	1756.09	(561.86)	1969.74	(851.17)	1.01	44	.321

Note. AI = Autobiographical Interview; LIWC = Linguistic Inquiry and Word Count. During free recall, participants were only prompted to retrieve details of the film without additional cues. During specific probing, participants were given verbal cues. Scoring based on AI yielded two main outcomes, namely the frequency of event (i.e., something that happened) and perceptual details. Scoring based on LIWC was automated and yielded two main outcomes, namely the frequency of perceptual process words (i.e., those referring to perceiving) and a total word count.

Episodic details based on AI. The number of total accurate details during *free recall* was not significantly different between groups [interference: $M = 65.83$, $SD = 33.39$; no-interference: $M = 59.35$, $SD = 32.69$; $t(44) = 0.67$, $p = .510$, $d = .20$]. Results are depicted in Figure 2.5, B. However, using the size of the interference effect on diary intrusion as the baseline ($d = .97$), the Bayes factor for the group difference in episodic details was 0.99, suggesting there is not enough evidence to accept the null over the alternative hypothesis (Dienes, 2011). The same pattern emerged when scoring was separated by event and perceptual details (see Table 2.3).

The same analyses were performed again by including additional details prompted by specific probing. These analyses indicated again that there were no significant group differences in the total number of overall episodic details [interference: $M = 116.80$, $SD = 44.30$; no-interference: $M = 119.00$, $SD = 49.58$; $t(44) = 0.16$, $p = .876$, $d = .05$]. The same pattern also emerged when scoring was separated by event and perceptual details (see Table 2.3).

LIWC outcomes. The automated text analysis revealed that for both free recall and specific probing, there were comparable outcomes for the number of perceptual process words and also the total word count between both groups (see details in Table 2.3). See Figure 2.7 for an example of an automatically coded transcript.

The partial Pearson Product-Moment Correlation coefficients between perceptual process words and perceptual details were $r = .44$, $df = 43$, $p = .003$ for free recall, and $r = .38$, $df = 43$, $p = .010$ for specific probing, after taking into account total word count. These suggest a moderate linear relationship between scores for perceptual details and processes (obtained from different analytical approaches).

Priming (involuntary retrieval with task-relevant cues).

Accuracy. Analyses were collapsed across matched and unmatched trials. See Table 2.4 for the main accuracy outcomes. A 2 (between-group factor: interference vs. no-interference group) × 2 (within-group factor: film vs. foil trials) mixed ANOVA revealed a significant main effect of trial type [$F(1,44) = 6.03$, $p = .018$, $\eta_p^2 = .120$], indicating that accuracy was higher for trials with film stills ($M = 0.84$, $SD = 0.12$) than foil stills ($M = 0.82$, $SD = 0.13$). The main effect of group [$F(1,44) = 2.43$, $p = .127$, $\eta_p^2 = .052$] was not significant, nor was the trial × group interaction [$F(1,44) = 0.07$, $p = .799$, $\eta_p^2 = .001$]. Therefore, the priming task appeared sensitive to a priming accuracy effect which did not significantly differ between groups.

Table 2.4

Means, Standard Deviations and Independent Group Comparisons for Accuracy and RT in the Priming Task by Trial Type and Groups in Experiment 1

	Interference (n = 23)		No-interference (n= 23)	
	M	*(SD)*	*M*	*(SD)*
Accuracy (proportions)				
Film trials	0.81	(0.15)	0.87	(0.08)
Foil trials	0.79	(0.16)	0.85	(0.08)
RT (sec)				
Film trials	4.14	(0.74)	3.98	(0.77)
Foil trials	4.28	(0.77)	4.08	(0.77)

Note. RT = Reaction times.

RT. A priming index was calculated based on RT for each participant (See Table 2.4) by subtracting the overall RT for foil trials minus the overall RT for film trials. One-sample t-tests indicated that the priming RT index was above chance for both groups [t(22)'s > 2.83, p's < .05], but an independent-sample t-test confirmed that the priming RT index did not significantly differ between groups [t(44) = 0.81, p = .420, d = .22]. Results are depicted in Figure 2.5, C. Using the size of the interference effect on diary intrusions as the baseline (d = .97), the Bayes factor for the group difference in priming RT index was 0.0065, suggesting there is substantial evidence to accept the null over the alternative hypothesis (Dienes, 2011).

Interaction between retrieval intention and task-relevant cues.

Z-scores across memory measures. A single outcome from each memory measure was standardized (using z-scores) to allow for comparison across different memory measures. The main outcomes representing 'successful' memory within each measure were as follow (see Table 2.5): frequency of diary intrusions (involuntary without task-relevant cues), number of accurate details at free recall (voluntary without task-relevant cues), recognition accuracy (voluntary with task-relevant cues) and priming RT index (involuntary with task-relevant cues). A 2 (between-group: interference vs. no-interference group) × 2 (within-group: involuntary vs. voluntary) × 2 (within-group: with and without task-relevant cues) mixed model ANOVA on these z-scores revealed that neither the main effects of group [$F(1,44) = 0.41$, $p = .525$, $\eta_p^2 = .009$], retrieval intention [$F(1,44) = 0.00$, $p = .997$, $\eta_p^2 = .000$], nor task-relevant cues [$F(1,44) = 0.00$, $p = .999$, $\eta_p^2 = .000$] were significant. The two-way interactions were also not significant, namely group × intention [$F(1,44) = 2.17$, $p = 148$, $\eta_p^2 = .047$], group × cue [$F(1,44) = 3.15$, $p = .083$, $\eta_p^2 = .067$] and intention × cue [$F(1,44) = 0.00$, $p = .997$, $\eta_p^2 = .000$]. Critically, the three-way interaction between group × intention × task-relevant cues was significant [$F(1,44) = 6.89$, $p = .012$, $\eta_p^2 = .135$]. A depiction of all the measures together (Figure 2.5) demonstrates that such a three-way interaction reflected the finding that the interference procedure modulated diary intrusions but not performance in any of the remaining memory tests.

Table 2.5

Means and Standard Deviations of Z-Scores for 'Retrieval Strength' Across Memory Measures by Retrieval Intention, Task-Relevant Cues and Groups in Experiment 1

	Interference (n = 23)		No-interference (n = 23)	
	M	*(SD)*	*M*	*(SD)*
Without task-relevant cues				
Involuntary (diary)	-0.44	(0.76)	0.44	(1.03)
Voluntary (free recall)	0.10	(1.01)	-0.10	(0.99)
With task-relevant cues				
Involuntary (priming)	0.12	(1.07)	-0.12	(0.94)
Voluntary (recognition)	-0.01	(1.08)	0.01	(0.94)

Matching image-based content. An exploratory analysis was conducted on z-scores across measures which were better proxies for image-based retrieval. This is because it remains possible that the interference task modulates specifically the image-based content of the memory. The main outcomes representing 'image-based' memory within each measure were the same for the frequency of diary intrusions as only image-based intrusions were counted; the priming RT index was used again as this task required a perceptual decision. For free recall, the number of accurate details was restricted to perceptual details only. For recognition, the number of high-confident hits was considered. The same analysis using this new set of z-scores (see Table 2.6) revealed exactly the same pattern: neither the main effects of group [$F(1,44) = 3.57$, $p = .065$, $\eta_p^2 = .075$], retrieval intention [$F(1,44) = 0.00$, $p = .997$, $\eta_p^2 = .000$], nor task-relevant cues [$F(1,44) = 0.00$, $p = .996$, $\eta_p^2 = .000$] were significant. The two-way interactions were not also not significant: group × intention [$F(1,44) = 0.40$, $p = 842$, $\eta_p^2 = .001$], group × cue [$F(1,44) = 2.62$, $p = .113$, $\eta_p^2 = .056$] and intention × cue [$F(1,44) = 0.00$, $p > .999$, $\eta_p^2 = .000$]. Critically again, the three-way interaction between group × intention × task-relevant cues was significant [$F(1,44) = 6.14$, $p = .017$, $\eta_p^2 = .122$].

Table 2.6

Means and Standard Deviations of Z-Scores for 'Retrieval Strength' Across Image-based Memory Measures by Retrieval Intention, Task-Relevant Cues and Groups in Experiment 1

	Interference (n = 23)		No-interference (n = 23)	
	M	(*SD*)	*M*	(*SD*)
Without task-relevant cues				
Involuntary (diary)	-0.44	(0.76)	0.44	(1.03)
Voluntary (free recall)	-0.07	(0.83)	0.07	(1.16)
With task-relevant cues				
Involuntary (priming)	0.12	(1.07)	-0.12	(0.94)
Voluntary (recognition)	-0.19	(1.22)	0.19	(0.69)

Discussion

The present experiment investigated the effect of an interference procedure (vs. no-interference) after trauma film viewing on subsequent memory for that film, as measured by a battery of memory tests that differed in retrieval intention (involuntary vs. voluntary) and task-relevant cues (with vs. without).

Summary of findings

The interference group reported fewer intrusive memories in the diary (involuntary without task-relevant cues) than the no-interference group, whereas no significant group differences were found inn performance accuracy on the recognition test (voluntary with task-relevant cues). However, there were also no significant group differences for the new measures, namely free recall (voluntary without task-relevant cues) and priming (involuntary with task-relevant cues). This suggests that neither task-relevant cues nor retrieval intention were critical factors, at least not sufficient, in explaining the interference effect on intrusive memories. Rather, it remains possible that some other factors at work in the diary methodology, which do not apply to the other three tests, could account for such an effect. Findings are summarised in more detail below, followed by possible explanations.

Findings in relation to hypotheses stated

In line with Hypothesis A, the interference procedure reduced the frequency of intrusive memories and spare performance on the new test of recognition, replicating Holmes et al. (2009). This pattern is also consistent with other studies using a similar interference procedure (Deeprose et al., 2012; Holmes, James, et al., 2010; James, Bonsall, et al., 2015) albeit at different time intervals between film viewing and interference. Several changes were made to the current recognition test. For example, the higher number of trials compared to previous research allowed it to be determine that performance was above chance and relied on a genuine ability to distinguish film from foil stills. Such stills were matched on emotionality as determined by an independent norming study, ruling out potential differences inherent to the stimuli used. Further, confidence ratings were introduced to gauge the phenomenological experience underlying correct performance in the test. Despite these methodological developments, there were still no signs of reliable group differences in recognition.

Contrary to Hypothesis B1, the interference procedure did not modulate free recall. This test used a systematic interview procedure and an exhaustive scoring of verbal transcripts distinguishing event from perceptual details (adapted from an established test of autobiographical memory to assess episodic content of a film). The lack of group differences in free recall suggests that the interference-task effect on intrusions cannot be readily explained by the contributions of task-relevant cues to retrieval. There are potential caveats to this conclusion. One could argue that the scoring system was idiosyncratic. However, inter-rater reliabilities were mostly in almost perfect agreement. Further, additional analyses were also performed using an automated text analysis software assessing word categories falling into perceptual *processes*. Regardless of how perceptual components of the memory were scored, findings converge to highlight the lack of group differences in recall. Another possibility is that the measure was inherently noisy. Bayesian analysis indicated that there was not enough evidence to accept the null as such (i.e., lack of group differences in episodic detail). One factor which may have contributed is that participants self-administered the test responding to a tape recorder. However, the same pattern of findings appeared even when participants were further 'pushed' by specific probes for each film clip, which provided more structure to the recall process.

Contrary to Hypothesis B2, the interference procedure did not modulate priming. This measure used a perceptual priming paradigm where an advantage in film trials should reflect mnemonic contributions from the film. The lack of group differences in priming therefore suggests that although intrusions by definition involve involuntary retrieval, the interference-task effect on intrusions cannot be sufficiently explained by the involuntary nature of the diary method. There are two possible caveats to this conclusion. First, the main effect of priming (in both groups) may simply reflect a stimulus difference between the film and foil stills (e.g., the film still-halves may be inherently easier to match). To establish this, a new group of participants, who have not seen the film before, would not be expected to show a performance advantage for film stills (i.e., no priming effect). However, norming data on these stills suggested that they were equivalent, at least by the ratings on emotionality that were considered. Second, it is possible that the priming task also recruits voluntary retrieval processes due to carry-over of voluntary retrieval mode following the free recall task and/or participants becoming aware that some stills belonged to the film. The priming index was numerically higher in the interference group, suggesting that power was unlikely an issue. The Bayesian analysis also provided strong support for the lack of group differences.

Alternative explanations

One difference between the diary and the other three tests concerns the nature of the content assessed. Memories noted down in the diary were image-based but that was not necessarily the case for all the remaining memory tests. One may argue that the (visuospatial) interference task selectively affected (visual) image-based content. However, the same pattern of results was found when the analyses were restricted to proxies of 'image-based' retrieval within each measure.

An additional difference concerns the retention interval. The diary count is summed across a one-week period after interference, whereas the other three tests were delivered post-diary, i.e., on day 8 in a second laboratory session. One may argue that the interference procedure may have only extended the time needed to consolidate memories or may have accelerated the rate of forgetting. Thus, one would see an effect shortly after the interference (e.g., during the first few days) but not after a longer delay (e.g., week), by which time memory performance becomes equivalent between groups. However, James, Bonsall et al. (2015) found an intrusion/recognition dissociation even when both were measured in the same follow-up laboratory session.

Chapter Summary and Next Steps

To summarise, the memory measures considered in this chapter demonstrated that the interference procedure reduced intrusion frequency but did not affect recognition accuracy, replicating the existing intrusion/voluntary dissociation (Holmes et al., 2009; Holmes, James, et al., 2010; James, Bonsall, et al., 2015). It was established that this dissociation is robust, because the intrusion/voluntary dissociation remained even after the diary measure was compared with a test of voluntary memory better-matched in terms of retrieval cues (i.e., free recall).

However, candidate factors considered were unable to provide an explanation of this effect. More specifically, such an interference effect on intrusive memory frequency could not be readily explain by either the absence of task-relevant cues (because free recall was not affected) nor purely by unintentional retrieval (because priming was not affected). A three-way interaction supported the finding that the interference procedure modulated diary intrusion frequency only.

These findings suggest that the (sensory-perceptual) content of the memory is not 'erased' and is retrievable with voluntary memory. This could be desirable from clinical/ethical perspectives where amnesia is counterindicated. However, further empirical and theoretical work is required to understand the precise mechanisms through which the interference procedure could exert such an effect while leaving the representation intact.

The current findings indicate two important directions. First, additional factors that are in place in the diary need to be investigated. One such factor is the degree of automatic attention towards *task-irrelevant* cues in the diary (bear in mind that 'task' would refer to activities in daily life), as opposed to *task-relevant* cues considered in the current experiment. Second, and more generally, further theoretical leverage is required to understand the factors that affect intrusive memories in daily life, distinct from those that affect memory in the laboratory. One way is to develop a method to simulate film-related intrusive memories in the laboratory, so potential modulating factors can then be tested. The next experiment takes steps forward in both of these directions.

In addition to exploring parameters of the memory measures, the next experiment also considers the relationship between the effects on intrusive memories and a parameter of the interference paradigm itself, i.e., timing of the effects. Specifically, how soon does the effect emerge?

3. Attention Bias & Non-Time-Dependent Effect

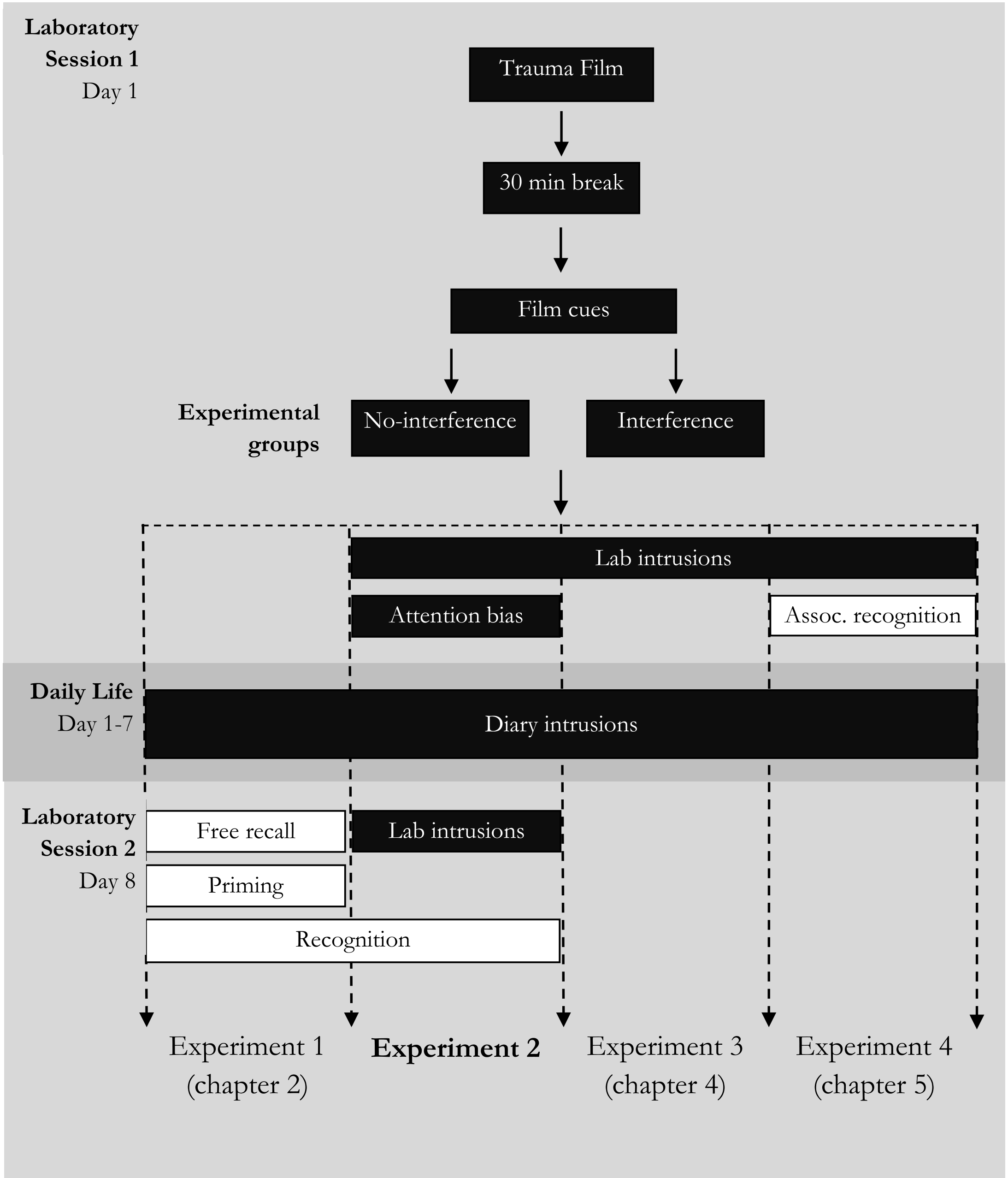


Figure 3.1. Experiment 2: procedural flow relative to other experiments. Black boxes highlight procedural components specific to this experiment, in their respective order; white boxes highlight procedural components included in other experiments in this thesis. Dotted lines separate the memory measures administered across experiments, indicating that *attention bias* (session 1) and *laboratory intrusions* (session 2) were specific to experiment 2; *laboratory intrusions* (session 1) were also examined in experiment 3 and 4 and *diary intrusions* (daily life) were examined across all experiments.

Introduction

Experiment 1 from Chapter 2 failed to find that *task-relevant* cues could account for the selective interference effect on intrusions but not on voluntary memory (i.e., free recall and single-item recognition). The experiment in this chapter investigated if the modulation on intrusion frequency can be explained by an attention bias to *task-irrelevant* cues. Two novel measures were developed for this purpose, including a performance-based measure in addition to an intrusion sampling method in the laboratory. Further, this experiment also investigated whether or not the effect emerges immediately after interference.

Attentional Bias to Task-Irrelevant Cues

The clinical phenomenology of intrusive trauma memories suggests that these are associated with trigger cues. In particular, selective attention to threat cues has been proposed to underline several anxiety disorders (Mathews & MacLeod, 2005; Ohman, Flykt, & Esteves, 2001), including the increase in frequency of intrusions (Ehlers & Clark, 2000). One proposal is that such cues can automatically capture or hijack attention (Clark & Mackay, 2015). There is experimental evidence that a preference for visual stimuli from a trauma film is linked to more intrusions (Verwoerd, Wessel, de Jong, & Nieuwenhuis, 2009; Verwoerd, Wessel, & Jong, 2010), and that training attention away from such visual film cues can reduce the frequency of film intrusions (Verwoerd, Wessel, & de Jong, 2012).

Possible Explanation for Findings from Experiment 1

It is possible that in the diary methodology, intrusive memories occur in response to external cues which could be deemed as task-irrelevant: the main 'task' would be activities in daily life in this context. It is possible that attention, initially focused on the task itself, can automatically 'spill-over' to the task-irrelevant cues, particularly if these cues are emotionality salient, e.g., when they serve as reminders of the trauma film. Thus, a bias in automatic selective attention to film-related cues could underlie the occurrence of intrusive memories of the film. Following this proposal, the interference procedure can be thought to disrupt this 'hijacking' effect by trauma reminders, consequently leading to fewer intrusions.

In contrast, cues presented across memory tests in Experiment 1 could be deemed as task-relevant. Both tests of recognition and priming required the explicit processing of the visual film stimuli. As such, participants were directly instructed to attend to such film cues, possibly diluting any group differences in incidental/automatic attentional processes. Novel measures are needed to test the degree of attention bias towards task-irrelevant film cues, which in turn holds the potential to explain intrusion modulation. To this end, Experiment 2 adapted a paradigm from the clinical experimental literature to assess attentional bias (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Ijzendoorn, 2007) to film stills as task-irrelevant cues.

Can Film-Related Intrusive Memories in Daily Life be 'Brought' into the Laboratory?

Can the diary method be supplemented with a laboratory-based measure of intrusive memories? In addition to developing memory tests to probe for hypothesised mnemonic components underlying intrusions *indirectly*, e.g., via performance measures, a complementary and important approach is to model intrusive phenomena *directly* to understand the factors that affect intrusions in daily life.

Once a good laboratory-based model exists, factors that moderate the interference effects on intrusions can be experimentally investigated, including the effects of attentional processing of (task-irrelevant) film cues. Such factors remain unknown because of the reliance of the trauma film paradigm on using the diary methodology. More ideally, the frequency of intrusive memories can be more experimentally tractable and conveniently investigated if a laboratory task of shorter duration (e.g., 20 min) can model intrusive memories recorded in the diary of a longer duration (e.g., one-week period). One way to inform the development of a diary-like sampling method in the laboratory is to look at existing research with measures of both laboratory and diary intrusions within the same study. Therefore, a mini-review was conducted to inform the development of such a model.

Mini-Review of Methods Used to Sample Intrusive Memories (of Trauma Film) in the Laboratory to Model the Diary

Within the trauma film paradigm, intrusive memories have been sampled mostly in daily life (e.g., via diaries) rather than in the laboratory. Although the earlier studies (Horowitz, 1975; Lazarus, 1963) sampled film intrusions within the lab using signal-detection tasks, the diary methodology has predominated since it was introduced by Butler, Wells, and Dewick (1995). Although sampling intrusions in daily life provides high ecological validity, such an approach neglects the study of *retrieval* processes pertaining to intrusions.

A minority of studies using the trauma film paradigm have considered laboratory-based sampling methods; however, there is little agreement regarding which is the most appropriate. A focussed review of these studies could inform key task parameters required to successfully model the diary, by examining under which circumstances laboratory and diary intrusions had been similarly influenced by the same experimental manipulations.

Aim and Scope

The aim of this mini-review was to examine if the frequency of intrusive memories sampled in the laboratory and of those recorded in a diary (i.e., in daily life) could be similarly affected by the same manipulation. To this end, a selective number of studies were chosen for this thesis from a broader review (James et al., 2016). Fourteen studies were included that met the following criteria: a) the main outcome was intrusion frequency; b) intrusions were assessed with both diary and laboratory sampling methods; c) and the main variable of interest was experimentally manipulated.

Relevant Studies

Intrusive memories during rest without a parallel behavioural task

Six studies sampled intrusions in the laboratory during some form of resting period. These studies revealed a mixed pattern of results. One study used retrospective estimates of laboratory intrusions, and found that diary and laboratory measures converged: inducing high self-efficacy pre-film led to fewer intrusions in both the laboratory and in the diary (Brown et al., 2012).

The majority of studies did not use retrospective estimates, but instead had participants report intrusions 'on the fly'. One study (Verwoerd et al., 2012) again found a diary and laboratory convergence: training participants post-film to attend away from film reminders led to both fewer diary intrusions and fewer laboratory intrusions (while monitoring their own breathing). The remaining studies found a lack of diary/laboratory convergence. Two studies found an effect on laboratory but not diary intrusions: pre-film nicotine administration (Hawkins & Cougle, 2013) and holding a cognitive load while hyperventilating during the film (Nixon, Nehmy, & Seymour, 2007) led to more laboratory intrusions without an impact on diary intrusions. Another study found the opposite pattern, whereby suppressing film-related thoughts while performing a concurrent task led to more diary intrusions without affecting laboratory intrusions (Nixon et al., 2009a); however, in a subsequent replication, the same manipulation had no apparent effects on either laboratory or diary intrusions (Nixon et al., 2009b).

Intrusions during a parallel task

Only one study was found which measured intrusions in the context of another primary task (Marks, Steel, & Peters, 2012). Here, laboratory intrusions were sampled simultaneously while participants had to read out loud a random series of digits. The main manipulation, i.e., visuospatial interference concurrent to film viewing, showed no impact on either laboratory or diary intrusions. However, an additional non-experimental variable, i.e., higher traits levels of data-driven processing (preferential focus on sensory rather than conceptual information), was related to more intrusions in both laboratory and diary.

Intrusions in response to film cues

Seven studies sampled laboratory intrusions while providing film-related cues. Overall, these studies showed a diary/laboratory convergence. Three studies used the Intrusion Provocation Task, which involved showing participants a few blurred film stills followed by a 2-min resting period in which they had to report an intrusion as it occurred. Using this method, both a visuospatial interference procedure (James, Bonsall, et al., 2015; Experiment 1 & 2) and a cognitive bias modification procedure (Lang, Moulds, & Holmes, 2009) delivered after film viewing led to fewer laboratory and diary intrusions. Nevertheless, the visuospatial interference procedure delivered before film viewing (James, Lau-Zhu, et al., 2015) had no impact on either intrusion type.

In other studies, participants made retrospective estimates but there was still a pattern of diary/laboratory convergence. In two studies, a resting period followed the presentation of visual and auditory cues (samples drawn from the same source of film footage but not from the exact same film). One study (Schaich, Watkins, & Ehring, 2013) found that for participants who received pre-film training in abstract but not concrete processing, higher trait rumination was related to more intrusions in both laboratory and diary. Another study (Zetsche, Ehring, & Ehlers, 2009) found that the same training delivered post-film showed no effect on either intrusion type.

Finally, one study (Wegerer, Blechert, Kerschbaum, & Wilhelm, 2013) directly compared the effect of laboratory-based cues on laboratory intrusions. In a Memory Trigger Task, three different types of sound cue were followed by a resting period, with these cues either associated with the film (conditioned cue), not associated with the film (unconditioned cue) or no cues at all. Conditioned laboratory cues elicited relatively more laboratory intrusions (but it was not possible to independently assess the effect of these same cues on diary intrusions). Further, a non-experimental variable – higher negative valence rating to cues – was associated with more intrusions both in the laboratory and daily life.

Discussion

Summary of studies

Of the 14 studies reviewed, eleven showed a pattern of laboratory/diary convergence. Specifically, seven studies showed that the same manipulation led to a similar effect on intrusive memory frequency both in the laboratory and diary. Of these converging studies, two sampled intrusive memories during a resting period without a parallel task, and five sampled sampled intrusive memories in response to film cues. Furthermore, four studies showed that the same manipulation had no effect on either intrusion type.

Implications for this thesis: developing a laboratory model of the diary

The importance of cues.

Despite the variability, a key task parameter that appeared important was the presentation of film-related cues. One study directly showed that cues provoked intrusions (Wegerer et al., 2013) at least when cues were auditory. The importance of cues is in line with both clinical (Brewin, Dalgleish, et al., 1996; Ehlers & Clark, 2000) and nonclinical models (Berntsen, 2009; Conway, 2001) of involuntary memory retrieval. Beyond the simple presence of cues, open questions remain regarding specific cue properties and cue-related processing that are critical for eliciting intrusions in daily life.

Considering the parallel task.

Only one study directly used a primary behavioural task parallel to intrusion sampling and no study to date has studied the role of competing tasks at *retrieval* on intrusions to trauma film (despite a wealth of studies on encoding/consolidation). It is unclear if the best way to model diary-linked processes is with resting periods, as it is reasonable to assume that participants take part in multiple activities in daily life when they are asked to carry a diary. Several authors on the autobiographical memory literature (Berntsen, 2009; Schlagman & Kvavilashvili, 2008) argue that a state of diffuse attention is important to promote involuntary retrieval, although emotional memories can also 'hijack' attention (LaBar & Cabeza, 2006; Vuilleumier, 2005). Clearly, a better understanding of the relationship between intrusions and parallel activities is required.

Reporting intrusions online or retrospectively.

The reviewed studies suggest that both forms of reporting could be reliable and the choice depends mainly on priorities set by the research question. Whereas online reporting avoids memory biases, it can also provide important timing information (Noreika et al., 2015). On the other hand, retrospective assessments would be useful if one were to investigate the effect of intrusions on a behavioural task, where uninterrupted performance can be crucial (particularly for reaction time measures).

Conclusion

Overall, this mini-review included only 14 studies, suggesting that trauma film studies using laboratory intrusion monitoring are in the minority (87 trauma film studies in the review by James et al., 2016). With this caveat, studies from this review suggested that to build a laboratory model for intrusion monitoring (rather than using the diary), film-related cues should be included. Further, there was less certainly about which parameters are essential in relation to the parallel task and the reporting method. For this thesis, a parallel task was included to provide additional performance measures during intrusion retrieval (Experiment 3). Further, both reporting methods were used according to the experimental design: the online reporting procedure whenever possible to avoid retrospective biases (Experiment 2, 3 and 4), and the retrospective procedure when online reporting was deemed less appropriate (when online reporting can disrupt the experimental manipulation of interest, e.g., Experiment 3 explored the relationship between intrusion retrieval and RT outcomes).

Experiment 2

The first aim of the experiment was to replicate the intrusion/recognition dissociation when both intrusion frequency and recognition were measured on the same day in the laboratory (e.g., James, Bonsall, et al., 2015). The second aim was to test if the interference-task effect on intrusion frequency can be explained by an impact on attention bias for film cues. The third aim was to test if there is an interference-task effect on intrusion frequency sampled soon after interference (for a short period while participants are still in the laboratory), which could potentially serve as an earlier marker for the subsequent modulation of intrusions in daily life (diary over a one-week period).

Two New Measures of Film Memory for the Current Experiment

Building on the mini-review, a task was designed to sample laboratory-based intrusions with the aim to simulate intrusion frequency in the one-week diary. This task adapted the basic structure of a digit vigilance task known as the Sustained Attention and Response Task (SART; Murphy, Macpherson, Jeyabalasingham, Manly, & Dunn, 2013; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). Two critical task features were: first, memory cues were included, which were stills drawn from the trauma film clips; and second, such cues were *task-irrelevant* because participants were instructed to focus on the stimulus that was in the foreground (e.g., visual digits) while the cues were presented in the background. These two features had parallels in the attention bias task described below. This intrusion task also instructed participants to directly report any intrusions of the film they may experience at any point during the task using the same definition of intrusive memories as with the diary methodology.

A measure of attention bias was adapted from the dot-probe task (MacLeod, Mathews, & Tata, 1986) and intended to assess the degree of attention bias to task-irrelevant film cues. Unlike the measure of priming in Experiment 1, these cues were *task-irrelevant* (as with the laboratory intrusion task) because participants were instructed to focus on a dot-probe (i.e., main task) rather than on the stills themselves. Further, task instructions made no reference to the film per se, hence any influence of film stills on task performance can be attributed as involuntary.

The same recognition test was administered as in Experiment 1, with the exception that participants also provided remember/know (R/K) judgments (Henson, Rugg, Shallice, Josephs, & Dolan, 1999; Migo, Mayes, & Montaldi, 2012; Rajaram, 1993) for each still they judged as belonging the film. The R/K procedure has been used to study recollection vs. familiarity processes underlying episodic memory.

The order of administering the various memory measures was again carefully considered to avoid potential carry-over effects. On day 8, laboratory-based intrusions (involuntary) were measured *before* recognition (voluntary); and on day 1 immediately after interference, laboratory-based intrusions were measured before attention bias.

Hypotheses

Replication of the pattern of results in James, Bonsall et al. (2015)

Hypothesis A: Compared to no-interference, the interference procedure reduces the frequency of laboratory-based intrusions (day 8), but leads to comparable performance on recognition memory (day 8), replicating the pattern of intrusion/recognition when both aspects are measured on the same day.

Extension to test two new measures of film memory

Hypothesis B: The interference procedure, compared to the no-interference condition, produces a stronger disruption of the attention bias to task-irrelevant film cues measured soon after interference.

Hypothesis C: Because most diary intrusions typically occur earlier in the week, the interference procedure may also affect intrusions reported much earlier on, i.e., frequency of laboratory-based intrusions immediately after interference.

Method

Participants

Sample size estimation. The interference effect on intrusion frequency in the diary had an effect size of $d = .91$ in Experiment 1. On this basis, a sample size of 18 participants per group was considered to ensure 80% power to replicate this effect at 5% significance level (two-tailed hypothesis testing). The same recruitment strategy was used as in Experiment 1. Two participants dropped out from the study: one could not attend the follow-up and the other did not wish to watch the whole film. The final sample used for analyses consisted of 36 healthy volunteers (28 females, age range = 19 – 49).

Materials, stimuli and procedure

All materials and stimuli were the same as in Experiment 1. This experiment also consisted of two separate laboratory sessions (See Appendix 3.1 for the protocol). All procedures remained the same as in Experiment 1 up to the interference task, except with the following differences:

Laboratory session 1 (day 1). Immediately after randomisation to either interference group, participants received instructions on how to perform the laboratory-based intrusion task after a short practice. Then they were asked to perform the attention bias task also after a short practice. At the end of the session, participants received instructions to fill in the diary as in Experiment 1. This session lasted for approximately 2 hr.

Laboratory session 2 (day 8). One week later, participants returned their diaries. This diary data will be reported in a combined diary analysis across all experiments (Chapter 6). They completed the laboratory-based intrusion task followed by the recognition test. This session lasted for 1 hr approximately.

Measures of Film Memory

All memory tests (i.e., except the diary) were presented using Matlab 2009 and Psychtoolbox.

Laboratory-based intrusions (immediately after interference & day 8).

This task used 11 still images, each taken from each scene of the trauma film, and 68 foil stills unrelated to the film which depict a variety of indoor and outdoor background scenes. All images were altered using Gaussian Blur 2.0 which meant that they were not exact replicas of the film. See Figure 3.2 for a schematic overview of the task.

Participants were asked to perform a digit vigilance task consisting of 270 trials. Each trial started with a centrally presented digit for 250 msec on a black background screen. The digits were white and chosen randomly from five different font sizes (48, 72, 94, 100 and 120 points) corresponding to stimulus heights of 12-29 mm approx. The digit then disappeared and the black screen remained for a further 1500 msec. Participants were instructed to press the GO key for any digit between 1 to 9 but withhold their response when the digit was 3 (low frequent target digit occurring 11% of the time). Every three trials starting from the first, a coloured background still appeared simultaneously behind the digit, and stayed on screen even when the digit disappeared. Each foil still was used once only whereas each film still was used twice. Film stills were never on a same trial as the target digit. Participants were told they may encounter background scenes but no responses were required. Both digits and stills were presented in a fixed randomised order. Participants were also told that image-based intrusions from the film may pop up spontaneously at any time during the task, and to stop the digit vigilance task with the INTRUSION key whenever an image-based intrusion occurred. They then briefly described the intrusion on a separate paper sheet, and upon completion resumed with the digit vigilance task. The viewing distance was approximately 60cm from the screen. Thirty-six practice trials were given prior to the task. The main outcome was the total frequency count of intrusive memories throughout the digit vigilance task (See Appendix 3.1. for the full protocol of this task).

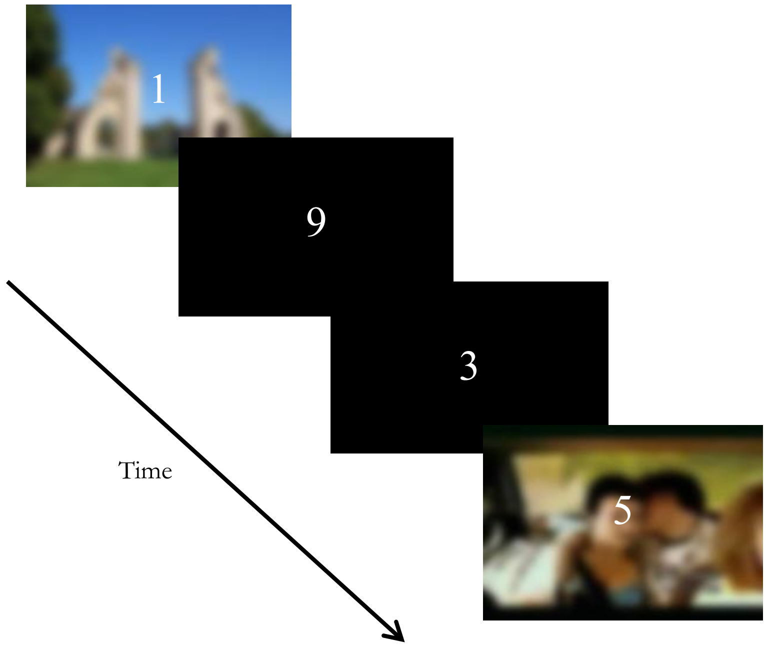


Figure 3.2. Schematic of the task structure in the laboratory-based intrusion task, illustrating four sample experimental trials. A digit was presented in every single trial. Additionally, a background still was presented every three trials. The majority of these stills depicted indoor and outdoor landscape scenes (such as in the first sample trial), with a minority depicting still moments of the trauma film (such as in the fourth sample trial). Participants were instructed to press the GO key every time they saw a digit that was not '3', and to press the INTRUSION key whenever they experienced an intrusive image-based memory of the film.

Attention bias (soon after interference)

The stimuli consisted of two sets of 96 still images each, each drawn from either the trauma film or foil sources. Some of these stills overlap with the sets used for the recognition test. Within each set, half were categorised as emotional stills (high emotionality) and half as neutral stills (low emotionality), based on the negative emotionality index obtained from independent norming data on participants who have not seen the film (see Appendix 2.8 for details of the norming study, and Appendix 3.2 for examples of stills used within each category). Such an index was not statistically different between the film and the foil sets for both emotional [film: $M = 6.91$, $SD = 0.56$; foil: $M = 6.78$, $SD = 0.56$; $t(46) = 0.79$, $p = .433$] and neutral stills [film: $M = 3.74$, $SD = 0.52$; foil: $M = 3.48$, $SD = 0.53$; $t(46) = 1.77$, $p = .084$]. See Figure 3.3. for a schematic overview of the task.

The experiment had four runs, each using the entire stimuli set. Within each run, a film and a foil still (both being emotional or neutral) would be randomly paired for each participant, resulting in 96 trials per run. The background colour remained dark grey throughout the task. On each trial, a central fixation cross appeared for 1000 msec followed by the presentation of each still pair, one to the left and one to the right of the fixation cross. The location of the film vs. foil still was also randomised across trials with equal frequency. The still pairs remained on screen for either 500 msec or 1000 msec also with equal frequency. The still pair disappeared and a small visual probe was then presented in the location where either still was shown, with equal frequency in the location on either still type. This location was determined from an imaginary 2 cm × 2 cm square behind the centre of each still for which the precise location was randomly determined to fall within this area on each trial. Participants judged whether the visual probe consisted of one or two small grey dots, and were instructed to make the decision as quickly and as accurately as possible.

If they made a mistake, an error-triggered delay message appeared for 5 sec before participants moved on to the next trial. The viewing distance was 60 cm approx. Participants had the opportunity of a short break between each run. Twelve practice trials with a different set of foil stills were given prior the four experimental runs. The main outcome was *attentional bias* towards film stills over foil stills expressed by the degree to which probe discrimination latency was speeded up when such a probe was presented in the location of a previously presented film still within each film-foil pairing. A high score on this index reflects greater attention bias to film stills.

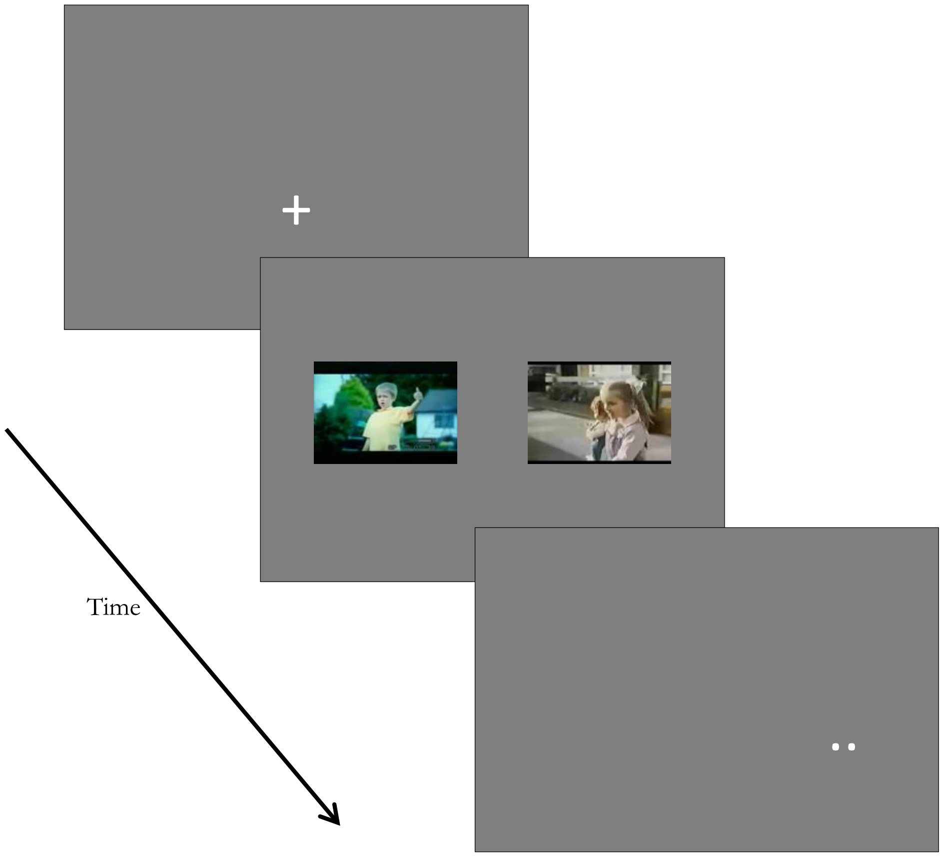


Figure 3.3. Schematic of an experimental trial in the attention bias task in Experiment 2. Following a fixation cross, participants were presented with a film-foil still pair. When the stills disappeared, a dot probe would appear on either side of the screen, behind the original location of either still. Participants were instructed to judge the identity of the dot probe (i.e., one or two dots) as accurately and as fast as possible[3].

[3] I am grateful for Colin MacLeod and Ben Grafton for advise on designing this task.

Recognition (day 8)

This measure was the same as in Experiment 1, except that rather than confidence ratings, participants made yes/no judgments to indicate as fast and as accurately as they could whether or not each still picture belonged to the film. For each yes response, they then had 5 sec to make a R/K judgment (Henson et al., 1999; Rajaram, 1993). R judgments referred to instances when recognition was accompanied by a conscious sense of recollection, whereby some other aspects of what happened in the film came to awareness. In contrast, K judgments referred to instances when one was certain that they recognised the picture but nevertheless did not consciously recollect anything else about the film (See Appendix 3.1 for the full protocol).

Results

Randomization and manipulation checks

Both groups were matched at baseline in terms of gender, age, depressive symptoms, trait anxiety, number of previous traumatic events and general use of imagery. Viewing the film also resulted in predicted increases in negative mood, which was matched between groups. Ratings for attention paid to the film and personal relevance of the film were also matched between groups. The no-interference group rated their diaries as less accurate than the interference group. See Appendix 3.3 for details. Nevertheless, this rating was used as a covariate in all analyses involving diary intrusions and the pattern of results remained the same (therefore only analyses without the covariate were reported).

Interference-task effects on each of the measures of film memory

Laboratory-based intrusions (involuntary retrieval on day 8).

Reliability of intrusion keys. To determine whether indeed each time participants pressed the INTRUSION key they also experienced an intrusion, the match between each intrusion description and film content was examined. There was only a minority of intrusions (5; 1.91%) which could not be matched to the film, and were therefore excluded from the analyses. There was also a significant positive Pearson product-moment correlation between the number of INTRUSION key presses and the number of descriptions matching film content [$r = 0.99$, $N = 36$, $p < .001$].

Frequency of intrusions. Participants in the interference group reported significantly fewer intrusions in the laboratory on day 8 compared to the no-interference group [interference: M = 5.00, SD = 6.36; no-interference: M = 9.28, SD = 3.95; $t(34) = 2.42$, $p = .021$, d = .81].

Recognition (voluntary retrieval on day 8).

Accuracy. Following Experiment 1, recognition accuracy was calculated for each participant by subtracting the false alarm rate from the hit rate. See Table 3.1 for the main accuracy outcomes. One-sample t-tests indicated that recognition accuracy was above chance in both groups [$t(17)$'s = 13.51, p's < .001]. An independent sample t-test indicated that recognition accuracy was not significantly different between groups [interference: M = 0.46, SD = 0.10; no-interference: M = 0.42, SD = 0.13; $t(34) = 1.07$, $p = .292$, d = .34]. Using the size of the interference effect on laboratory intrusions on day 8 as the baseline (d = 0.81), the Bayes factor for recognition accuracy was .0032, indicating substantial evidence to accept the null over the alternative hypothesis (Dienes, 2011).

R/K. These responses were not collected for two participants from the no-interference group due to error with the software. With the available data, recognition performance scores were obtained separately for trials endorsing R vs. K judgments. A 2 (between-group: interference vs. no-interference) × 2 (within-subject: R vs. K) × 2 (within-subject: hit vs. false alarm rates) mixed ANOVA revealed a significant main effect of judgment [$F(1,32) = 14.62$, $p = .001$, $\eta_p^2 = .314$], suggesting that accuracy was higher for stills accompanied by R (M = 0.25, SE = 0.02) than K responses (M = 0.15, SE = 0.01). The main effect of rate was also significant [$F(1,32) = 490.99$, $p < .000$, $\eta_p^2 = .939$], suggesting that hit rates (M = 0.31, SE = 0.01) were higher than false alarm rates (M = 0.09, SE = 0.01). There was no main effect of group [$F(1,32) = 0.07$, $p = .789$, $\eta_p^2 = .002$]. There were no two-way significant interactions between judgment × group [$F(1,32) = 0.26$, $p = .613$, $\eta_p^2 = .008$] or rate × group [$F(1,32) = 0.53$, $p = .473$, $\eta_p^2 = .016$]. However, the judgment × rate interaction was significant [$F(1,32) = 30.93$, $p < .001$, $\eta_p^2 = .492$]. When this was decomposed into two separate paired-sample t-tests, it was found that hit rates were higher for R (M = 0.41, SE = 0.03) compared to K (M = 0.21, SE = 0.02) responses [$t(33) = 4.76$, $p < .001$], but false alarm rates were not significantly different between R (M = 0.08, SE = 0.01) and K (M = 0.10, SE = 0.01) responses [$t(33) = 1.36$, $p = .184$]. Finally, the three-way interaction between group × judgment × rate was not significant [$F(1,32) = 0.07$, $p = .789$, $\eta_p^2 = .002$]. Thus, critical to this thesis, no significant effects emerged with group.

Table 3.1

Means and Standard Deviations for Performance on Recognition Memory by Groups in Experiment 2

	Interference (n = 18)		No-interference (n = 18)	
	M	*(SD)*	*M*	*(SD)*
Overall performance				
Hits	56.39	(12.93)	54.67	(16.61)
FA	15.22	(11.23)	19.72	(14.15)
R responses				
Hit rate	0.41	(0.15)	0.43	(0.19)
FA rate	0.07	(0.08)	0.09	(0.09)
K responses				
Hit rate	0.20	(0.14)	0.10	(0.07)
FA rate	0.22	(0.11)	0.10	(0.06)

Note. FA = False alarms; R = Remember; K = Know.

Interaction between intrusions and recognition on day 8

Z-scores across memory measures. Both intrusion frequency and recognition accuracy (involuntary vs. voluntary memory obtained on day 8 in the lab) were standardised (obtaining z-scores) to allow for comparison across metrics (see Table 3.2). A 2 (between-group: interference vs. no-interference) × 2 (within-group: involuntary vs. voluntary) mixed model ANOVA on such z-scores revealed that neither the main effect of group [$F(1,34) = 0.70$, $p = .408$, $\eta_p^2 = .020$] nor intention [$F(1,34) = 0.00$, $p = .998$, $\eta_p^2 = .000$] were significant. However, the group × intention interaction was significant [$F(1,34) = 7.06$, $p = .012$, $\eta_p^2 = .172$], confirming that the interference procedure affected intrusions but not recognition, even when both were matched on day of testing.

Table 3.2

Means and Standard Deviations of Z-Scores on Laboratory-Based Intrusion Frequency and Recognition Accuracy (both on Day 8) by Groups in Experiment 2

	Interference (n = 18)		no-interference (n = 18)	
	M	*(SD)*	*M*	*(SD)*
Intrusion frequency	-0.38	(1.23)	0.38	(0.70)
Recognition accuracy	0.17	(0.88)	-0.17	(1.11)

Laboratory-based intrusions (immediately after interference).

Reliability of intrusion keys. There was 1 intrusion (0.26%) which could not be matched to the film, and was therefore not included in the analyses. A significant positive Pearson product-moment correlation emerged between the number of INTRUSION key presses and the number of descriptions matching film content [$r = 0.88$, $N = 36$, $p < .001$].

Frequency of intrusions. The interference group reported significantly fewer intrusions immediately after interference compared to the no-interference group [$t(34) = 2.87$, $p = .007$, $d = 0.96$]. See also Figure 3.5. A multiple regression model was used to investigate the relationship between lab intrusion frequency immediately after interference and subsequent diary intrusion frequency, and whether it varied according to groups. Both main predictors (laboratory intrusions and group) were entered into a first block and the interaction term in a second block, with diary intrusions as the dependent variable. The model with both predictors was significant [$F(2,33) = 13.54$, $p < .001$, $R^2 = .45$] confirming that more laboratory intrusions [b = 0.36, $SE_b = 0.11$, $\beta = .45$, $p = .003$] and the no-interference group [b = -3.61, $SE_b = 1.56$, $\beta = -.33$, $p = .027$] were both associated with more diary intrusions. However, the model with the interaction term did not result in a significant R^2 Change [$F(1,31) = 0.99$, $p = .328$, R^2 change = .02]. These findings suggest that intrusion frequency early on in the lab after interference is predictive of subsequent intrusion frequency in daily life (irrespective of group). See Figure 3.4.

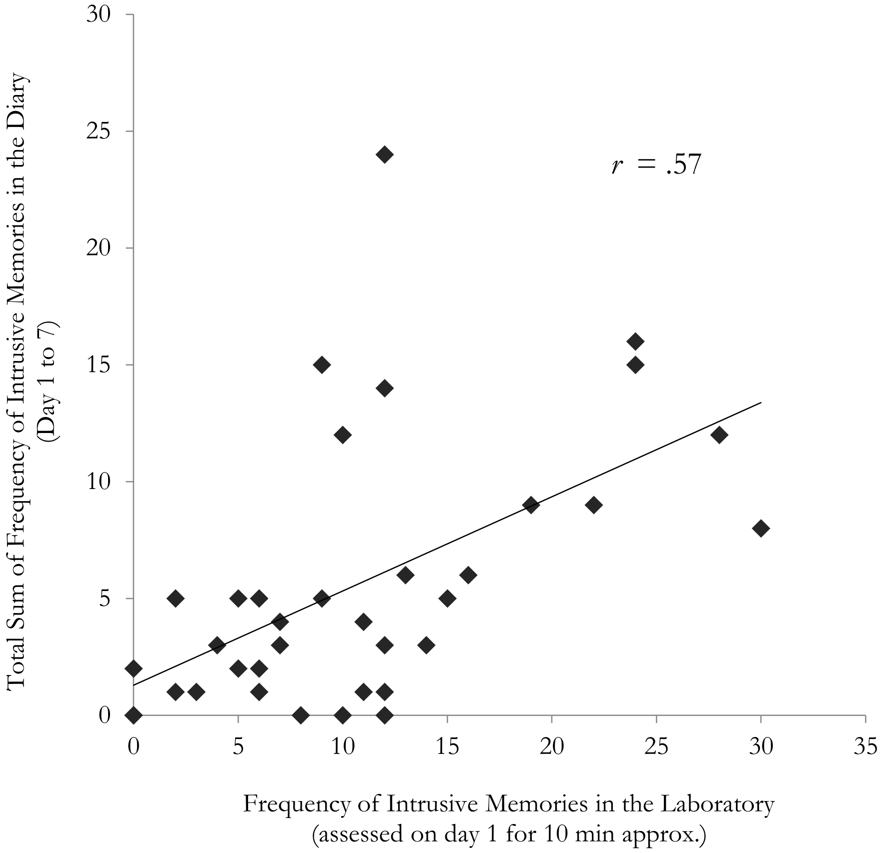


Figure 3.4. Scatterplot depicting intrusion frequency immediately after interference within the laboratory (assessed for 15 min approximately) by diary intrusion frequency in daily life (total sum for day 1 to 7) across groups. The straight line represents the linear trend demonstrating a positive relationship.

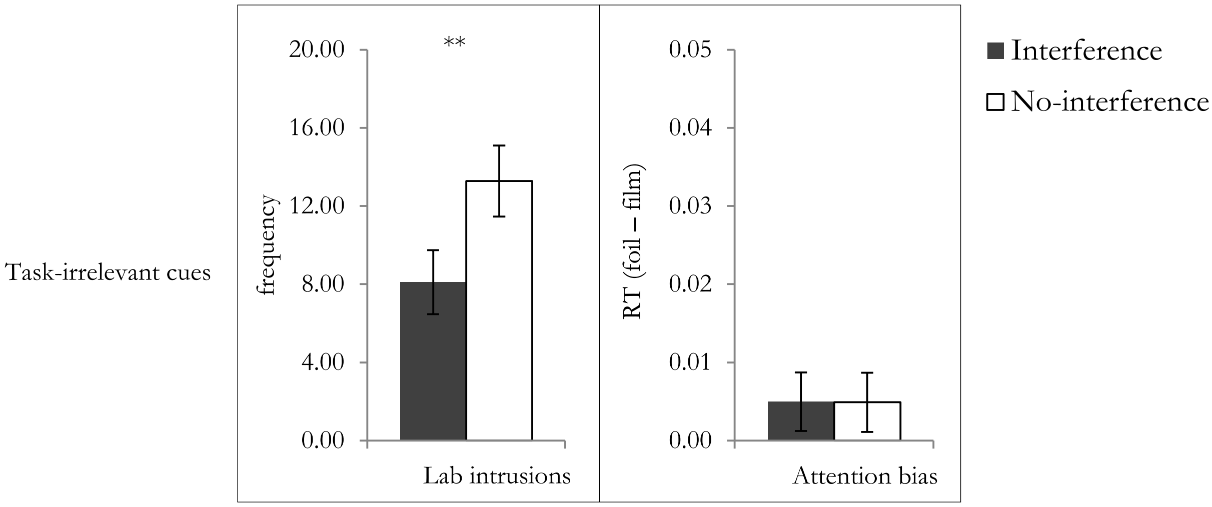


Figure 3.5. 'Retrieval strength' on each memory measure delivered soon after interference within the laboratory by groups in Experiment 2. The main outcome for each memory measure was: for lab intrusions, the frequency of intrusive memories over a 10-15 min period; for attention bias, an index was derived by collapsing across trials with emotional or neutral stills and by subtracting RT to trials with probes matching the location of foil stills from RT to trials with probes matching the location of film stills. Positive scores indicated the presence of attention bias to film stills. A one-sample t-test indicated that this attention bias across both groups was significantly above chance (one-tailed, alpha <.10). Error bars represent standard errors. Significant two-tailed group comparisons within each memory measure were flagged, i.e., only for laboratory intrusions (** alpha <.01).

Attentional bias (soon after interference).

Accuracy. The proportion of correct trials across the four runs was calculated for each participant. An independent-sample t-test revealed that both the interference (*M* = 0.98, *SD* = 0.02) and the no-interference group (*M* = 0.97, *SD* = 0.06) had matched levels of accuracy [$t(34) = 0.88$, $p = .381$, $d = 0.22$].

Table 3.3

Means and Standard Deviations for Attention Bias in RT (sec) by Still Type and Groups in Experiment 2

	Interference (*n* = 18)		No-interference (*n* = 18)	
	M	*(SD)*	*M*	*(SD)*
Emotional stills	0.011*	(0.019)	0.008*	(0.018)
Neutral Stills	-0.002	(0.024)	0.002	(0.023)

Note. Positive values indicate the presence of an attentional bias towards film stimuli. Significant one-sample t-tests were flagged (one-tailed; * alpha <.10) indicating that the corresponding bias score was above chance, i.e., only for emotional stills in both groups.

RT. Across the four runs and time lags between stills and dot-probe, RTs were obtained from all correct trials in which RT <2000 msec (Hoppitt et al., 2014; MacLeod, & Bridle, 2009). An attention bias score was calculated for each participant by subtracting the RT for responding to dot-probes sharing location with foil stills from those sharing location with film stills, with positive scores indicated a bias for film stills. See Table 3.3. A 2 (between-group: interference vs. no-interference) × 2 (within-subject: emotional vs. neutral still pairs) mixed ANOVA on bias scores revealed a significant main effect of emotionality [$F(1,34) = 4.12$, $p = .050$, $\eta_p^2 = .108$], suggesting that attention bias was more pronounced for emotional (*M* = 0.10, *SE* = 0.003) than neutral pairings (*M* = 0.00, *SE* = 0.004). However, the main effect of group was not significant [$F(1,34) = 0.00$, $p = .995$, $\eta_p^2 = .000$], nor the interaction between group × emotionality [$F(1,34) = 0.67$, $p = .421$, $\eta_p^2 = .019$]. Given that this interaction was not significant, an attentional bias score for each participant was obtained across emotionality (i.e., collapsing emotional and neutral trials). Results are depicted in Figure 3.5. Using the size of the interference effect on laboratory intrusions immediately after interference as the baseline (*d* = 0.92), the Bayes factor for the group difference in attention bias was <.0001, indicating there is substantial evidence to accept the null over the alternative hypothesis (Dienes, 2011).

Interaction between attentional bias and intrusions (soon after interference).

Table 3.4

Means and Standard Deviations of Z-Scores on Laboratory-Based Intrusion Frequency and Attention Bias Index (both Soon After Interference) by Groups in Experiment 2

	Interference (n = 18)		No-interference (n = 18)	
	M	*(SD)*	*M*	*(SD)*
Laboratory intrusions	-0.44	(0.66)	0.44	(1.11)
Attention bias to film	0.002	(1.01)	-0.002	(1.02)

Z-scores across memory measures. A single outcome was selected from each memory measure administered in the laboratory soon after the experimental manipulation on day 1. These were standardised (using z-scores) to allow for comparison across tasks (see Table 3.4). The outcomes were the frequency of laboratory intrusions and the index of attentional bias to film stimuli. Both measures were thought to recruit involuntary retrieval in the context of task-irrelevant cues. A 2 (between-group: interference vs. no-interference) × 2 (within-group: intrusion frequency vs. attentional bias) mixed model ANOVA did not reveal a main effect of group [F(1,34) = 3.45, p = .072, η_p^2 = .092] nor a main effect of task [F(1,34) = 0.00, p > .999, η_p^2 = .000]. The two-way interaction between group and task was near-significant [F(1,34) = 3.93, p = .055, η_p^2 = .104]. A depiction of both tasks together (Figure 3.5) illustrates that the interference procedure modulated laboratory intrusions but not attention bias.

Discussion

The present experiment investigated the effect of the interference procedure (vs. no-interference) after trauma film viewing on subsequent memory for that film, using a measure of attention bias to film cues and a measure of laboratory-based intrusion frequency, both delivered soon after interference.

Summary of findings

First, the interference group reported fewer intrusions in the laboratory on day 8 compared to the no-interference group, whereas no group difference was found on the recognition test also administered on day 8. There were also no group differences in a measure of attentional bias to task-irrelevant film cues administered on day 1 soon after interference. Importantly, the interference group reported fewer laboratory intrusions sampled immediately after interference.

Findings in relation to each hypothesis

In line with Hypothesis A, the interference procedure reduced the frequency of laboratory-based intrusions on day 8, albeit using a new laboratory method to sample intrusions. Although the current sampling method and the one used by James, Bonsall et al. (2015) differ in several aspects, a shared feature is the presentation of blurred images depicting neutral moments from the original film. This suggests that such stills may play an important role in bringing about the effects on intrusions. Further, the interference task continued to spare recognition performance, even with the introduction of the R/K procedure. The intrusion/recognition dissociation is robust, as both were matched in terms of day of testing (day 8).

Contrary to Hypothesis B, the interference procedure did not appear to disrupt the attentional bias to task-irrelevant film cues. Across the whole sample, participants developed a bias towards film stimuli which was most pronounced for stills depicting emotional scenes of the film. As each emotional film still was matched with an equivalent emotional foil still, a bias to film still would not be purely driven by the inherent emotional qualities of the still, but also by virtue of its previous exposure in the context of the trauma film. However, the lack of group differences indicates that such attention bias was not sufficient to explain the interference effect on intrusions. There are possible caveats to this conclusion. For instance, one may argue that such attention bias occurred deliberately because participants realised that the stills were not entirely 'task-irrelevant', i.e., stills could share locations with the dot-probe targets; however, the likelihoods of a dot-probe sharing location with either film or foil stills were equal. Another possibility is that the attention bias measure is inherently noisy; however, this measure was able to capture an interaction effect of film and emotionality across all participants despite the lack of group-level differences. A final possibility is that unlike other memory measures that have captured an interference effect, the measure of attention bias was administered within the first laboratory session very soon after interference. One could argue that consolidation-based effects take time to emerge and may even require sleep (Dudai, 2004). However, this suggestion is ruled out by the interference effect on laboratory-based intrusion frequency during the same assessment period as discussed next.

Consistent with Hypothesis C, the interference procedure also reduced the frequency of intrusions reported on day 1 immediately after interference within the laboratory. It was established for the first time that the interference effect on intrusions can be observed this early on. Laboratory-based intrusions were able to both demonstrate a group-level effect in line with diary intrusions, but also predict diary intrusions at an individual level. The interference effect on laboratory-based intrusions dissociated from its effect on attention bias, both measured within the same period (i.e., soon after interference). Thus, intrusions dissociated from other measures of involuntary retrieval considered so far, namely priming (Experiment 1, Chapter 2) and attention bias (current experiment).

From a theoretical perspective, it is surprising to see a 'consolidation' effect appearing so soon after the manipulation. Typical system-type consolidation effects occur after sleep (Walker & van der Helm, 2009), if not at least after a few hours (Dudai, 2004; McGaugh, 2000, 2004). Nevertheless, from a methodological perspective, the laboratory-based intrusion task confers leverage to test, for the first time, potential moderating factors in subsequent experiments.

Methodological Caveat

For laboratory intrusions soon after interference, the no-interference group would have stopped the digit vigilance task more often compared to the interference group to write down the content of each intrusion (therefore spending more time overall to complete all trials). One may argue the group difference in intrusion frequency can be explained by differences in time taken to complete the intrusion task. As the number of INTRUSION key presses is indeed a reliable measure of the frequency of intrusions matching film content, the next experiments will not instruct participants in either group to write down the content of each intrusion for verification.

Chapter Summary and Next Steps

To summarise, the memory measures considered in this chapter showed that the interference procedure reduced intrusion frequency but not recognition accuracy, even when both were better matched on the time of testing (i.e., both tested on day 8). This provides further evidence that the intrusion/voluntary dissociation is robust.

However, a candidate factor considered was unable to provide an explanation of this intrusion/recognition dissociation. Specifically, such an interference effect could not be readily explained by an impact on attention bias to *task-irrelevant* film cues (because attention bias soon after interference, observed in both groups, was not affected by interference). Interestingly, the effect on intrusion frequency was revealed also in a laboratory-based measure of intrusions administered immediately after interference. Thus, the effect on intrusions does not appear as time-dependent, i.e., it does not take time to emerge.

These findings again provide support that the interference procedure does not 'erase' the content of the memory per se. The findings also suggest that the same procedure spares influences that the memory trace may have on subsequent external attention. Importantly, the ability to assess the interference effect early on (i.e., day 1 in the lab) is useful from a clinical perspective, as it points towards the possibility of early markers of intervention effectiveness which could be used to predict their subsequent effect in daily life for each individual. Such early effect confers methodological advantages as well, as it allows more tractable experimental studies using a 15-min diary-like task in the laboratory within a single session as opposed to a one-week long diary.

What additional factors are in place in both laboratory and diary intrusions? One such factor, yet to be considered, is the assumed low-demanding nature typically associated with the retrieval of an intrusion (i.e., low WM load). This could be studied by manipulating load within the laboratory-based intrusion task in the next experiments.

As with the current experiment, the next experiment also considers the relationship between the effects on intrusive memories and another parameter of the interference paradigm, i.e., reminder cues prior to interference. Specifically, are reminder cues needed to exert interference, even when the memory is still 'labile' during consolidation?

4. Working Memory Load & Cue-Dependent Interference

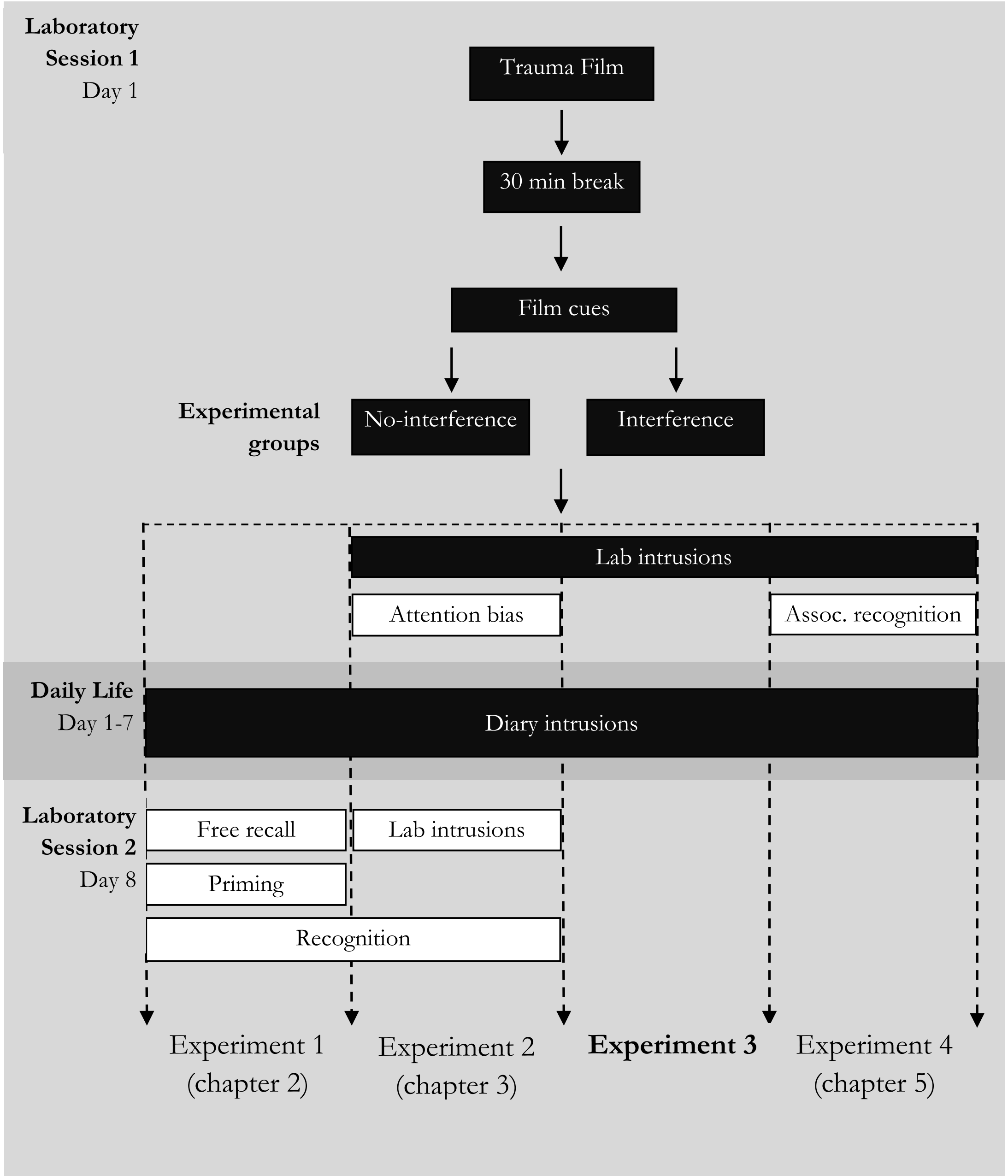


Figure 4.1. Experiment 3: procedural diagram relative to other experiments. Black boxes highlight procedural components specific to this experiment; white boxes highlight procedural components included in other experiments in this thesis. Dotted lines separate the memory measures administered across experiments, indicating this experiment focussed on both *laboratory intrusions* (session 1) and *diary intrusions* (daily life), similarly to other experiments. A third group was used (interference-task without reactivation) which was not depicted in the diagram.

Introduction

The previous experiment from Chapter 3 failed to find that attention bias to task-irrelevant cues could explain the interference effect on intrusive memory frequency. The present chapter investigated instead if such an effect can be explained by retrieval load, by manipulating both load levels (no vs. high) and modalities (visuospatial vs. verbal). Here, WM load during the *retrieval* of intrusions was manipulated by leveraging the new method developed in the previous chapter to sample intrusions in the laboratory.

WM Load and Imagery Generation

It has been proposed that the generation of mental imagery requires cognitive resources from WM. WM refers to the ability to both store and dynamically manipulate temporary information from memory (Baddeley, 2003; Kane, Bleckley, Conway, & Engle, 2001). Recent evidence suggests a common neural circuitry between WM and mental imagery (Albers, Kok, Toni, Dijkerman, & de Lange, 2013; J. Pearson et al., 2015). As intrusive memories constitute a form of mental imagery possibly requiring WM resources for their development, it can be speculated that the interference procedure affects the association between intrusions and WM load at retrieval.

An influential model of WM (Baddeley, 2003) proposes the existence of a central executive which manipulates information maintained in two auxiliary modality-specific stores for phonological (phonological loop) and visuospatial information (visuospatial sketchpad), respectively. One view argues that the relationship between WM and imagery is modality-specific, in that visual imagery is dependent on the visuospatial sketchpad, whereas auditory imagery is dependent on the phonological loop (Andrade, Kavanagh, & Baddeley, 1997; Baddeley & Andrade, 2000). In contrast, a general load view suggests that imagery generation (e.g., image-based autobiographical memories) relies on resources from the central executive, irrespective of modality (Gunter & Bodner, 2009; van den Hout & Engelhard, 2012). However, both research perspectives have solely focused on *voluntarily*-generated imagery, with the assumption that similar principles must also apply to *involuntarily*-generated imagery, such as intrusive image-based memories.

WM Load and Intrusive Memory Retrieval

Although some work has investigated the link between WM and intrusive memories, the available research has focussed on the role of WM at the time window of memory encoding (Corin Bourne et al., 2010; Holmes et al., 2004; Krans, Naring, et al., 2009; Krans et al., 2010) or consolidation (Deeprose et al., 2012; Holmes et al., 2009; Holmes, James, et al., 2010) of a memory that can subsequently become intrusive.

In contrast, there is little research on the role of WM during the *retrieval* of intrusive memories. There is one exception (Hellawell & Brewin, 2004), but such a study did not require participants to involuntarily retrieve the memory with concurrent WM tasks, nor did it assess intrusion *frequency*, the key outcome relevant to this thesis. The paucity of studies has possibly been amplified by the predominance of paradigms (e.g., diary studies) that do not confer experimental control on retrieval processes. The laboratory-based intrusion task from the previous chapter overcomes this limitation, and can help answer whether or not the interference-task influences the association between intrusion frequency and WM load at retrieval.

Potential Explanation for Findings from Experiment 2

In Experiment 2, the interference task affected the frequency of intrusions in the laboratory-based intrusion task, but showed negligible effect on the attention bias task. A critical difference between both tasks may concern the level of WM retrieval load. The cognitive demands of the laboratory-based intrusion task were low. Here, participants engaged in a monotonous and repetitive activity that typically induces a state of mind-wandering; similarly, it could be argued that intrusions in the diary are experienced while participants are performing activities low in cognitive demands.

In stark contrast, the cognitive demands of the attention bias task can be considered high, as such a task emphasised both speed and accuracy with performance feedback. Moreover, visual stills in this task appeared to capture attention, possibly consuming capacity on visual maintenance (Konstantinou, Beal, King, & Lavie, 2014; Pasternak & Greenlee, 2005) which may also be required for intrusion development.

It is possible that intrusions affected by the interference procedure occur in contexts that are deemed low-demanding, i.e., those that require low levels of WM resources, but not in contexts that are deemed highly demanding, i.e., those that already consume high levels of WM resources, particularly if such resources share modality with the image-based quality of the memory, i.e., predominantly in the visual domain.

Experiment 3

The aim of this experiment was threefold: first, to replicate the interference effect on intrusion frequency in the laboratory-based intrusion task soon after interference; second, to test if the interference task influences the association between intrusion frequency and WM load at retrieval – more specifically, if the interference effect is more pronounced during low compared to high retrieval load; and third, to test whether or not the effect of the interference procedure on intrusion frequency was dependent on the combination of two components of the procedure: i.e., reminder cues followed by Tetris game play.

Main Modifications to the Laboratory-Based Intrusion Task

This experiment leveraged the newly developed laboratory-based intrusion task from Experiment 2 and a few modifications to test new hypotheses. The main modification concerned the manipulation of WM load during performance of the laboratory-based intrusion task, entailing three levels of load: one level required participants to perform no additional tasks, whereas the remaining two levels required participants to complete parallel tasks which had previously been established to compete for resources in visuospatial and verbal WM, respectively. Instead of INTRUSION key presses, retrospective estimates were used for intrusion estimation, so as to avoid any potential interference in the WM manipulations themselves.

Hypotheses

Replication of pattern on early laboratory-based intrusions (Experiment 2)

Hypothesis A: The interference procedure reduces intrusion frequency in the laboratory-based intrusion task administered immediately after interference.

Extension to manipulate retrieval load on the frequency of intrusive memories

Hypothesis B: The interference effect on reducing intrusion frequency is specific to intrusions during low load. Therefore, the interference procedure reduces the frequency of intrusions that occur during low but not high (visuospatial) WM load (or to a greater extent in low load compared to high load).

Further dismantling the interference procedure in 'consolidation'

Hypothesis C: The interference procedure, applied within the time window of memory 'consolidation' (i.e., 30 min after trauma film viewing), is effective in reducing intrusion frequency only if the manipulation involves both reminder cues and interference task (Tetris game play); each component in isolation would not be as effective.

Method

Participants

Sample size estimation. The interference effect on laboratory-based intrusions soon after interference had an effect size of $d = 0.97$ in Experiment 2. On this basis, a sample size of at least 18 participants per group was considered to ensure 80% power to replicate this effect at 5% significance level (two-tailed hypothesis testing).

The same recruitment strategy was used as in Experiment 1. Two participants dropped out from the study: one could not attend the follow-up session and the other stopped the film. The final sample consisted of 36 volunteers (28 females, age range = 19 – 49).

Materials, stimuli and procedure

All materials and stimuli were the same as in Experiment 1 and 2, with a critical exception that this experiment consisted of a single laboratory session only (See Appendix 4.1 for the full protocol). All procedures remained the same as in Experiment 2 up to the filler task break. Afterwards, participants were randomly assigned to three groups: both cue+interference and cue+no-interference groups were the same as previous experiments. A third group (interference-task only) played Tetris only without reminder cues.

After randomisation, instructions were given on how to perform the first laboratory-based intrusion task after a short practice, which was similar to Experiment 2. They also received training on how to perform the modified version of the laboratory-based intrusion task, followed by practice in the verbal and visuospatial WM tasks (see details in the next section). They then completed the modified version of the laboratory-based intrusion task with three different WM load manipulations.

At the end of the session, instructions on filling in the diary were explained and participants were sent away. They were asked to return the diary by post (unlike in previous studies where diaries were returned in person). Upon diary return participants were debriefed by email. The diary data for this experiment is reported in a subsequent combined analysis across all experiments (Chapter 6). There was not a follow-up laboratory session.

Measures of Film Memory

All memory tests (i.e., except the diary) were presented using Matlab 2009 and Psychtoolbox.

Laboratory-based intrusions original version (online reporting)

This task was exactly as in Experiment 2 with one critical difference. Similar to Experiment 2, participants were told to press the INTRUSION key as soon as they noticed that an intrusive image-based memory of the film had occurred, i.e., online reporting. However, unlike Experiment 2, participants were not told to stop the digit vigilance task to describe the content of the intrusions. This procedure was not included because 1) Experiment 2 showed that INTRUSION key presses by themselves are reliable indicators of film-related intrusions and 2) it helps to equate the differences in task length across groups (so that higher intrusion frequency is not confounded by more time spent on describing the intrusions).

Laboratory-based intrusions modified version (retrospective estimates)

The original lab-based intrusion task was modified to allow for WM load manipulations during the *retrieval* of intrusions, a manipulation that was extremely difficult in daily life (diary) contexts. All procedural details remained the same, except four modifications were made. First, participants were told to perform the digits vigilance task using their non-dominant hand and by clicking on the Mouse button. This freed up their dominant hands needed to perform the visuospatial WM task (i.e., concealed pattern tapping). Second, participants were told they did not need to press the INTRUSION key when they experienced an intrusion.

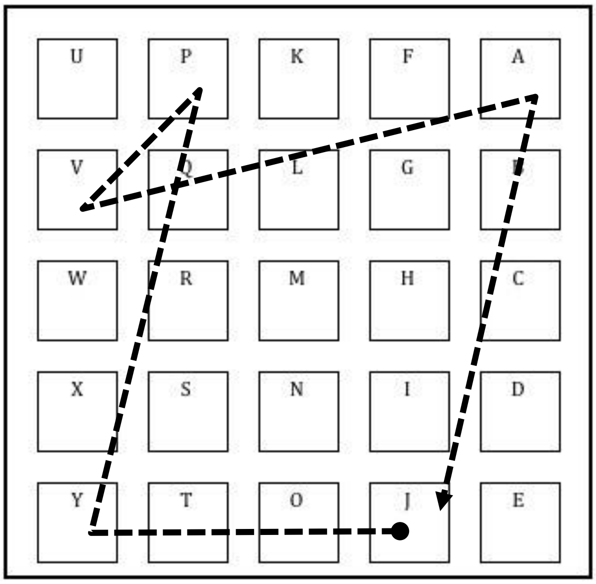


Figure 4.2. An illustration of the tapping box used for concealed complex pattern tapping in Experiment 3. This task was used to tax visuospatial working memory during intrusive memory retrieval in the modified versions of the laboratory-based intrusion task. Following training, participants were asked to tap a pre-specified key pattern steadily and continuously without looking at the tapping box, while also holding a visual image of that pattern produced in mind. The pattern was JYPVA as shown in the dotted lines, with the pattern starting from the black dot and continuing following the direction of the arrow[4].

[4] I am grateful for Joni Holmes for advice on designing the WM manipulations for this experiment

Third, the task structure was adapted to introduce a retrospective estimation procedure for intrusion assessment (Schaich et al., 2013; Zetsche et al., 2009). To minimise the risk of retrospective recall bias, the original design (270 trials) was divided into three runs (of 90 trials each), with each lasting for 3 min approximately. At the end of each 3-min run, participants were asked to estimate how many intrusions they had retrospectively (*How often did memories of the event in the form of mental images pop into your mind in the last three minutes?*) by typing in the corresponding count. Intrusion frequency within each WM load condition was summed across the three runs. After frequency estimations, participants also completed three Visual Analogue Scales (VAS) ranging from 0 (not at all) to 100 (extremely) to describe phenomenological qualities of the intrusions they may have experienced. These scales assessed the overall degree of intrusion distress (*How distressing did you find these image-based memories?*), vividness (*How vivid did you find these image-based memories?*) and nowness (*To what extent did you feel you were watching the film again when these image-based memories popped up?*). Ratings for vividness, distress and nowness were available only if participants experienced at least one intrusion in the specific run. The available ratings were averaged across runs within each retrieval load condition.

Finally, a higher number of film stills were used overall in this modified version (although all stills were filtered with Gaussian Blur 2.0). Whereas the original version had each film still presented twice across the 270 trials in the task, the modified version had each film still presented once within each of the three runs (i.e., every 90 trials, therefore repeated three times for the whole task). Each run also contained 19 non-film stills, which were different from those presented in the original laboratory-based intrusion task. Thus, participants were never exposed to each non-film still more than once (across both original and modified versions).

The order of load type was counterbalanced using a combinatorial design to control for both effects of WM load order and time. This counterbalancing procedure resulted in six different task order combinations: 1) visuospatial-verbal-no load, 2) visuospatial-no load-verbal, 3) verbal-visuospatial-no load, 4) verbal-no load-visuospatial, 5) no load-visuospatial-verbal and 6) no load-verbal-visuospatial. Each of these orders was performed by three participants within each group (with the exception of the first load order being performed by four participants within each group to make up for the uneven numbers).

No load. Participants performed the modified v lab-based intrusion task without additional WM tasks.

Verbal WM load (counting backwards in 1s). Counting backwards (in 3s and 7s) has been used to tax the phonological loop within contemporary WM models (Baddeley & Andrade, 2000; Baddeley, 2003). Participants were told that in addition to monitoring digits presented on the screen, they had to simultaneously count backwards aloud. Counting backwards in 1s was considered because earlier pilot data indicated that it was too difficult for participants to monitor visually-presented digits and simultaneously count backwards in 3s.

In the training stage, participants were asked to count backwards from the seed number 576 for 1 min. At least 10 consecutive correct numbers were required, otherwise this training was repeated. Participants then counted backwards for additional 5 min without feedback. They were encouraged to count backwards steadily and continuously but without rushing. In the experimental stage, participants were presented with pre-designated number seeds (958, 845 and 969 respectively, as in Deeprose et al., 2012) at the beginning of each run. They received a reminder at the start of the run to start counting without stopping until further notice. Their verbal responses were tape-recorded while the experimenter left the room.

Visuospatial WM load (over-practiced complex tapping). Finger pattern tapping has been demonstrated to tax the visuospatial sketchpad within contemporary WM models (Baddeley & Andrade, 2000; Baddeley, 2003). Participants were told that in addition to monitoring visually-presented digits with their non-dominant hand, they had to use their dominant hand to simultaneously tap a sequence of keys on a concealed box. This was a square box with a 5x5 array of buttons (Moar, 1978; Bourne et al., 2010; Deeprose et al., 2012). Each button was labelled with an individual letter from A to Y running from left to right. Participants had to tap an irregular pattern of five keys (JYPVA, see Figure 4.2)

In the training stage, participants first tapped the pattern while being able to see the box, and then while the box was hidden out of sight but still receiving visual feedback from the screen. Both of these lasted for at least 1 min each. Participants had to produce at least 10 consecutive patterns correctly; else the corresponding stage would be repeated. Participants then over-practised this task by tapping the sequence for 5 min without interruption, with the box out of sight and without visual feedback. They were encouraged to hold the pattern in mind and visualise it in their mind's eye while tapping continuously and steadily. In the experimental stage, participants began each run with a reminder to tap the pattern continuously without stopping until further notice. Their pattern tapping presses were recorded by the computer while the experimenter left the room.

Results

Randomization and manipulation checks

All groups were matched at baseline in terms of gender, age, depressive symptoms, trait anxiety, number of previous traumatic events and general use of imagery. Viewing the film also resulted in predicted increases in negative mood which were matched between groups. Ratings for attention paid to the film, personal relevance of the film and self-reported diary accuracy were also matched between groups. See Appendix 4.2. for details.

Interference-task effect on each measure of film memory

All analyses were performed by comparing the two main groups that were the same across all experiments in this thesis (i.e., 'cues+interference' and 'cues+no-interference'), unless otherwise indicated.

Laboratory-based intrusion frequency via online reporting.

Frequency of intrusions. Participants in the interference group reported significantly fewer laboratory intrusions compared to the no-interference group [interference: M = 9.37, SD = 8.48; no-interference: M = 21.11, SD = 10.98; t(36) = 3.69, p = .001, d = 1.20].

Laboratory-based intrusion frequency via retrospective estimates.

Compliance on WM manipulation tasks. The verbal counting task was performed consistently across groups, with comparable mean numbers counted per min [no-interference: M = 29.63, SD = 6.95; interference: M = 30.31, SD = 7.23; t(36) = 0.30, p = .770] and mean percentage of total correct numbers [no-interference: M = 97.76, SD = 2.25; interference: M = 96.79, SD = 2.94; t(36) = 1.14, p = .262]. The visuospatial tapping task was also performed consistently across groups, with comparable mean number of key presses per min [no-interference: M = 68.74, SD = 30.12; interference: M = 58.80, SD = 28.06; t(36) = 1.05, p = .300] and mean percentage of total correct 5-key sequences [no-interference: M = 74.67, SD = 22.47; interference: M = 71.49, SD = 24.28; t(36) = 0.42, p = .678].

Laboratory
intrusions

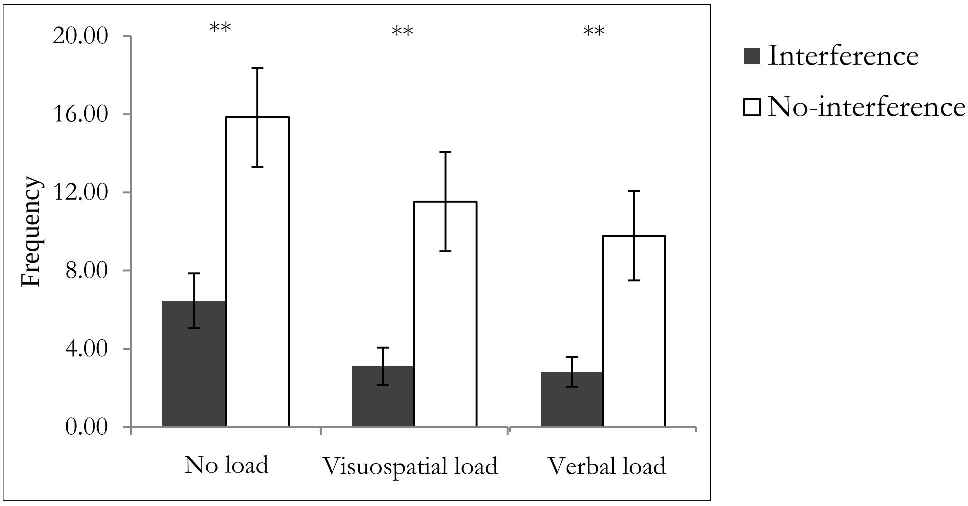


Figure 4.3. Intrusive memory frequency in the laboratory-based intrusion task (modified version) by retrieval working memory loads and groups in Experiment 3. Error bars represent one standard error. Significant two-tailed comparisons within each load condition were flagged, i.e., across all load conditions (** alpha <.01).

Interaction between groups and retrieval load. A 2 (between-group: interference vs. no-interference) × 3 (retrieval load: no load, visuospatial WM load and verbal WM load) mixed model ANOVA yielded a main effect group [F(1,36) = 12.46, p = .001, η_p^2 = .257], whereby the interference group (M = 4.25, SE = 1.62) estimated significantly fewer intrusions overall than the no-interference group (M = 12.31, SE = 1.62). Further, there was a significant main effect of retrieval load [F(2,72) = 7.22, p = .001, η_p^2 = .167]. Subsequent pairwise comparisons showed that compared to the no load condition (M = 11.16, SE = 1.44), there were fewer intrusions estimated for retrieval during visuospatial WM load (M = 7.44, SE = 1.50; p = .006) or verbal WM load (M = 6.24, SE = 1.19, p = .002), with no significant differences between both high WM loads (p = .358). Critically, the group × retrieval load interaction was not significant [F(2,72) = 0.42, p = .657, η_p^2 = .012], suggesting that the interference effect on intrusion frequency was equivalent regardless of the *level* or *modality* of the WM load at retrieval. See Figure 4.3. for a depiction of these results. Overall, the association between intrusion frequency and WM load at retrieval was not significantly affected by the interference procedure.

Dismantling the interference procedure during 'consolidation'

This analysis aimed to compare the effect of the interference task with and without pre-interference reminder cues on later intrusion frequency. The analysis combined both measures of laboratory-based intrusion frequency (with online reporting and retrospective estimates) during no load. A 3 (between-group: cues+no-interference, cues+interference or interference-only) × 2 (within-group: online reporting or retrospective estimates) mixed ANOVA on intrusion frequency revealed a significant main effect of intrusion task [F(1,54) = 6.56, p = .013, η_p^2 = .108], suggesting that online reporting (M = 15.54, SE = 1.42) was linked to more intrusions than retrospective estimation (M = 12.40, SE = 1.21). The main effect of group was also significant [F(2,54) = 7.29, p = .002, η_p^2 = .212]. Subsequent post-hoc pairwise comparisons indicated the cues+interference group (M = 7.92, SE = 2.02) reported significantly fewer intrusions than those in the cues+no-interference (M = 18.47, SE = 2.02, p = .001) or interference-only groups (M = 15.53, SE = 2.02, p = .010); intrusion frequency between the latter two groups was not statistically different (p = .306). The group × intrusion task interaction was also not significant [F(2,54) = 0.90, p = .414, η_p^2 = .032]. Overall, this analysis revealed that to produce the beneficial effects on intrusion frequency, the interference-task is not sufficient on its own, but requires exposure to reminder cues beforehand.

Exploratory analyses.

These analyses included all three groups.

Laboratory-based intrusions: other phenomenological qualities beyond frequency of occurrence. Exploratory analyses examined 1) whether or not the interference procedure affected other properties of intrusions in addition to their frequency of occurrence and 2) whether or not the relationship between those intrusion properties and retrieval WM load was moderated by the interference procedure. The availability of each data point on vividness, distress and nowness was dependent on intrusions indeed occurring in a particular condition for that participant. However, because some load conditions had *no* intrusions, these became 'missing' data on other intrusion qualities. Therefore, these repeated measures with missing data were analyzed with mixed effects models (between-group: cue+interference, cue+no-interference or interference-only; within-group: no load, visuospatial WM load or verbal WM load at retrieval) which use all available data with no imputation of missing values (Field, 2005). See Table 4.1 for the summary data.

Vividness. The main effect of group was not significant [$F(2,51.06) = 0.54, p = .580, \eta_p^2 = .021$], but there was a significant main effect of load [$F(2,52.56) = 9.27, p < .001, \eta_p^2 = .261$]. Subsequent pairwise comparisons revealed that intrusion vividness was estimated as significantly lower during visuospatial load ($M = 25.89$, $SE = 3.26$) compared to no load ($M = 38.42$, $SE = 3.48$, $p < .001$) and (marginally) lower compared to verbal load ($M = 30.73$, $SE = 3.36$, $p = .075$); intrusion vividness was also lower during verbal load compared to low load ($p = .014$). The group × load interaction was not significant [$F(4,53.11) = 0.56, p = .691, \eta_p^2 = .040$]. Thus, visuospatial WM load at retrieval, compared to verbal load or no load, was most disruptive to intrusion vividness; however such an effect was not influenced by the interference procedure.

Distress. The main effect of group was not significant [$F(2,51.20) = 0.86, p = .427, \eta_p^2 = .033$], but there was a significant main effect of load [$F(2,51.96) = 5.58, p = .006, \eta_p^2 = .169$]. Subsequent pairwise comparisons revealed that intrusion distress was estimated as significantly lower during visuospatial load ($M = 20.30$, $SE = 3.32$) compared to no load ($M = 30.02$, $SE = 3.58$, $p = .002$). However, distress did not significantly differ between visuospatial and verbal load ($M = 24.87$, $SE = 3.47$, $p = .096$) or between verbal load and no load ($p = .103$). The group × load interaction was not significant [$F(4,52.18) = 1.28, p = .289, \eta_p^2 = .089$]. Thus, visuospatial WM load at retrieval appeared to be relatively most disruptive to intrusion distress, though such an effect was not influenced by the interference procedure.

Table 4.1

Means and Standard Deviations for Ratings of Intrusion Vividness, Distress and Nowness by Working Memory Load Manipulations and Groups in Experiment 3

	Cue+Interference			Cue+No-interference			Interference-only		
	n	*M*	*(SD)*	*n*	*M*	*(SD)*	*n*	*M*	*(SD)*
Vividness									
No load	15	42.52	(25.36)	18	40.69	(29.90)	19	32.76	18.45
Visuospatial load	12	27.28	(21.83)	19	27.58	(26.86)	18	24.08	19.22
Verbal load	11	31.61	(18.10)	16	37.63	(29.41)	17	27.48	19.73
Distress									
No load	15	32.21	(22.78)	18	31.69	(33.47)	19	26.04	20.16
Visuospatial load	12	22.01	(17.97)	19	23.25	(29.19)	18	19.05	18.75
Verbal load	11	23.88	(17.00)	16	37.58	(30.35)	17	19.11	20.64
Nowness									
No load	15	33.54	(29.09)	18	33.07	(29.41)	19	24.56	14.02
Visuospatial load	12	27.43	(20.16)	19	16.83	(21.97)	18	23.76	20.24
Verbal load	11	25.62	(22.57)	16	23.25	(24.39)	17	23.11	23.28

Nowness. The main effect of group was not also significant [$F(2,48.49) = 0.19$, $p = .829$, $\eta_p^2 = .008$], but again there was a significant main effect of load [$F(2,46.22) = 4.34$, $p = .019$, $\eta_p^2 = .158$]. Subsequent pairwise comparisons revealed that compared to no load ($M = 30.39$, $SE = 3.37$), intrusion nowness was estimated as significantly lower during both visuospatial ($M = 21.86$, $SE = 3.26$, $p = .009$) and verbal load ($M = 22.62$, $SE = 3.23$, $p = .017$), while there was not significant difference between both WM load types ($p = .795$). The group × load interaction was not significant [$F(4,47.75) = 1.27$, $p = .296$, $\eta_p^2 = .096$]. Thus, WM load at retrieval, irrespective of modality, was disruptive to intrusion nowness, though again such an effect was not influenced by the interference procedure.

Taken together, there were no group differences in other phenomenological properties of intrusions (vividness, distress and nowness) beyond frequency.

Performance measures in the digit vigilance task during which intrusions were sampled. The use of retrospective estimates for intrusion assessment meant that performance during the digit vigilance (SART) task was 'clean', i.e., there was no motor interference on RT from having to also press an INTRUSION key. Subsequent exploratory analyses examined 1) whether or not the interference procedure affected standard performance measures on the SART task and 2) whether or not the relationship between retrieval load and SART measures was moderated by the interference procedure. A 2 (between-group: interference vs. no-interference) × 3 (retrieval load: no load, visuospatial WM load or verbal WM load) mixed model ANOVA was performed on each relevant outcome of the SART. See Table 4.2 for the summary data.

Commissions. This measure represents the frequency with which participants mistakenly pressed the GO key in response to seeing the digit 3. The main effect of group was not significant [$F(2,54) = 0.67$, $p = .514$, $\eta_p^2 = .024$], but there was a significant main effect of retrieval load [$F(2,108) = 9.74$, $p < .001$, $\eta_p^2 = .153$], with verbal load ($M = 13.40$, $SE = 0.79$) associated with more commissions than visuospatial load ($M = 10.23$, $SE = 0.60$, $p < .001$) or no load ($M = 10.21$, $SE = 0.81$, $p = .001$), while the latter two did not significantly differ ($p = .983$). The group × load interaction was not significant [$F(4,108) = 0.34$, $p = .851$, $\eta_p^2 = .012$]. Thus, verbally counting numbers (verbal but not visuospatial load) was more likely to impair one's ability to detect the to-be-avoided digit target; however, this effect was not influenced by the interference procedure.

Omissions. This measure represents the frequency with which participants were unable to press the GO key in response to all remaining non-3 digits. The main effect of group was not significant [$F(2,54) = 0.43$, $p = .656$, $\eta_p^2 = .015$], but there was a significant main effect of load [$F(2,108) = 47.84$, $p < .001$, $\eta_p^2 = .470$]. Compared to no load ($M = 3.70$, $SE = 0.74$), there were more omissions during visuospatial ($M = 37.40$, $SE = 4.03$, $p < .001$) and verbal load ($M = 30.97$, $SE = 3.42$, $p < .001$), while the difference between both WM load types was not significant ($p = .111$). The group × load interaction was also not significant [$F(4,108) = 0.25$, $p = .910$, $\eta_p^2 = .009$]. This means that having an additional load, regardless of modality, increases the likelihood of omitting a response to the digit; though such an effect was again not influenced by the interference procedure.

RT mean. The main effect of group was not significant [$F(2,54) = 1.36$, $p = .267$, $\eta_p^2 = .048$], while the main effect of load was significant [$F(2,108) = 80.56$, $p < .001$, $\eta_p^2 = .599$]. Compared to no load ($M = 0.42$, $SE = 0.13$), both visuospatial ($M = 0.59$, $SE = 0.02$, $p < .001$) and verbal load ($M = 0.56$, $SE = 0.02$, $p < .001$) slowed down RTs, and visuospatial load led to slower RTs than verbal load (p = .022). The group × load interaction was not significant [F(4,108) = 1.41, p = .237, η_p^2 = .049]. Thus, an additional load slowed down RTs, particularly if it is visuospatial tapping; such an effect was again not influenced by the interference procedure.

Table 4.2

Means and Standard Deviations of Performance Measures in the Digit Vigilance Task by Working Memory Loads Manipulations at Retrieval and Groups in Experiment 3

	Cue + Interference (*n* = 19)		Cue + No-interference (*n* = 19)		Interference only (*n* = 19)	
	M	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
Commissions						
No load	10.00	(7.39)	10.16	(5.36)	10.47	(5.40)
Visuospatial load	10.00	(3.61)	9.53	(4.18)	11.16	(5.57)
Verbal load	13.11	(5.73)	12.21	(6.83)	14.89	(5.28)
Omissions						
No load	1.68	(3.50)	4.58	(6.14)	4.84	(6.67)
Visuospatial load	37.16	(20.10)	35.32	(35.45)	39.74	(33.46)
Verbal load	28.68	(25.87)	27.95	(23.50)	36.26	(27.86)
RT mean (sec)						
No load	0.39	(0.08)	0.44	(0.10)	0.45	(0.12)
Visuospatial load	0.59	(0.12)	0.58	(0.11)	0.60	(0.12)
Verbal load	0.51	(0.10)	0.58	(0.12)	0.57	(0.13)
RTCV (sec)						
No load	0.30	(0.09)	0.33	(0.08)	0.36	(0.10)
Visuospatial load	0.51	(0.08)	0.50	(0.11)	0.50	(0.12)
Verbal load	0.54	(0.11)	0.51	(0.09)	0.53	(0.14)

Note. RT = Reaction times; RTCV = Reaction time coefficient of variability.

RT coefficient of variability (RTCV). This measure is calculated by dividing mean RT by its SD within each condition, and is thought to represent the fluctuation of RTs for a given participant across the whole task, i.e., a higher value indicates a higher degree of variability in one's attentional state (Murphy et al., 2013; Robertson et al., 1997). The main effect of group was not significant

[F(2,54) = 0.25, p = .779, η_p^2 = .009]. The main effect of load was significant [F(2,108) = 115.18, p < .001, η_p^2 = .681], indicating that compared to no load (M = 0.33, SE = 0.01), both visuospatial (M = 0.50, SE = 0.01, p < .001) and verbal load (M = 0.53, SE = 0.02, p < .001) led to more RTCV, whereas both load types did not significantly differ (p = .074). The group × load interaction was not significant [F(4,108) = 1.34, p = .260, η_p^2 = .047]. Therefore, an additional load increases RTCV regardless of modality, though such an effect did not depend on the interference procedure.

In summary, the groups did not significantly differ in their performance measures on the digit vigilance task.

Discussion

The primary aim of the present experiment was to investigate whether the interference procedure moderated the association between intrusion frequency and WM load (visuospatial, verbal or none) at retrieval – more specifically, whether or not the interference effect on intrusions was more pronounced when these occurred during no load than higher (visuospatial or verbal) load. Further, the experiment explored whether such a procedure necessarily needs to involve reminder cues prior interference for its effect on intrusion frequency. Two further exploratory analyses assessed whether or not the interference procedure had an impact on other phenomenological properties of intrusions and outcomes in a digit vigilance task (during which intrusions were sampled).

Summary of findings

First, the interference group reported fewer intrusions in the laboratory soon after interference compared to the no-interference group. While more intrusions occurred during low compared to high WM load at retrieval, the effect of the interference procedure on intrusion frequency did not vary according to WM load manipulations. An interference task *without* reminder cues, relative to the no-interference control, did not significantly reduce the frequency of intrusions. Further, the interference procedure did not affect other phenomenological properties of intrusions, nor performance measures of the digit vigilance task.

Findings in relation to each hypothesis

Consistent with Hypothesis A, the interference effect on intrusions soon after interference was replicated, in line with Experiment 2 by removing the need to report the content of each intrusion. This modification removed the possibility that lower intrusion frequency in the interference group was confounded with less time spent on reporting the content of their intrusions.

Contrary to Hypothesis B, the effect of the interference procedure on intrusion frequency did not vary according to the load level at retrieval, at least when considering WM load. It did not depend on load level (i.e., no load vs. higher load) or modality (visuospatial vs. verbal). Participants continued to experience intrusive memories even during high levels of WM load at retrieval – and the frequency of such intrusions was also modulated by the interference procedure. One possible caveat to this conclusion is that the load manipulation was insufficient, but this is unlikely as there was a main effect of retrieval load on intrusion frequency (and even differential load effects on other intrusion properties, as discussed later). These findings indicate that the interference procedure did not influence the association between intrusive memories and WM load at retrieval.

Consistent with Hypothesis C, the interference procedure was most effective in reducing intrusion frequency only if the manipulation involved both reminder cues and Tetris game play. Although it has already been shown that the interference procedure is effective only when reminder cues are included (James, Bonsall, et al., 2015), such findings are interpreted within a 'reconsolidation' framework (Kindt et al., 2009; Merlo et al., 2014; Nader et al., 2000), with such cues hypothesised to 'reactivate' an already-consolidated memory (e.g., 24 hours after film viewing). However, memory reactivation procedures are not deemed necessary for influencing memories that are still undergoing consolidation, which is the time window being studied in this thesis. Thus, the current findings are inconsistent with standard views of consolidation. This point will be further elaborated in the General Discussion, Chapter 7.

Findings from exploratory analyses

There were not apparent interference effects on intrusion vividness, distress or nowness. Hence, the interference effects on intrusions appear to be specific to frequency. This suggests that mechanisms governing frequency are distinct and dissociable from those underlying the other phenomenological qualities of an intrusive memory.

Further, there were also no apparent interference effects on performance measures of the vigilance task. It is possible that performance on the digit vigilance task is automatic and effortless, therefore immune to competing cognitive phenomena (including intrusive memories). Such explanation seems unlikely as all outcomes from the vigilance task (commissions, omissions, RT mean, RT CV) were affected by the presence of additional retrieval load, visuospatial and/or verbal. Thus, these data suggest that outcomes for the vigilance task cannot be used as indirect proxies for the effects on intrusion frequency.

Novel findings on the role of WM load on intrusive memory *retrieval*

There were several findings from this experiment that, although they did not explain the interference effects on intrusion frequency, are nevertheless worth highlighting due to their broader relevance to the literature on emotional imagery and memory. The majority of research manipulating concurrent WM load on the *retrieval* of image-based memories has relied on memories that are voluntarily retrieved. The current thesis, for the first time, manipulated concurrent WM load at retrieval on involuntarily-retrieved memories, i.e., intrusive memories. Findings demonstrated that visuospatial and verbal WM load reduced intrusion frequency and nowness. In contrast, the visuospatial load had a more evident impact on dampening intrusion vividness and distress.

Such findings provide several novel contributions to the literature. First, the importance of load modality for intrusion vividness and distress is in line with the literature proposing a special link between imagery and emotionality (Holmes & Mathews, 2010). It can be inferred that intrusion distress is dependent on (visual) intrusion vividness, and therefore both rely on visuospatial WM resources. Such a pattern is distinct from research on the vividness and distress of voluntarily generated memories, for which it is argued that general load matters instead of modality (van den Hout & Engelhard, 2012). Thus, involuntary and voluntary imagery, specifically their vividness and distress, may be functionally dissociable (J. Pearson & Westbrook, 2015).

Second, modality appears less relevant for intrusion frequency and nowness at least at retrieval, where perhaps higher-order processes such as meta-memory can play a role (Schwartz, 1994). This general load account on effects at *retrieval* is distinct from the modality-specific account proposed in studies where WM loads have been manipulated at either *encoding* or *consolidation*. Thus, the role of WM load on intrusion frequency may vary depending on the specific memory stage (Wixted, 2004).

Overall, the laboratory-based intrusion task has opened up the possibility of investigating the role of WM load on intrusive memory retrieval which is then more comparable to the literature on voluntary memory retrieval. The findings reported in this chapter, in combination with the wider literature, suggest possible dissociations warranting further investigation between involuntary and voluntary memory retrieval, and even among different intrusive memory qualities.

Chapter Summary and Next Steps

To summarise, the interference procedure reduced the frequency of intrusions sampled within the laboratory soon after interference, replicating the novel findings from the previous chapter. However, such an effect occurred across all retrieval load manipulations, i.e., the interference procedure reduced intrusion frequency regardless of WM load level (no load or higher load) or modality (visuospatial or verbal) at intrusion retrieval. These findings suggest that retrieval load is not a candidate factor that can explain the interference effects of intrusive memories. From a clinical perspective, it is valuable to know that the interference procedure – applied during 'consolidation' – had a beneficial effect on intrusion frequency above and beyond the effect of other concurrent WM tasks during the *retrieval* of the intrusion.

In addition, the effectiveness of the interference procedure appeared to depend on both reminder cues and Tetris game play, even when it was administered 30 min after trauma film viewing (i.e., during memory consolidation). The importance of these cues has been argued to reflect the need to reactivate an already-consolidated memory – thus it remains unclear why 'reactivation' cues are needed for a 'fresh' memory not yet consolidated. Nevertheless, this finding informs the potential importance of cues for an effective intervention even soon after trauma (i.e., not just days later).

The findings across chapters so far converge to suggest that the interference procedure has an effect on intrusion frequency in the diary (Experiments 1 & 2) and laboratory (Experiments 2 & 3); however, the same procedure has no apparent impact on various tests of voluntary memory (Experiments 1 & 2), and does not appear to impact the relationship with external attention (Experiment 2) or WM (Experiment 3). Taking these into account, the next experiment will test a new hypothesis that intrusive memories not only depend on representation of the content in memory, but also on the associations binding different film scenes (e.g., non-intrusive scenes with scenes depicting the specific content of the intrusion).

5. Associative Memory

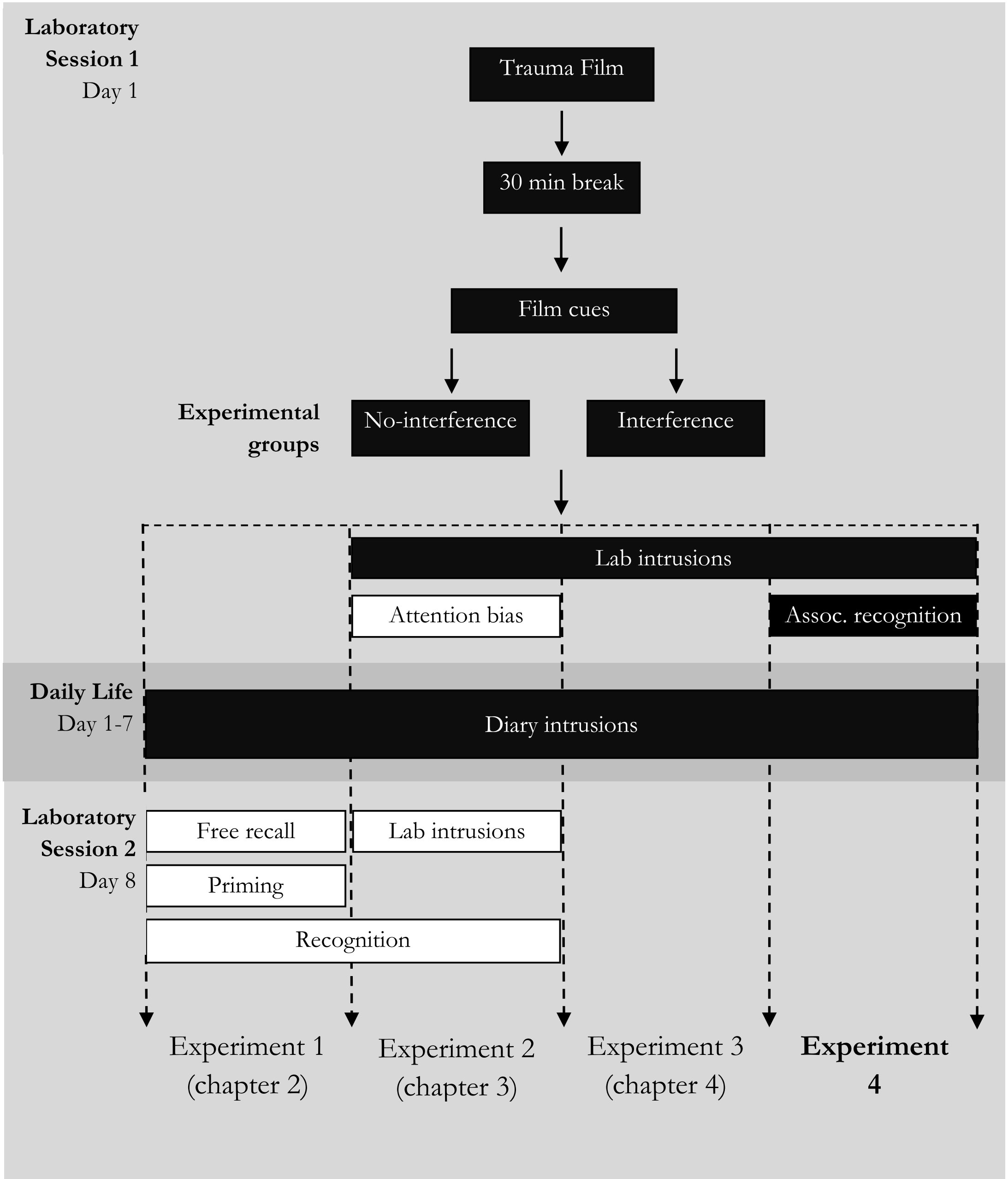


Figure 5.1. Experiment 4: procedural diagram relative to other experiments. Black boxes highlight procedural components specific to this experiment. White boxes highlight procedural components included in other experiments only. Dotted lines separate the memory measures administered across experiments, indicating that *associative recognition* was specific to Experiment 4; whereas *laboratory intrusions* (day 1) were examined in Experiments 2 and 3 as well.

Introduction

The previous experiment from Chapter 4 failed to find that low WM load at retrieval could account for the effect of interference on reducing intrusion frequency. The present chapter investigated whether this interference effect can be explained by the modulation of the associative binding between film scenes. More specifically, an intrusive memory could be hypothesised to depend on the association between sensory-perceptual cues (i.e., a non-intrusive 'snapshot' moment of the film) and image-based memory (i.e., a 'snapshot' moment of the film that becomes intrusive). Testing this hypothesis involved two methodological developments: 1) modifying the laboratory-based intrusion task and 2) building a novel measure of associative memory.

Associative Memory

Associative memory refers to the link between discrete stimuli rather than memory for the stimuli themselves. When an associative memory is formed, the presentation of one stimulus (cue) can automatically retrieve its associate (target). Here the focus is on associations acquired after a single exposure to an event (i.e., one-shot learning). This type of process has been widely discussed in the literature on intrusive memories. It has been argued, for instance, that intrusive memories of trauma result from strong associative learning (Ehlers & Clark, 2000), the formation of a network memory with excessive fear-eliciting associations (Foa, Steketee, & Rothbaum, 1989), or spread activation within an associative autobiographical memory network (Berntsen, 2009). There are also suggestions that associative memory processes can be potentiated via mental imagery (Dadds, Bovbjerg, Redd, & Cutmore, 1997).

The ease of triggering of intrusive memories by sensory-perceptual cues (Berntsen, 2009; Conway, 2001; Ehlers & Clark, 2000) suggests the existence of associative links among elements of a trauma film. Thus, it is possible that the interference procedure reduces intrusion frequency by virtue of disrupting such associations, e.g., among film scenes (i.e., memory for a non-intrusive scene with memory for an intrusive scene).

Potential Explanation for Findings from Previous Experiments

A closer inspection of memory measures in previous experiments indicates that despite the inclusion of sensory-perceptual cues, none of them have directly assessed associative memory. The tests of priming (Experiment 1), attention bias (Experiment 2) and single-item recognition

(Experiment 1 & 2) presented sensory-perceptual cues that probed memory for specific scenes, but not necessarily associations between scenes. The test of free recall (Experiment 1) did not present sensory-perceptual cues at all.

The tasks assessing laboratory-based intrusions (Experiment 2 & 3) presented film cues which were hypothesised to trigger intrusive memories (e.g., a still depicting a non-intrusive scene can trigger memory for an intrusive scene); however, it has not been directly established that these film cues were indeed necessary for the interference effect on intrusions to be observed.

Experiment 4

The main aims were twofold. The first aim was to test whether the interference effect on intrusion frequency was dependent on the presence of film cues in the laboratory-based intrusion task. The second aim was to test whether or not the interference procedure modulated performance on a novel test designed to measure memory for associations between scenes of the film.

Main Modifications to the Laboratory-Based Intrusion Task and a Novel Recognition Task for This Experiment

This experiment used two versions of the laboratory-based intrusion task, one *with* film cues (as in Experiment 2 and 3), and one *without* film cues (replaced by foil cues). The rationale was that the version with film cues, but not the version with foil cues, would provide a cueing advantage to trigger intrusive film memories (links that are in turn disrupted by interference).

Additionally, a novel task was developed to directly probe for *associative* components of the trauma film. This task was adapted from an associative recognition memory paradigm (Burianová, Ciaramelli, Grady, & Moscovitch, 2012; Ciaramelli, Grady, Levine, Ween, & Moscovitch, 2010). The rationale was that film cues, but not foil cues, by virtue of activating associative memory links among film scenes, would provide a cueing advantage boosting performance on subsequent recognition for a target scene which was presented within the same footage as the cue scene. There were therefore four randomly intermixed trial types, obtained by independently manipulating film vs. foil cues with film vs. foil targets. Both the associative recognition task and the laboratory intrusion task share the crucial element that they require explicit judgment of the memory content (i.e., for an intrusive memory to be reported, it has to be recognized as such).

Hypotheses

Replication and extension of laboratory-based intrusions (Chapter 4)

Hypothesis A: Compared to no-interference, the interference procedure will reduce intrusion frequency in a task *with* film cues (which triggers associative links among film scenes), but not in a task *without* film cues (replaced with foil cues instead).

Extension to test a new aspect of memory

Hypothesis B: Compared to no-interference, the interference procedure will reduce the advantage conferred by film over foil cues in a test of associative recognition (because film cues activate associative links among scenes).

Method

Participants

Sample size estimation. In Experiment 3, the interference effect (vs no-interference) on laboratory-based intrusion frequency was $d = 1.20$ for intrusions reported online, and $d = 1.05$ for intrusions reported retrospectively. Using the latter as a more conservative estimation, a sample size of 18 participants per group was required to ensure 80% power and to replicate the effect at 5% significance level (two-tailed hypothesis testing).

The same recruitment strategy was used as in previous experiments. The final sample consisted of 36 volunteers (27 females, age range = 19 – 36).

Materials, stimuli and procedure

All materials and stimuli were the same as in previous experiments in this thesis. The experiment consisted of a single laboratory session (see Appendix 5.1 for the full protocol). Similar to Experiment 1 and 2, but in contrast to Experiment 3, there were only two groups (i.e., both interference and no-interference conditions involved the reminder cues task). All procedures were the same up to the interference manipulation. Immediately after interference, participants were given instructions on how to perform the laboratory-based intrusion tasks (with film or foil cues) with a short practice. Then they were asked to perform the associative recognition task, also after a short practice. At the end of the session, they were given instructions to fill in the diary as in previous experiments. This session lasted for 3 hr approximately. Participants returned their diaries by post and were debriefed by email (this diary data is reported in a combined diary analyses, Chapter 6). There was no follow-up laboratory session.

Measures of Film Memory

All memory tests (i.e., except the diary) were presented using Matlab 2009 and Psychtoolbox.

Laboratory-based intrusions

Four modifications were made to the laboratory-based intrusion task from Experiment 3 (original version with online reporting). First, participants were asked to press a key only to 3's which appeared infrequently (as opposed to non-3's in previous experiments). This is because during the piloting stage, this reduced response requirement was deemed more appropriate for the test of associative recognition also in this experiment (see section below), and it was deemed important that this task parameter was constant across tasks.

Second, there were two versions, one with film cues and one with foil cues. The version with film cues was the same as in Experiment 3. The version with foil cues used 11 foil cues instead (each presented twice) depicting still moments from other films not shown as the trauma film. The foil cues were also blurred with a Gaussian filter 2.0. A pilot study confirmed that film stills were indeed more likely to trigger intrusive memories than foil stills. Foil cues were presented in the same trial order as the film cues (i.e., in a fixed randomized order). See Appendix 5.3 for more details on both film and foil cues.

Third, the version with film cues was delivered in the original room where the whole experiment took place, whereas the version with foil cues was delivered in a different experimental room. A similar procedure has been carried out in other memory studies (Hupbach, Gomez, Hardt, & Nadel, 2007; Kroes et al., 2013) which suggest that the experiment room itself can provide retrieval cues. Finally, participants always started with the version with foil cues, followed by the version with film cues. The rationale was that this order would prevent carry-over effects from the film cue condition into the foil cue condition.

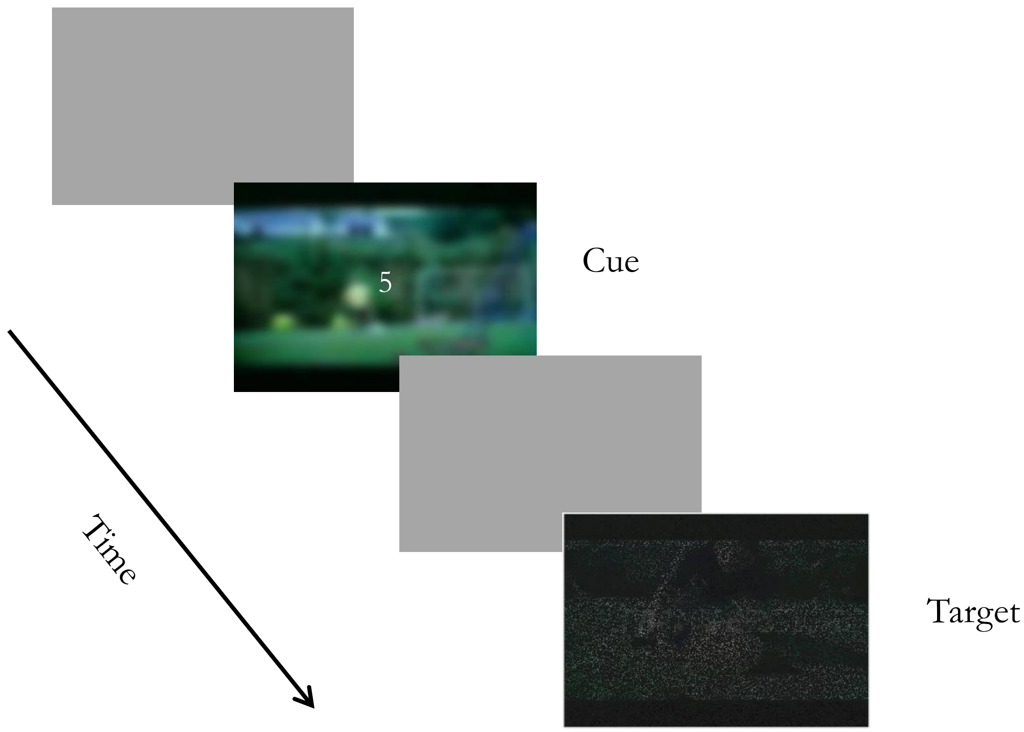


Figure 5.2. Schematic of an experimental trial in the associative recognition memory task. Each trial began with a blank screen. Then the cue stimulus appeared with a digit overlaid. Participants were instructed to press a key if they saw the number 3 being presented. The cue stimulus disappeared followed by another brief blank screen. Afterwards, the target stimulus appeared and participants were instructed to decide quickly and accurately as to whether or not they recognised the target from the trauma film they saw earlier. The target stimulus disappeared after 5 sec if no responses were made. One half of targets were from trauma films and the other half from foil films; one half of targets were preceded by cues from the same film and the other half from a different (non-trauma) film (as in the example above). In the above example, the cue still depicts the moment when a boy is about to be hit by a car; the target still depicts the moment when the father cries while seeing his dead son (both cue and target belong to the same film sequence)[5].

[5] I am grateful for Roni Tibon for advice on the design of this task.

Associative recognition

This recognition task had two main differences from those used in Experiment 1 and 2. First, it was delivered in the first (day 1 soon after interference) rather than second laboratory session (day 8). Second, whereas each trial in previous experiments consisted of a single target only, each trial in the current version consisted of a cue-target pairing. See Figure 5.2. for a schematic overview of the task.

There was a set of stimuli for cue scenes and another set for target scenes. For the cue stimuli, there were 24 stills from films, blurred in the same way as in the intrusion task above. Of these, 11 were drawn from the trauma films (the same as those used for the intrusion task with film stills), and another 11 were taken from other film footages (the same as those used for the intrusion task with foil stills). Both film and foil cues were selected to depict emotionally neutral scenes. Finally, two additional stills depicting indoor/outdoor scenes (similar to those used in the intrusion task) were used in filler trials. Filler trials were excluded in the analyses. For the target stimuli, there were 236 stills in total, all of which were blurred with salt-and-pepper noise (as used for the priming task in Experiment 1) to avoid ceiling effects by increasing task difficulty. Half were film stills taken directly from the trauma film and half were foil stills taken from other film footage. There were 34 additional still images used for filler trials, which depicted various indoor and outdoor scenes.

The background colour remained dark grey throughout the task. Each trial began with a blank screen for 1500 msec. Then a cue scene appeared and stayed on screen for 1500 msec. Simultaneously, a digit from 1 to 9 would appear in the middle of the scene, overlaid on top of the cue scene for 750 msec. Participants were asked to press the GO key as soon as the digit 3 appeared (this digit vigilance component is matched with the laboratory-based intrusion task; piloting indicated that performing frequent GO responses in the context of a recognition test left few opportunities for processing of the background cue stimuli). Afterwards, the cue scene disappeared and another blank screen appeared for 1500 msec. Finally, a target scene appeared and remained on screen until a response was made. Participants were instructed to decide as quickly and as accurately as possible whether this target scene was taken from the trauma film (YES-response) or not (NO-response). The target scene disappeared after 5 sec even if no responses were made.

Within each film and foil target set, half of the targets were paired with film cues and half with foil cues. When there was a source match between cue and target (i.e., film cue with film target or foil cue with foil target), both would have been drawn from the exact same footage, thus any performance advantage conferred by film vs. foil cues can be attributed to the mnemonic relationship between cues and targets within the same footage rather than purely a perceptual match (e.g., same colour palette). There were 270 trials in total (of which 36 were filler trials), matching the number of trials of each intrusion task. Trials were presented in a fixed random order. The whole task lasted for 40 min approximately. Participants initially practised this task with 12 filler trials that were not repeated in the main experimental task.

There were two versions of the associative recognition test. When a target scene was preceded by a matching film cue in version A, the same target scene was instead preceded by a non-matching foil cue in version B. Having these two versions minimised the likelihood that performance was driven by the effects of specific cue-target pairings. The same number of participants in each group did either version A or B. Analyses were collapsed across versions.

Results

Randomization and manipulation checks

Both groups were matched at baseline in terms of gender, age, depressive symptoms, trait anxiety, number of previous traumatic events and general use of imagery. Viewing the film also resulted in the predicted increases in negative mood, which were matched between groups. Ratings for attention paid to the film, personal relevance of the film, and diary accuracy were also matched between groups (see Appendix 5.2 for details).

Interference-task effects on each measure of film memory

Laboratory-based intrusions

Frequency of intrusions. A 2 (between-group: interference vs. no-interference) and 2 (within-group: film vs. foil cues) mixed model ANOVA was conducted to compare whether the association between film cues and intrusion frequency was influenced by the interference procedure. The main effect of group was significant [$F(1,34) = 6.64$, $p = .014$, $\eta_p^2 = .163$], indicating that the interference group ($M = 5.92$, $SE = 2.39$) reported fewer intrusions overall than the no-interference group ($M = 14.67$, $SE = 2.39$). The main effect of cues was also significant [$F(1,34) = 19.61$, $p < .001$, $\eta_p^2 = .366$], with more intrusions associated with film cues ($M = 12.75$, $SE = 1.81$) than foil cues ($M = 7.89$, $SE = 1.74$), as predicted. However, the critical group × cues interaction was not significant [$F(1,34) = 2.38$, $p = .132$, $\eta_p^2 = .065$]. Thus, the interference effect on intrusion frequency was similar regardless of the cue conditions.

Independent sample t-tests were conducted to investigate the simple effects of cues within each group (see also Figure 5.3). For intrusions to film cues, the interference group reported significantly fewer intrusions compared to the no-interference group [$t(34) = 2.88$, $p = .007$, $d = .96$]. For intrusions to foil cues, the interference group also reported fewer intrusions than the no-interference group, with a near-significant albeit smaller effect [$t(34) = 2.01$, $p = .053$, $d = .67$].

Table 5.1

Means and Standard Deviations for Performance on Associative Recognition Memory by Cue Conditions and Groups in Experiment 4

	Interference (n = 18)		No-interference (n = 18)		Independent Group Comparisons		
	M	*(SD)*	*M*	*(SD)*	*t*	*df*	*p*
Foil cues							
Hits	41.44	(7.52)	42.28	(6.12)	0.37	34	.718
FA	19.11	(9.92)	16.00	(8.33)	1.02	34	.316
Film cues							
Hits	41.22	(4.61)	45.11	(5.78)	2.31	34	.027
FA	17.44	(9.39)	15.11	(7.45)	0.83	34	.415
Accuracy							
Foil cues	0.38	(0.21)	0.46	(0.17)	1.15	34	.260
Film cues	0.41	(0.17)	0.51	(0.17)	1.83	34	.076

Note. FA = False alarms; Accuracy = Hit rate minus false alarm rate.

Associative recognition

Accuracy. This was measured as in previous experiments, with positive scores indicating memory performance above chance, i.e., hit rates above false alarm rates (See Table 5.1 for a more detailed data summary). One-sample t-tests confirmed that memory was above chance in each cue condition within each group [$t(17)$'s > 7.59, p's < .001]. A 2 (between-group: interference vs. no-interference) × 2 (within-group: film vs. foil cues) mixed ANOVA on accuracy revealed that the main effect of cue missed the significance threshold [$F(1,34) = 3.25$, $p = .080$, $\eta_p^2 = .087$], but was in the predicted direction, with performance with film cues ($M = 0.46$, $SE = 0.03$) associated with higher accuracy than with foil cues ($M = 0.42$, $SE = 0.03$). Although overall accuracy for the interference group (M = 0.40, SE = 0.04) was lower than for the no-interference group (M = 0.48, SE = 0.04), this main effect of group did not reach significance either [$F(1,34) = 2.40$, $p = .131$, $\eta_p^2 = .066$]. There was also no evidence for a significant group × cue interaction [$F(1,34) = 0.59$, $p = .447$, $\eta_p^2 = .017$], suggesting that interference effect did not vary with the cue manipulation (See Figure 5.3). Neither simple effect of interference on recognition with film or foil cues reached significance, though approached significance with film cues, as shown in Table 5.1.

The Bayes factors for group differences in recognition accuracy was obtained for each cue condition, based on the size of the interference effect on intrusion frequency also for the same cue condition (d = .96 and .67 for film and foil cues, respectively). The Bayes factors were 0.01 and 0.006 for recognition with film and foil cues respectively, suggesting evidence in favour of the null over the alternative hypothesis (Dienes, 2011).

Interaction between retrieval intention and cues.

Z-scores across memory measures. A single outcome from each memory measure (intrusion frequency and recognition accuracy) was standardized using z-scores to allow for comparison across different tasks (see Table 5.2). A 2 (between-group: interference vs. no-interference group) × 2 (within-group: intrusion vs. recognition) × 2 (within-group: film or foil cues) mixed ANOVA on these z-scores revealed a significant main effect of group [$F(1,34) = 11.59$, $p = .002$, $\eta_p^2 = .254$], with the interference group (M = -0.31, SE = 0.13) retrieving 'less' than the no-interference group (M = 0.31, SE = 0.13). Neither the main effects of retrieval intention [$F(1,34) = 0.00$, $p > .999$, $\eta_p^2 = .000$] or cues [$F(1,34) = 0.00$, $p > .999$, $\eta_p^2 = .000$] were significant. The two-way interactions between group × intention [$F(1,34) = 0.32$, $p = .575$, $\eta_p^2 = .009$], group × cues [$F(1,34) = 0.01$, $p = .940$, $\eta_p^2 = .000$] and intention × cueing [$F(1,34) = 0.00$, $p = .998$, $\eta_p^2 = .000$] were also not significant, nor the group × intention × cueing three-way interaction [$F(1,34) = 2.64$, $p = .113$, $\eta_p^2 = .072$].

Table 5.2

Means and Standard Deviations for Z-Scores of 'Retrieval Strength' Across Memory Measure by Cue Conditions and Groups in Experiment 4

	Interference (n = 18)		No-interference (n = 18)	
	M	*(SD)*	*M*	*(SD)*
Laboratory intrusions				
Film cues	-0.44	(0.58)	0.44	(1.15)
Foil cues	-0.32	(0.33)	0.32	(1.32)
Associative recognition				
Film cues	-0.29	(0.97)	0.29	(0.97)
Foil cues	-0.19	(1.11)	0.19	(0.87)

Discussion

The main aim of this experiment was to investigate the effect of the interference procedure on subsequent associative memory for the film, in terms of links between film scenes. The latter was assessed in two ways, first by manipulating the nature of the cues within the laboratory-based intrusion task and second, by using a novel associative recognition task.

Summary of main findings

For the intrusion task, the interference group reported overall fewer intrusions compared to the no-interference group. Critically, such an effect occurred when intrusions were sampled both with film or foil cues. For the associative recognition task, no significant group differences were found in memory accuracy, regardless of whether recognition involved film or foil cues. Surprisingly, in an analysis combining all measures using standardized scores, the interference procedure appeared to have a general disruptive effect across both memory tasks, with any interaction with task failing to reach significance.

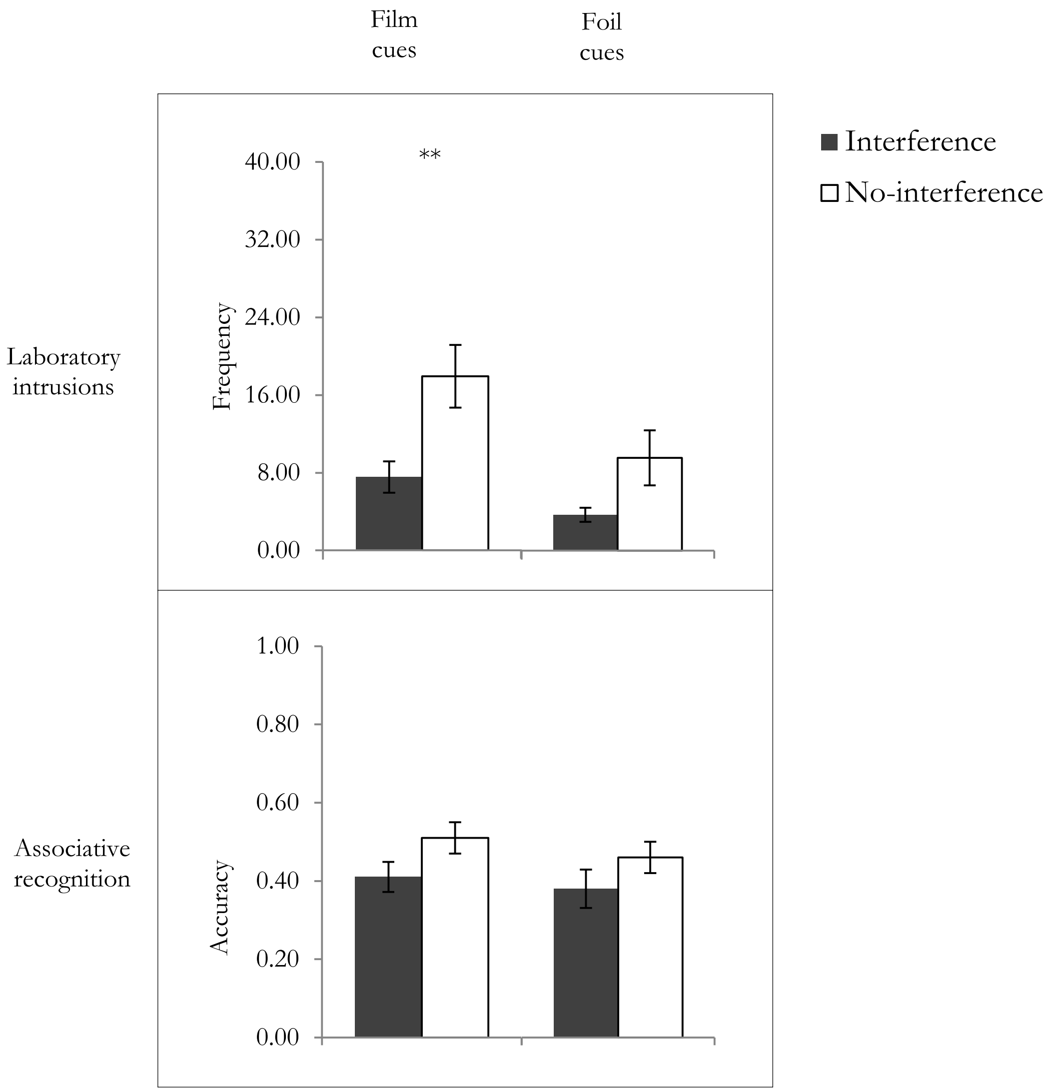


Figure 5.3. 'Retrieval strength' on each memory measure by cue condition and groups in Experiment 4. The main outcome for each memory measure was: for laboratory intrusions, the frequency of intrusive memories across a 10-min period; for recognition, accuracy was determined by obtaining the difference between the rates of hits and rates of false alarms. Error bars represent one standard error. Significant two-tailed group comparisons within each memory measure were flagged, i.e., only for laboratory intrusions with film cues (** alpha <.01; it just missed the significance threshold for laboratory intrusions with foil cues, i.e., $p < .053$).

Findings in relation to each hypothesis

Hypothesis A was not supported, in that the interference effect on intrusion frequency did not reliably differ by cue type. One possibility is that the hypothesis was wrong, and that the interference-task does not disrupt associative memory. Another possibility is that the hypothesis was correct, but there was insufficient power to detect the interaction. This would be consistent with the numerically bigger effect of interference with film cues than with foil cues. However, such numerical difference could also reflect a floor effect, since overall intrusion rates were lower with foil cues (corresponding to the predicted main effect of film vs foil cues, which the experiment did have sufficient power to detect).

As theoretical and clinical perspectives argue that intrusive memories are triggered mostly by external sensory-perceptual cues, this experiment operationalized such cues as visual film stills (i.e., 'snapshots') that were slightly blurred, retaining many of their original visual features. While there was evidence that those film stills indeed provoked more film-related intrusions than foil stills, intrusions still occurred in the context of foil stills. It is possible that low-level visual qualities of the foil stills also served as relevant cues triggering intrusions, albeit at a lower rate than with film cues. Such an account is in line with clinical observations suggesting that intrusive memories of trauma can be triggered by situations with little similarity to the trauma, but nevertheless with overlapping sensory impressions, e.g., just colours (Ehlers & Clark, 2000). Indeed, an individual may have triggers that are highly idiosyncratic, and of which they may even be unaware (Ehlers & Clark, 2000). Following this interpretation, both film and foil cues contained sensory-perceptual cues that activated associative links to intrusive memories. That is, a cue is not the whole scene but perhaps discrete components of a scene. An experimental alternative is to compare film cues with other black and white cues, or no cues whatsoever. Nevertheless, it may be difficult to create laboratory cues that are matched on every dimension except their ability to trigger intrusions (e.g., an inevitable confound in this case would be attentional load differences), prompting the need to better understand features of triggering cues present in daily life (see combined analysis of diary data in Chapter 6). To conclude, one possibility is that the interference procedure did disrupt associative memory, but not among film scenes. Instead, the associative links may be formed among discrete elements within or across scenes. This possibility requires further methodological refinements to the cue conditions in future experiments.

Hypothesis B was also not supported, as there was not a reliable interference effect on accuracy of associative recognition. While there was a numerical trend in the predicted direction indicating better recognition following film than foil cues, this main effect of cue did not reach significance (unlike for the intrusion task), which questions how effectively the (film) cues were being used to affect subsequent recognition of the target (as elaborated below). Moreover, like with previous voluntary measures in this thesis, there was no significant interference effect on recognition.

The associative recognition test was designed so that film cues (but not foil cues) should improve recognition of the subsequent film target. More specifically, a film cue may trigger an intrusive memory, which in turn could aid with recognition of the target, as both an intrusion and the target come from the same film. Why did this film cue advantage fail to reach significance? One possibility is a power issue, as the sample size was determined based on the interference effect on the intrusion task. Another possibility is that intrusions triggered by the cues could both impair and facilitate target recognition, for example sometimes the intrusion can be of the same content as the target (facilitation effect) but sometimes it may represent a different part of the film (impairing effect). Further, intrusions could be triggered by the targets themselves, which might disrupt cognitive processes needed to make an accurate recognition decision. Intrusions generated within one cue-target pair can also (repeatedly) persist and inadvertently be carried over into the next trial. These various effects may converge to create a net effect, cancelling the effect of film cue within a given trial. The fact that we cannot control when an intrusion occurs means we cannot constraint its effects within a trial, underscoring the broader difficulty in developing performance-based and time-locked measures for intrusion frequency constrained to an experimental trial.

One final observation is that, unlike the analyses of standardized scores across memory tasks in previous chapters, any interaction between involuntary vs voluntary tasks and interference procedure failed to approach significance. Indeed, there was, for the first time, a trend towards an interference effect in the voluntary (recognition) task, at least when film cues were used. This should be interpreted with caution, as the results do not follow the pattern of findings on raw scores indicating an intrusion/recognition dissociation which is more consistent with previous data (based on either frequentist or Bayesian statistics). However, it is possible that voluntary memory may indeed be affected by interference when memory is specifically tested for associations between elements of the trauma film (as opposed to single-item recognition), which could be tested in a more powerful replication study by further refining the present associative recognition task.

To conclude, the present experiment failed to support either hypothesis about the interference procedure specifically targeting associative memory among film scenes. Nonetheless, the data revealed interesting patterns, and prompted important theoretical and methodological issues that deserve further investigation in future studies.

Methodological caveats

A possible limitation of the laboratory-based intrusion results was that the order of cue conditions was not counterbalanced, as participants always completed the version with foil cues first. While this was intended to avoid carry-over effects into the foil cue condition, it is still possible that intrusion frequency in this type of task changes with the passage of time, and this caused the main effect of cue type. This seems unlikely, however, because comparisons across experiments suggest that the interference effect on laboratory-based intrusion does not change over time, remaining both immediately after interference and at one-week follow-up (see next chapter on Combined Diary Analysis 3). Furthermore, one would expect a general decline in intrusion frequency with time (also see Combined Diary Analysis 3), yet more intrusions occurred *with* film cues, which were administered later in time. Thus, the results in the intrusion tasks seem unlikely to be due to the lack of counterbalancing.

One caveat with the associative recognition task is that norms were not available for all the film and foil stills, unlike in Experiments 1 and 2. Thus, it is possible that the film and foil stills were not matched on dimensions such as emotionality. This may have confounded the main effect of cue conditions, though note that the assignment of film/foil stills cues to targets was counterbalanced across participants, meaning that advantages provided by film cues were not confined to the specific cue-target pairings.

Chapter Summary

To summarise, the interference procedure reduced the frequency of intrusive memories sampled within the laboratory, either in response to film or foil cues. Further, the same procedure did not appear to significantly impact performance on associative recognition memory, whether cued by film or foil cues.

Interestingly, it appeared that recognition memory was intact even when measured this early on. This would be the first demonstration that the intrusion/recognition dissociation can be induced instantly, providing tentative evidence that these involuntary/voluntary memory differences are already in place immediately post-intervention (though see findings on z-scores).

This finding requires replication. The more important point is that the film cue manipulation across memory measures within this chapter could not explain the interference effect on intrusive memories. Potential methodological refinements were discussed for future experiments.

The experiments so far have taken a laboratory-based approach to reconcile insights from experimental psychopathology with typical paradigms in mainstream memory/cognitive psychology research. However, this thesis has revealed a continuous discrepancy between measures of intrusive memories and other measures derived from laboratory-based research traditions. The next chapter returns from the lab to the phenomenon 'in the wild', by returning to the diaries which contain the main (clinically-relevant) phenomena motivating this thesis, i.e., intrusive memories in daily life. Real-world investigations can reveal insights that are missing in laboratory tasks. More specifically, the next chapter combines the diary data across Experiments 1 to 4 to examine the hypothesis that the interference procedure selectively disrupts the ability of sensory-perceptual cues in everyday life (as opposed to non-sensory-perceptual cues) to trigger intrusive memories, putatively via disrupting their associative links. The diary data also allow for observation of other features of intrusive memories, including their content and time course.

6. Intrusion Diaries

Table 6.1

Frequency of Intrusive Memories that Matched or Not with the Trauma Film By Experiments

	Experiments			
	1	2	3	4
Intrusions that matched				
Total (%)	251 (87%)	229 (98%)	190 (73%)	180 (98%)
Image-based intrusions				
Total (%)	**191 (66%)**	**202 (87%)**	**156 (60%)**	**151 (82%)**
M (SD)	**4.15 (3.31)**	**5.61 (1.29)**	**4.11 (5.02)**	**4.19 (4.70)**
Range	**0-14**	**0-24**	**0-22**	**0-16**
Verbal-based intrusions				
Total (%)	60 (21%)	27 (12%)	34 (13%)	29 (16%)
M (SD)	1.30 (1.80)	0.75 (1.59)	0.90 (1.80)	0.81 (1.28)
Range	0-7	0-6	0-7	0-5
Intrusions that did not match				
Total (%)	39 (13%)	4 (2%)	69 (27%)	3 (2%)
Inter-rater reliability of intrusion match				
Interclass correlation	1.00	0.98	0.99	1.00

Note. ** p <.001. Only film-matched and image-based intrusions were analysed **(in bold)**, as these were considered analogous to intrusive memories in clinical post-traumatic distress. Interclass correlations were based on two-way mixed effects model, consistency, single measures (Mcgraw & Wong, 1996).

Introduction: Combined Data Analyses of Intrusive Memory Diaries across Experiments

The present chapter combined data from both interference and no-interference groups in the daily diary measure (see Appendix 6.1) across all experiments (156 participants and 700 intrusive memories). Three aspects were explored: 1) reported triggers of intrusive memories, 2) content of intrusive memories, and 3) the time course of intrusive memories over a one-week period.

The diary data were used to explore three specific questions. The first question was whether or not the interference procedure disrupts the associative link between sensory-perceptual cues and image-based memory. Sensory-perceptual cues were identified based on description of triggers in daily life reported by the participants themselves (rather than blurred film stills as in the laboratory studies). More specifically, the combined analyses examined whether the interference procedure preferentially reduced the frequency of intrusions that were triggered by sensory-perceptual cues compared to other types of cues. A second question examined whether or not the content of intrusive memories was affected by interference. The content scoring protocols were the same as in Experiment 1, albeit applied to examine free recall. These protocols allowed for the separation of different types of details, highlighting those referring to perceptual components. A third question examined whether or not the time course of intrusion frequency over a one-week period in daily life was influenced by interference. Whereas the majority of memory measures considered in this thesis lasted for a short period of time (10 to 40 min) in the laboratory, the diary data could be divided by days. Such a daily breakdown can reveal whether interference procedure affects the forgetting rates, for example.

It is important to note that each of the experiments delivered the diary measure after different experimental procedures. To recap: the diary measure was delivered before any other memory measure in Experiment 1, but after other procedures in Experiment 2 (attention bias task), Experiment 3 (various WM load manipulations) and Experiment 4 (associative recognition task). Therefore, the three exploratory analyses of diary data also included 'experiment' as a between-subject factor in order to account for experiment-specific effects. All analyses were performed on intrusive memories that were image-based and film-matched (see Table 6.1), as with previous experiments (e.g., Holmes et al., 2009; James, Lau-Zhu, et al., 2015; James, Bonsall, et al., 2015) and with chapters within this thesis so far.

Exploratory Analyses

Analysis 1: Retrieval Cues in Daily Life

Aim

This analysis aimed to investigate if the interference effect on reducing intrusion frequency can be explained by the modulation of the associative link between sensory-perceptual cues (in daily life) and image-based memory of the film that subsequently becomes intrusive.

Method: Cue Classification

The classification system was closely based on Mace (2004), which distinguishes sensory-perceptual cues from other externally-generated cues. Unlike Mace (2004), the classification used in this chapter was performed by the researchers (A. Lau-Zhu and another rater) based on the descriptions provided rather than by the participants themselves. See Appendix 6.2 for the cue classification system for this thesis.

Table 6.2

Means and Standard Deviations of the Proportions of Cue Types by Groups (Across Participants and Experiments)

	Interference (n = 58)		No-interference (n = 75)		Independent Group Comparisons		
	M	*(SD)*	*M*	*(SD)*	*t*	*df*	*p*
Intrusions with cues reported	0.78	(0.31)	0.74	(0.31)	0.72	131	.472
Classifiable cues	0.67	(0.37)	0.66	(0.33)	0.06	131	.956
Unclassifiable cues	0.11	(0.28)	0.08	(0.18)	0.91	131	.365
Intrusions with no cues reported	0.22	(0.31)	0.26	(0.31)	0.72	131	.473

Note. This table contains information only for participants with at least one intrusion, because zero intrusions meant that no data on cues are available for a given participant. Despite the (inevitably) unequal number of participants between groups, these scores indicate that the proportion of cue information available for classification was matched between groups, ruling out potential biases in selecting out more data on a specific group (e.g., equivalent proportion of classifiable cues for analyses).

Table 6.3

Examples of Cues for Intrusive Memories Reported in the Diary across Experiments 1-4 and Their Classification (Sensory-Perceptual or Abstract Cues) by Film Clip

Films (footage type)	Example cues: sensory-perceptual (P); abstract (A)
30 for a Reason (car crash)	Seeing a bag by the door (P) Young doll girl (P) A small girl got on the bus with a rucksack on (P)
The Big Shave (self-harm)	Saw razor blade in the grocery store (P) Cleaning bathtub (P) Nutella with caramel dripping on food on the cover of a magazine (P)
Never, Ever Drink and Drive (car crash)	Walking past my local pub (P) Seeing father and son in the street (P) Saw little boys playing in the street (P)
Eye Surgery (medical procedure)	Saw advert for contact lenses (P) Seeing the reflection of the right of my friend's eyes in the dark (P) Seeing someone take off their glasses (P)
No Seatbelt, No Excuse (car crash)	Putting on my seatbelt (P) Walking past queueing traffic (P) An ambulance (P)
Ghosts of Rwanda (genocide)	Watching a clip of African children during Comic Relief night (P) The image of a naked man on the floor on a news website (P) My landlord talking about Islamic State (A)
Drink and Drowning (drowning)	Water in the cup (P) Washing my hair (P) Someone mentioned the word *drown* (A)
The Faster the Speed (car crash)	Cycling past a brick wall (P) People sitting on a wall at work (P) Speeding car overtaking me (P)
Orthopaedic Surgery (medical procedure)	My professor was in shorts (P) Cooking and cutting chicken (P) Somebody mentioned *first aid* (A)
Texting and Road Cross (car crash)	I saw a girl in school uniform (P) Phone in hand of a kid (P) I was texting while crossing (P)
Elephant Rampage (animal attack)	Ethnic shop window display (P) Friend showed me a new jacket which resembled ring master costume (P) Article about grizzly bear killing a man (A)

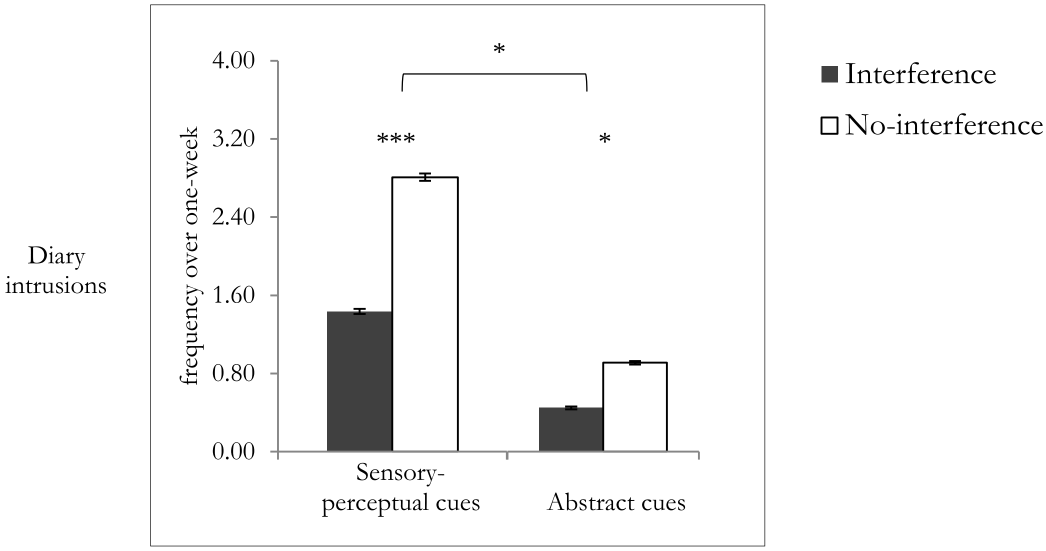


Figure 6.1. The frequency of intrusive memories over one week triggered by sensory-perceptual or abstract cues as reported in the diary by group. Data were combined across Experiments 1-4, 156 participants and 700 intrusive memories. Error bars represent one standard error. Significant comparisons were flagged (*** alpha <.001; * alpha <0.05).

The first step of the classification was to determine if a triggering cue had been reported by every single intrusive memory for each participant. Intrusive memories that were reported as not being triggered by a cue were excluded from the analysis, because a participant may not always be aware of the relevant triggers (Ehlers & Clark, 2000). The second step was then to classify each trigger as one of three types. Abstract cues were defined as triggers that were elicited by thoughts (e.g., 'thinking on the previous day') or language-based experiences (e.g., 'my landlord mentioned Islamic State' or 'seeing the word *elephant*'). Sensory-perceptual cues were defined as any sensory and perceptual experiences or activities performed that explicitly linked to memory of the film (e.g., 'saw razor blade in the grocery store', 'cycling past a brick wall', 'I was texting'). State cues were defined as physiological or emotional states that were linked to viewing the film. Fewer than 10 cues were classified as state and were therefore not considered in the analysis. Cues that could not be classified as any of the three types were also excluded from the analysis. Table 6.2 showed that this classification method was applied similarly across groups. Table 6.3 showed examples of different cues by film clip. Thus, two outcomes were generated for each participant: the frequency of intrusive memories triggered by a *sensory-perceptual* cue and the frequency of intrusive memories triggered by an *abstract* cue.

Results

Inter-rater reliability. The main researcher performed the classification system on all intrusive memories reported in the diaries. A subsample of 18% of the intrusions (129/700) was also scored by an independent researcher who did not run the study and did not know which group each intrusion belonged to. There was substantial agreement among raters [*Kappa* = 0.72, $p < .001$].

Intrusive memories and cue type. A 2 (between-group: interference vs. no-interference) × 4 (between-group: Experiments 1 to 4) × 2 (within-group: sensory-perceptual vs. abstract cues) mixed model ANOVA was conducted on intrusion frequency. This analysis revealed a main effect of group [$F(1,148) = 15.25$, $p < .001$, $\eta_p^2 = .093$], indicating that overall the interference group (M = 0.92, SE = 0.17) reported fewer intrusions than the no-interference group (M = 1.87, SE = 0.17). The main effect of cues was also significant [$F(1,148) = 46.48$, $p < .001$, $\eta_p^2 = .239$], with more intrusions associated with sensory-perceptual cues (M = 2.09, SE = 0.20) than abstract cues (M = 0.70, SE = 0.10). Neither the main effect of experiment [$F(3,148) = 0.86$, $p = .465$, $\eta_p^2 = .017$], the two-way interaction between experiment × cueing [$F(3,148) = 2.00$, $p = .117$, $\eta_p^2 = .039$] nor the three-way interaction between experiment × cueing × condition [$F(3,148) = 1.94$, $p = .125$,

η_p^2 = .038] was significant. Critically, the two-way interaction between group × cues was significant [F(1,148) = 5.58, p = .019, η_p^2 = .036]. Subsequent independent sample t-tests revealed that interference effect on diary intrusions was more pronounced for intrusions triggered by sensory-perceptual cues [t(154) = 3.61, p < .001, d = .59] than intrusions triggered by abstract cues [t(154) = 2.30, p = .023, d = .37]. See Figure 6.1.

Analysis 2: Content of Intrusive Memories

Aim

This analysis aimed to investigate whether or not there were differences in the number of episodic details used to describe each intrusive memory between the interference and the no-interference group.

Method: Content Scoring

Two scoring procedures were used. First, the description for each intrusive memory was categorized by the main researcher (A. Lau-Zhu) by adapting the AI procedure (Levine et al., 2002; McKinnon et al., 2014): for each intrusion, two types of details were counted that were directly linked to episodic film content, i.e., event and perceptual details. Second, each description was automatically analyzed by the LIWC software (Pennebaker et al., 2007), resulting in two types of counts: total word count and count for perceptual processes words. See Table 6.5 for example of intrusion descriptions.

Results

A series of 2 (between-group: interference vs. no-interference) × 4 (between-group: Experiments 1 to 4) ANOVAs were conducted to examine the interference effect on content of each intrusion description. These data were from 463 intrusive memories in the no-interference group and 237 intrusive memories in the interference group (see Table 6.4).

Episodic details according to AI. A subsample of intrusion descriptions (191/700 = 27%) were scored by an additional researcher (the same who acted as the second rater for the free recall scripts in Experiment 1). Interclass correlations (two-way mixed effects model, consistency, single measures; Mcgraw & Wong, 1996) were as follows: 0.67 for event, 0.09 for perceptual and 0.77 when both were combined. These suggest that unlike the strong agreement observed for scoring of the free recall scripts in Experiment 1 (at least above 0.80), scoring of intrusion entries had less agreement. Agreements are still good for event details, but there appear to be difficulties in classifying a detail as perceptual. This is evidenced by the higher agreement obtained when both event and perceptual details were combined, suggesting that the disagreements may be partially explained by difficulties in distinguishing event from perceptual details when presented within short verbal entries as it is with intrusive memory descriptions. With this caveat, both event and perceptual details will be analysed separately given the exploratory nature of these analyses; but any findings on perceptual details will be interpreted cautiously given that their scoring may be unreliable.

Table 6.4

Means, Standard Deviations for Scoring Outcomes of the Content of Intrusive Memories in the Diary across Experiments by Scoring Method (AI and LIWC) and Groups

	Interference (n = 237)		No-interference (n = 463)	
	M	*(SD)*	*M*	*(SD)*
Scoring based on AI				
event details	1.96	(0.93)	1.80	(0.93)
perceptual details	0.58	(0.75)	0.56	(0.75)
Scoring based on LIWC				
perceptual process words	0.66	(0.86)	0.73	(0.88)
total word count	8.85	(5.40)	7.98	(5.48)

Note. AI = Autobiographical Interview; LIWC = Linguistic Inquiry and Word Count.

For the number of *event* details, the main effect of group [$F(1,692) = 2.65$, $p = .104$, $\eta_p^2 = .004$] was not significant, but the main effect of experiment was significant [$F(3,692) = 3.26$, $p = .021$, $\eta_p^2 = .014$]. Further post-hoc pairwise comparisons, with Bonferroni-corrected alpha levels of .0083 per test (.05/6), found that fewer event details were reported in Experiment 2 ($M = 1.71$, $SE = 0.07$) compared to Experiment 1 ($M = 1.99$, $SE = 0.07$) or Experiment 3 ($M = 1.99$, $SE = 0.07$), but not compared to Experiment 4 ($M = 1.85$, $SE = 0.08$). All other comparisons between experiments were not significant. The interaction between group × experiment was also not significant [$F(3,692) = 0.12$, $p = .949$, $\eta_p^2 = .001$].

For the number of perceptual details, neither the main effect of group [$F(1,692) = 1.10$, $p = .294$, $\eta_p^2 = .002$] nor the main effect of experiment were significant [$F(3,692) = 2.46$, $p = .061$, $\eta_p^2 = .011$]. There was a significant interaction between group × experiment [$F(3,692) = 4.33$, $p = .005$, $\eta_p^2 = .018$]. Further post-hoc group comparisons, with Bonferroni-corrected alpha levels of .0125 per test (.05/4) within each experiment, indicated that the interference group ($M = 0.80$, $SE = 0.11$) reported *more* perceptual details than the no-interference groups ($M = 0.46$, $SE = 0.07$) in Experiment 4 only [$t(149) = 2.66$, $p = .009$], but not in the other experiments. These findings are likely to be spurious; because it only occurred for one experiment, the effect was in the opposite direction to what would be predicted, and scoring of perceptual details appeared to be unreliable.

LIWC outcomes. For the total word count, the main effect of group was significant [$F(1,692) = 3.98$, $p = .046$, $\eta_p^2 = .006$], with the interference group ($M = 8.94$, $SE = 0.35$) describing each intrusion with *more* words than the no-interference group ($M = 8.07$, $SE = 0.26$). The main effect of experiment was also significant [$F(3,692) = 7.27$, $p < .001$, $\eta_p^2 = .031$], with further post-hoc pairwise comparisons, with Bonferroni adjusted alpha level of .0083 per test (.05/6), showing that fewer words were used for each intrusion in Experiment 2 ($M = 6.78$, $SE = 0.43$) compared to Experiment 1 ($M = 9.06$, $SE = 0.41$), Experiment 3 ($M = 8.90$, $SE = 0.43$) or Experiment 4 ($M = 9.28$, $SE = 0.47$); all other comparisons between experiments were not significant. Finally, the interaction between group × experiment was also significant [$F(3,692) = 6.57$, $p < .001$, $\eta_p^2 = .028$]. Further post-hoc group comparisons, with Bonferroni-corrected alpha levels of .0125 per test (.05/4) within each experiment, indicated that the interference group ($M = 11.7$, $SE = 0.80$) used *more* words per intrusion than the no-interference groups ($M = 7.09$, $SE = 0.52$) in Experiment 4 mainly [$t(149) = 4.65$, $p < .001$], but not in the other experiments.

Table 6.5

Examples of Intrusive Memory Descriptions in the Diary across Experiments; Three per Film Clip

Films (footage type)	Example of intrusive memories reported in the diary
30 for a Reason (car crash)	"the scene of the girl cracking her bones after the crash" "girl with blood in ear, sound of rustling grass" "child pulled into road"
The Big Shave (self-harm)	"blood streaming down face of man" "I saw the scene of a man shave and his skin ripped off so there was lots of blood" "guy committing suicide while shaving"
Never, Ever Drink and Drive (car crash)	"I saw the scene where the car flips through the fence and breaks the fence" "I saw the scene of the boy looking through the fence as the car come tumbling towards him" "scene where guy kills child by rolling car over hedge"
Eye Surgery (medical procedure)	"an image of the eye with the circles indenting" "image of the eye and the instrument poking it" "I could see the eye getting marked and I thought about the pain"
No Seatbelt, No Excuse (car crash)	"boy travelling head first from the back to the front of a car in a crash with broken glass flying" "image of people colliding at each other in slow motion accident" "I saw four friends in car accident"
Ghosts of Rwanda (genocide)	"I saw massacres, people lying in the dirt and though t that it would be horrible to live there" "African babies of army" "people covered on floor"
Drink and Drowning (drowning)	"guy flailing in the sea" "I saw the guy drowning and felt a little bit like him" "the thought of drowning and the scene of the boy"
The Faster the Speed (car crash)	"car crash scene when the lovers were kissing, the girl sitting on the wall" "saw the couple kissing before being smashed by the car" "imagined the couple sitting on the stone wall together, before the crash"
Orthopaedic Surgery (medical procedure)	"image of bone being repaired" "bone sticking out" "I heard and saw a few seconds of surgery on joint operation"
Texting and Road Cross (car crash)	"image of the student texting while crossing the road and the incoming car" "boy smiling across road to girl before being run over" "thought of the young texting kids. Thought of uniform and tie"
Elephant Rampage (animal attack)	"man trampled by elephant" "image of the elephant running down the street" "elephant crushing people"

Finally, the analysis for the number of perceptual *process* words (including as a covariate the total word count, given that a group difference in word count was found) revealed that the main effect of group was significant [$F(1,691) = 4.25, p = .040, \eta_p^2 = .006$], with the interference group ($M = 0.63$, $SE = 0.05$) reporting fewer perceptual *process* words than the no-interference group ($M = 0.76$, $SE = 0.04$). The main effect of experiment was also significant [$F(3,691) = 3.48, p = .016, \eta_p^2 = .015$]. Further post-hoc pairwise comparisons, with Bonferroni adjusted alpha level of .0083 (.05/6) per test, found that fewer perceptual *process* words were used for intrusions in Experiment 2 ($M = 0.55$, $SE = 0.06$) compared to Experiment 4 ($M = 0.83$, $SE = 0.07$); all other comparisons between experiments were not significant. The interaction between group × experiment was not significant [$F(3,691) = 0.97, p = .406, \eta_p^2 = .004$].

Overall, these exploratory analyses suggested that based on AI scoring, there were no reliable group differences in the number of event or perceptual details. Further, based on the LIWC software there were relatively *more* words but *fewer* perceptual process words used to describe each intrusion in the interference compared to the no-interference group.

Analysis 3: Time Course Across the One-Week Period

Aim

The final analysis aimed to investigate whether or not the interference procedure affected the day-to-day time course of intrusive memories across the one-week period in the diary.

Results

For this analysis, a frequency count for intrusive memories was obtained per day for each participant (See Figure 6.2). A 2 (between-group: interference vs. no-interference) × 4 (between-group: Experiments 1 to 4) × 7 (within-group: days 1 to 7 in the diary) mixed model ANOVA was conducted to examine the interference effect on intrusion frequency. Greenhouse-Geisser corrections were applied to address non-sphericity (Field, 2005). This analysis yielded a main effect of group [$F(1,148) = 28.85, p < .001, \eta_p^2 = .163$], confirming again that intrusion frequency was higher in the no-interference ($M = 0.86$, $SE = 0.06$) than the interference group ($M = 0.37$, $SE = 0.06$). The main effect of days was also significant [$F(3.98, 589.01) = 35.39, p < .001, \eta_p^2 = .193$]. Further within-subject contrasts revealed both a significant linear [$F(1,148) = 105.38, p < .001, \eta_p^2 = .438$] and quadratic trend [$F(1,148) = 20.56, p < .001, \eta_p^2 = .122$] representing a day-by-day decline in intrusion frequency. Neither the main effect of experiments [$F(3,148) = 1.39, p = .248$,

η_p^2 = .027] nor any of the two-way interaction were significant, namely days × group [F(3.98, 589.01) = 1.58, p = .178, η_p^2 = .011], and day × experiment [F(11.94, 589.01) = 1.35, p = .187, η_p^2 = .027] and group × experiment [F(3,148) = 2.12, p = .100, η_p^2 = .041].

Finally, the three-way interaction between day × group × experiment was significant [F(11.94, 589.01) = 1.82, p = .042, η_p^2 = .036]. When this interaction was separated according to each within-subject polynomial contrast (days), it did not reach significance for the linear trend [F(3,148) = 2.24, p = .087, η_p^2 = .047] but it did for the quadratic trend [F(3,148) = 3.15, p = .027, η_p^2 = .060]. Thus, the day × group interaction for the quadratic trend was examined separately within each experiment, but none of the analyses reached significance [F's < 3.44, p's > .072].

Overall, this analysis indicated that intrusion frequency declined across the one-week period. Such a decline followed both a linear and quadratic trend. The most consistent finding appears to be that, across experiments, the decline in intrusion frequency (linear or quadratic) was comparable between both groups.

Discussion

Summary of main findings across exploratory analyses

When pooling all experiments, analyses of daily diary data (156 participants, 700 intrusions) showed that the majority of intrusive memories appeared to be triggered by sensory-perceptual cues in daily life rather than by abstract cues. Importantly, the interference effect on intrusion frequency was more pronounced for intrusions triggered by sensory-perceptual cues. Further, the pattern of differences in intrusion descriptions was mixed, with the interference group reporting *more* total words but *fewer* perceptual *process* words, or no difference in event details. Finally, the interference procedure did not appear to influence the rate of decline of intrusion frequency across a one-week period.

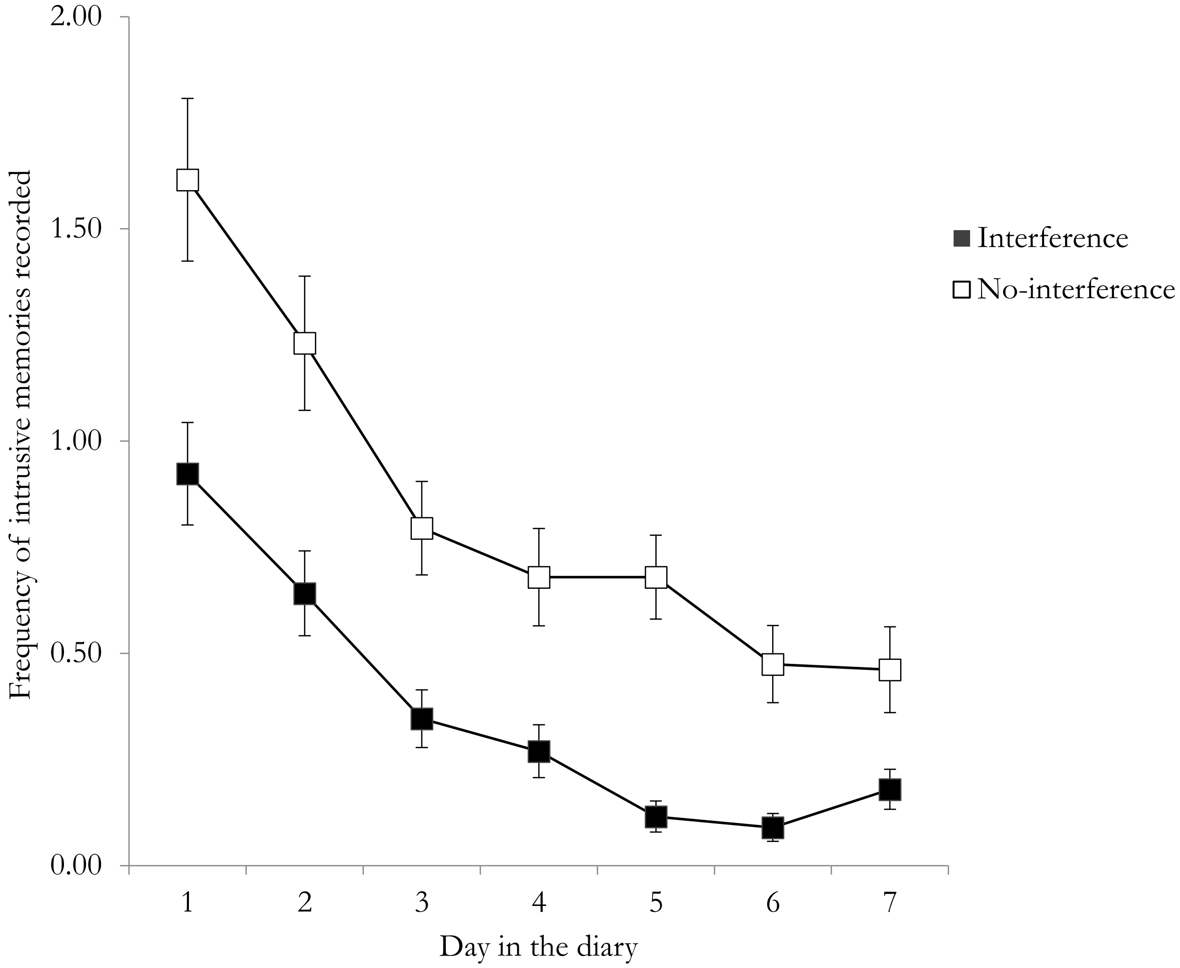


Figure 6.2. The frequency of intrusive memories recorded in daily life by days in the diary (for a one-week period after interference) and by groups combined across Experiments 1-4.

Findings in relation to findings from previous experiments

The current findings are consistent with the idea that the interference procedure disrupts the associative memory links between image-based memories (i.e., intrusions) and sensory-perceptual cues in daily life (i.e., triggers reported in the diary). Such cues were different from the ones used in the laboratory, i.e., still moments from the film. This suggests that the associative links underlying intrusion formation may be between sensory-perceptual elements within the unfolding of the film (e.g., colours, objects and shapes) rather than between still scenes (as explored in Experiment 4). These results should be followed up by an experimental study.

The pattern of intrusion content differed depending on the scoring protocol, with intrusive memories in the interference group relative to the no-interference group being equally 'episodic' or 'perceptual' according to one protocol, but involving less 'perceptual' processes according to another. Such a pattern is distinct from the analyses of free recall content in Experiment 1 for which neither scoring protocol revealed group differences. It is possible that the findings on intrusions reflect differential interference effects on two distinct perceptual components, with perceptual *processes* reflecting the associative link among sensory-perceptual elements, and perceptual *details* reflecting the content itself. This explanation is tentative only and the data require replication.

The lack of interference effects on the rate of intrusion frequency decline suggests that the effect on memory cannot be explained by differences in the rate of forgetting. Instead, the pattern points towards some form of trace-based differences between groups. These consistent group differences in intrusion frequency across days are in line with findings from Experiment 2 and 3, showing that differences in intrusions were established instantly after interference. The non-time-dependent effect on intrusions is difficult to explain with standard theories of consolidation. A more elaborated explanation will be developed in the General Discussion.

Novel findings in relation to triggering cues and intrusive memories

A novel finding from the combined diary analyses is that intrusive memories induced by trauma films appear to be preferentially triggered by environmental cues that share sensory-perceptual features with the content of the film. This represents the first direct demonstration that intrusions to trauma films are in line with the clinical phenomenology of intrusive memories after psychological trauma with regard to the triggering cues, thus providing further support for the validity of film-induced intrusions as an experimental psychopathology model of trauma-relevant processes.

Such preferential triggering by sensory-perceptual cues is by no means trivial, since research has found that not all involuntary phenomena are 'Proustian', i.e., linked to sensory-perceptual cues. For example, Berntsen (2009) initially found that the majority of involuntary autobiographical memories were triggered by external environmental cues. However, Mace (2004) then asked participants to classify an external cue as sensory-perceptual or abstract, and found that involuntary autobiographical memories were more likely to be triggered by abstract cues rather than sensory-perceptual cues as assumed previously. Furthermore, Kvavilashvili and Mandler (2004) found that involuntary semantic (non-autobiographical) memories were reported as occurring without any apparent cues. Clearly, not all involuntary phenomena are 'Proustian'.

Alternative explanations

The analyses performed in this chapter were exploratory, hence the results should be interpreted with caution. The findings cannot be attributed to differences in diary compliance since both groups provided a comparable amount of information for cue-related analysis and the cue classification system was performed by the researchers.

It is possible that participants did not provide full enough descriptions of the content of their intrusions to allow for proper analyses of group differences. The main purpose of the diaries was to elicit sufficient details to allow matching the intrusion with the film, i.e., only a few words were necessary (i.e., reporting the word 'shave' was sufficient to match); however, short descriptions may not fully capture what participants are seeing in their 'mind's eye'. The application of either scoring protocol on short entries such as intrusion description may suffer from reliability and validity issues. Future research can consider detailed interview-based protocols and other forms of content analysis that can give a fuller picture of the intrusion phenomenology, for instance, by adapting protocols from patient studies (Ehlers et al., 2004; Holmes et al., 2005).

Chapter Summary

To summarise, exploratory analyses of daily diary data indicated that the interference procedure reduced the frequency of intrusive memories triggered by sensory-perceptual cues more so than intrusive memories triggered by abstract cues. The interference procedure appeared not to affect the episodic 'content' associated with intrusive memory, but methodological refinements tailored to content analyses of intrusive phenomena were suggested to draw firmer conclusions.

Finally, there were no overall group differences in the rate of intrusive memory frequency decline over a one-week period after interference. This is also consistent with the effect on intrusions immediately after interference found in the other experiments in this thesis. How can this lack of a time-dependent effect be explained by current consolidation theories highlighting time-dependent effects? This issue will be further discussed in the next chapter.

7. General Discussion

Thesis Overview

This thesis provided an experimental investigation of intrusive emotional memories – a key feature across psychological disorders – to account for the mechanisms underlying an apparent functional dissociation between involuntary and voluntary retrieval of the same emotional memory. Studying clinically-relevant forms of memory may inform psychological interventions targeting pathological memory processes, and critically feedback to mainstream theories where intrusive phenomena have been neglected.

Experiments in this thesis focused on a well-replicated demonstration that an interference-task procedure (reminder cues followed by Tetris game play), delivered 30 min after trauma film viewing (i.e., during 'consolidation), can selectively reduce the frequency of subsequent (involuntary) intrusive memories in daily life recorded in a one-week diary, while apparently sparing (voluntary) recognition accuracy tested post-diary (Holmes et al., 2009; Holmes, James, et al., 2010). Such a pattern of findings, however, contradict mainstream memory theories which would expect that interfering with memory consolidation would affect both involuntary and voluntary memory since they stem from the same memory trace. Note that a similar intrusion/recognition pattern has been found with other experimental procedures also targeting encoding/consolidation (e.g., Deeprose et al., 2012; Krans, Naring, et al., 2009; Krans et al., 2010; D. G. Pearson et al., 2012), and with a similar procedure targeting memory 'reconsolidation' (i.e., 24 hr after film viewing; James, Bonsall, et al., 2015).

Using a diverse battery of memory measures, four experiments in the thesis aimed to a) replicate the intrusion/recognition dissociation on existing measures, b) establish if the involuntary/voluntary memory dissociation extends to improved measures, and c) investigate candidate factors that could explain such dissociation. These experiments also investigated the relation between two additional procedural features and the effect on intrusive memories: the timing of intrusion measurement and the role of reminder cues prior interference.

These measures revealed the following profile of memory effects: a) the intrusion/recognition dissociation was consistently replicated (Experiment 1,2 and 4); b) the involuntary/voluntary memory dissociation still held even with improved measures (Experiment 1, 2 and 4); and c) the novel measures ruled out several candidate factors as explanations for this dissociation, including task-relevant cues (Experiment 1), attention bias to task-irrelevant cues (Experiment 2), WM load at retrieval (Experiment 3) and associations between scenes (Experiment

4). Additionally, the interference effect on intrusions appeared as non-time-dependent, i.e., emerged almost immediately after interference (Experiment 1, 2 and 3). Another new finding was that the effect was cue-dependent, i.e., interference was effective when delivered after reminder cues but not without such cues (Experiment 3). Finally, a meta-analysis of data across experiments showed that the interference effect on diary-based intrusions of the film was more pronounced for those intrusions triggered by sensory-perceptual rather than abstract cues in daily life.

Thus, these findings are consistent with clinical perspectives whose stance aims to reduce intrusion frequency while sparing voluntary memory (e.g., Holmes, Sandberg, et al., 2010). The dissociation between intrusive and voluntary memory, however, cannot be readily explained by mainstream memory theories of consolidation (see Chapter 1), nor by the candidate factors considered in this thesis. This raises the question of what unique aspects of memory drive intrusive memory frequency in daily life. Before proposing a theoretical account, a more detailed summary of findings per chapter will be provided first.

Summary of Main Findings by Chapter

A framework derived from mainstream memory theories guided the conceptualization of four experiments in this thesis (Chapter 1). Experiment 1 (Chapter 2) aimed to establish whether the involuntary/voluntary dissociation was robust, and whether task-relevant cues could explain such effect. Results revealed that there was an interference-task effect on diary intrusion frequency but not voluntary memory as revealed by single-item recognition, replicating previous findings. Furthermore, the intrusion diary was compared with free recall, a better-matched measure of voluntary memory (i.e., both lacking task-relevant cues). Despite this better match, there was also no interference effect on free recall, thus establishing that the intrusion/voluntary dissociation is robust. Furthermore, there was also no interference-task effect on involuntary memory revealed by priming. Taken together, neither task-relevant cues nor involuntary retrieval of perceptual content per se (priming) could explain the current findings on intrusive memories. Such findings suggest that an impact on intrusion frequency can occur without affecting the (voluntary or involuntary) content of the memory per se, i.e., the episodic memory trace for the trauma film.

Experiment 2 (Chapter 3) then considered whether the interference procedure disrupted the link between memory content and external attention (i.e., memory leading to attention bias). First, there was an intrusion/recognition dissociation even when both were tested on the same day

(day 8), providing further evidence that the dissociation is real. Importantly, while attention bias to external task-irrelevant film cues was apparent following film viewing, there was no evidence that this bias was modulated by the interference-task, despite the presence of an effect on intrusion frequency sampled around the same time period (soon after Tetris within the same day) in a laboratory-based diary analogue. Thus, attention bias to task-irrelevant cues could not account for the findings on intrusion/voluntary dissociation. Importantly, this effect on 'early' laboratory-based intrusion frequency was predictive of the subsequent interference effect on diary-based intrusions. The latter finding has both practical and theoretical implications. Practically, it makes the study of intrusive memories more tractable (using a 15-min assessment within a single laboratory session rather than one-week diary later), and facilitates further manipulations of retrieval context while intrusions occur (as leveraged in later experiments). Theoretically, it appears to suggest that the disrupted (re)consolidation of intrusive memories is not time-dependent, but takes effect almost immediately after interference.

Using the newly developed laboratory-based intrusion task, Experiment 3 (Chapter 4) investigated whether the interference procedure influenced the association between intrusive memory retrieval and WM, using three manipulations of WM load (no load, verbal and visuospatial load) while intrusions were sampled. If so, the relative proliferation of intrusion frequency during no (vs. high) load would have reduced to a greater degree by the interference procedure. Such an effect was not found; instead, interference led to fewer intrusions across all retrieval WM load manipulations. Thus, retrieval load cannot explain the findings on intrusion frequency modulation. Moreover, Experiment 3 also revealed that interference was cue-dependent, i.e., it was effective only when delivered following reminder film cues.

Experiment 4 (Chapter 5) investigated whether the interference task weakened the associative links binding different film scenes across time, i.e., scenes that served as film cues for retrieval, with scenes depicting moments of the film that became 'intrusive' (as opposed to weakening the content of each individual scene). The hypothesis was that the interference procedure should disrupt the advantage of cueing memories with stills from the same films, in both the laboratory intrusion task and a new associative (rather than single-item) recognition task. That was not the case: while film cues did increase intrusion frequency more so than foil cues, this cueing advantage was not modulated by interference; and any effect of cues or interference on the associative recognition task failed to reach significance. Whilst methodological refinements are required to draw firmer conclusions, it appeared that binding among film scenes across time could not readily account for the findings on intrusive memories. Nevertheless, this experiment provided a first suggestion that an intrusion/recognition dissociation could occur soon after interference.

Finally, intrusion data on the one-week diary was used to explore whether specific features of the diary methodology could reveal novel insights about the interference effects on memory. A combined analysis across the four experiments (Chapter 6) suggested that the interference effect on intrusion frequency appeared to be stronger for intrusions triggered by sensory-perceptual cues (compared to abstract cues), which shared sensory-perceptual feature overlap with film content. There was no consistent interference-task effect across experiments on either the episodic content of an intrusion (echoing the absence of an effect on free recall), or on the rate of decline of intrusion frequency over the week (i.e., forgetting rate). The latter supports the idea that the interference effect on intrusion frequency is *not* time-dependent, i.e., it emerges early and is maintained throughout.

Theoretical Implications

To fully account for the pattern of findings in this thesis concerning intrusive memories, a memory theory needs to explain why the interference-task effect on memory is selective, i.e., leading to a dissociation between (involuntary) intrusive memory frequency and deliberately-retrieved content of the same (voluntary) memory. Such a theory should also take into account that several candidate factors have been ruled out, including task-relevant cues, perceptual content (priming), attention bias and retrieval WM load. It should also explain why the interference effect on intrusion frequency is *non*-time-dependent (i.e., emerges instantly after interference), but cue-dependent (i.e., effective only following reminder cues) and more pronounced for intrusions triggered by sensory-perceptual rather than abstract cues in daily life. The pattern of findings do not seem to be fully explained by any of the current memory theories (presented in Chapter 1), each of which will be reviewed in turn.

Episodic Memory

There are several challenges to mainstream accounts of episodic memory that assumes single-trace systems (Squire & Zola-Morgan, 1991; Tulving, 2002). First is the intrusion/voluntary dissociation. If these are represented by the same underlying episodic trace, then the dissociation must be explained by retrieval-based processes. However, the intrusion/voluntary dissociation persisted despite a better match in retrieval context (task-relevant cues, Experiment 1; time/day of testing, Experiments 2 & 4; associative film cues, Experiment 4). Interference effects on intrusion frequency also persisted despite attentional manipulations at retrieval (of WM load, Experiment 3), and the absence of an interference-task effect on voluntary memory remained despite varying the availability of retrieval cues (Experiment 1). Therefore, retrieval-based explanations considered so far cannot explain the current findings; nor can consolidation-based accounts that assume a single trace, because the 'episodic' and image-based nature after the interference procedure remains intact (Experiment 1).

As single-trace explanations are insufficient, one alternative account could be derived from the Multiple Trace Theory (Nadel & Moscovitch, 1997). It remains possible that intrusive memory frequency and voluntary retrieval require a different amount of the existing 'multiple' traces. This possibility is elaborated later when three potential theoretical accounts are discussed.

Autobiographical Memory

Similar limitations apply to the autobiographical memory literature, which does not tend to assume distinct (episodic) traces underlying involuntary and voluntary memory of the same event. However, theories by both Conway and Berntsen provide more specificity regarding retrieval differences that could potentially account for the current findings, particularly the fact that voluntary memory appears to be intact. One explanation is that voluntary retrieval, in addition to being accompanied by the intention to retrieve, typically recruits top-down search processes involving executive functions (Berntsen, 2009) or higher-order memory organizational structures (Conway & Pleydell-Pearce, 2000). Such conceptualization therefore treats retrieval intention and retrieval effort as related but orthogonal processes. Thus, traces that are weakened – but not fully destroyed – can benefit from voluntary retrieval as an alternative/compensatory route, particularly if a complex network of associations exists to help access emotional episodic memories. Under this view, involuntary retrieval is therefore more likely to suffer from such trace-based disruption, as this relies more on automatic activation of such associative network (e.g., via spreading activation).

Thus, these views would predict that voluntary retrieval should also be affected, as long as it occurs without effort (known as "directly retrieved" voluntary memories as opposed to "generatively retrieved" memories), though coming up with an experimental test where intention and effort can be cleanly separated might be challenging. However, these views do not readily explain what aspects of a memory trace need to be weakened in order to selectively affect intrusion frequency.

PTSD Memory

The dual-representation theory and its revised version (Brewin, Dalgleish, et al., 1996; Brewin, 2001, 2013) would argue for separate traces for involuntary and voluntary retrieval. In fact, the intrusion/voluntary dissociation, as demonstrated by studies using the trauma film paradigm, has been used as support for this theory (Brewin, 2013). However, it does not explain why a visuospatial interference procedure (such as Tetris game play) would disrupt the sensory features of intrusions but not those of the voluntary memory trace, especially as sensory features were specifically probed (free recall in Experiment 1). The theory also suggests that intrusions may be subserved by a long-term perceptual memory system (Brewin, 2013) – but perceptual priming appeared intact despite the reduction in intrusion frequency (Experiment 1). As a theory that is meant to explain PTSD-specific memory processes, direct evidence in PTSD remains elusive (Kvavilashvili, 2014). It remains possible that the dual-representation theory applies to PTSD, but is less applicable to non-PTSD intrusions induced with an experimental paradigm.

An alternative clinical perspective by Ehlers and colleagues (Ehlers & Clark, 2000; Ehlers et al., 2010) suggests that intrusive and voluntary memories might refer to distinct moments of the traumatic episode. Again, this possibility may apply to PTSD, but not to the current results because it seems unlikely that the interference procedure would 'delete' moments of the film that constitute part of the intrusion, as these are typically key moments of the narrative that are accessible by voluntary retrieval.

Fear Memory

A possible suggestion from the fear (conditioning) memory literature is that the reduction of intrusion frequency is explained by a reduction in memory emotionality, independent from changes in sensory-perceptual content of the memory. Although emotionality was not directly tested, such a suggestion seems unlikely because intrusion distress (the closest index of memory emotionality in this thesis) was equivalent between the interference and no-interference groups.

Further, if interference influenced memory emotionality, then one would expect influences also on memory qualities and cognitive outcomes that are linked to emotionality. That was not the case. For instance, although emotional film cues led to a more pronounced attention bias

(Experiment 2), this emotional bias was not modulated by interference. Further, the interference procedure did not appear to affect intrusion vividness, distress or nowness, all of which are in turn influenced by emotionality.

Towards a theoretical account of the selective effect on intrusive memory frequency

Broadly speaking, the experimental dissociation between intrusive memory frequency and the voluntary counterpart (e.g., recognition) across experiments appears to be better explained by a combination of trace-based and retrieval-based mechanisms. From a trace-based perspective, the current data raises the possible existence of a specific type of code within complex episodic memories (e.g., as opposed to word lists) that is modified by interference. Such trace-based modification may not be fully detrimental if compensation exists, e.g., via retrieval-based processes (e.g., voluntary retrieval).

More specifically, there are at least three theoretical frameworks (each will be elaborated below) that could be used to explain what is changed in memory (i.e., what mnemonic component underlies intrusion frequency), what the roles of reminder and interference are, and why voluntary retrieval appears intact. It is important to note that the current results cannot tease apart these three potential explanations. Given that none of the explanations could fully account for all the findings, it is possible that a combination of these – or a new approach – is needed. A schematic overview of the three accounts is provided in Figure 7.1.

Account 1: Sensory-perceptual (un)binding

A first account is based on the working assumption that mnemonic components with the specific emotional memory have changed after interference. Rather than associative links between different still moments of a moving scene, these appear to be associative links among the disparate *sensory-perceptual* elements of the episode (Chun & Johnson, 2011). These refer to, for example, the link between a man 'cutting' himself and the red colour of his blood, the shape of the razor, the bathroom tiles, the white tap, the running water, his hairstyle, his skin colour, and so on, which are needed for the conscious experience of an image-based memory.

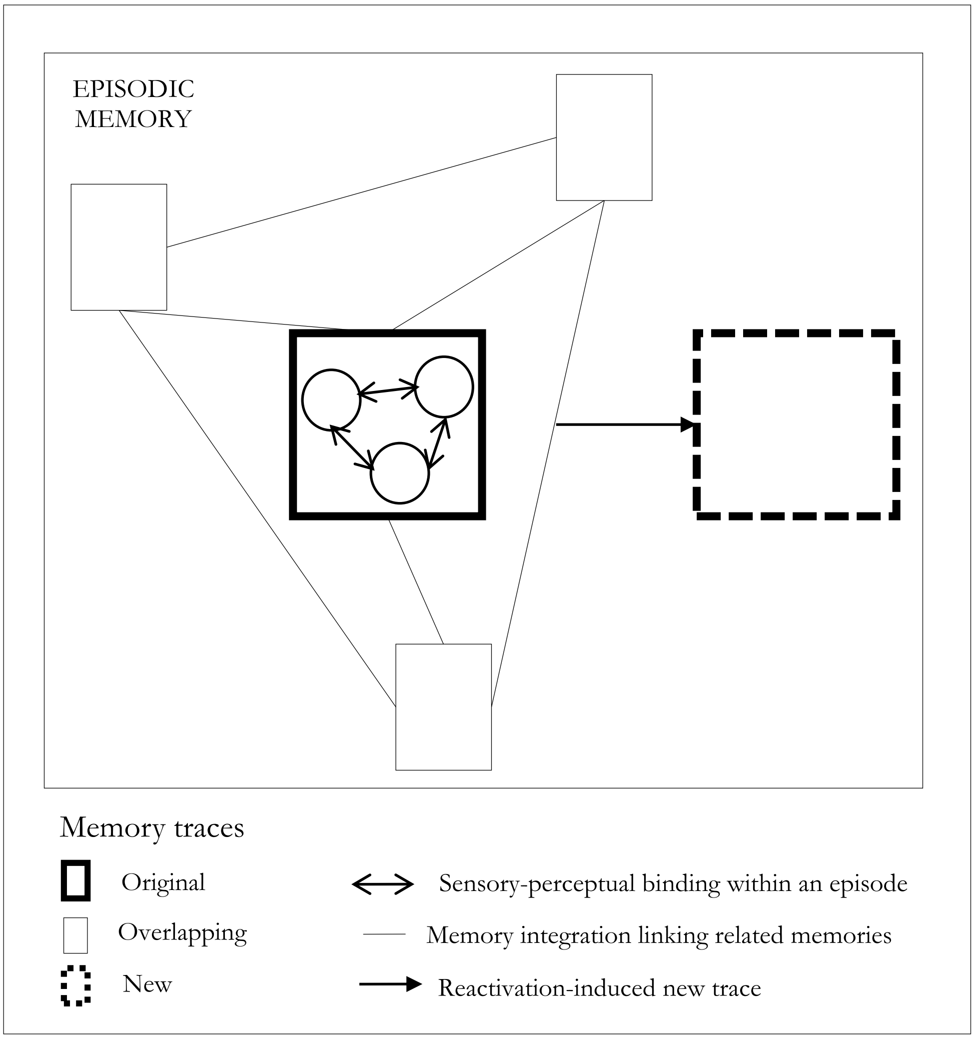


Figure 7.1. Schematic overview of three possible theoretical accounts for findings on intrusive frequency (sparing voluntary memory) in the current thesis. The reduction on intrusion frequency can be explained by 1) disruption of the binding between sensory-perceptual discrete elements of an episode, 2) disruption of the links within a network of pre-existing and overlapping memories, and 3) interrupted formation of new/multiple trace(s). These accounts may not be mutually exclusive.

The strength of such links then determines intrusion frequency, i.e., the probability of successful scene (re)construction (Hassabis & Maguire, 2007) in order to surpass a threshold sufficient for that memory activation to reach awareness and subsequently be reported as an intrusive memory. Thus, reminder cues may first lead to the reactivation and destabilization of these binding links, with the interference task selectively competing with resources required for their stabilization. Weakening of such sensory binding, i.e., unbinding, means that the remaining disparate sensory-perceptual details would be less likely to act as effective cues for the successful retrieval of each other based on automatic spread activation. Compared to standard single episodic memory system, this account proposes that complex memories are organized by associative links among sensory-perceptual details within a specific episode.

Changes in sensory-perceptual associative links do not per se distinguish involuntary from voluntary retrieval. However, such a trace-based change is less disruptive to voluntary retrieval because alternative retrieval routes remain, e.g., via strategic search and generation of internal (semantic) and other autobiographical cues, that are more likely to be recruited during voluntary retrieval. An important assumption from this proposal is that the involuntary/voluntary intention dissociation (wanting to remember) maps onto a distinction in terms of retrieval effort (making effort to remember), in that voluntary retrieval typically recruits more effortful processing (Berntsen, 2009) and can therefore generate additional retrieval cues. This intention/effort distinction is inherently difficult to disentangle, because involuntary processes are by definition effortless, whereas voluntary processes under laboratory instructions are typically effortful. However, recent theoretical advances suggest that effortless voluntary retrieval, also known as 'direct voluntary retrieval' (Barzykowski & Staugaard, 2016; Harris, O'Connor, & Sutton, 2015; Schlagman & Kvavilashvili, 2008; Uzer, Lee, & Brown, 2012; Uzer, 2016), could be measured in the lab. If the interference procedure indeed influences memory retrieval when it is effortless, then both effortless involuntary and voluntary memory should be affected. This possibility warrants further methodological refinements that can clearly disentangle intention from effort in measures of retrieval for a trauma film.

This explanation suggests that there are interference effects on memory when retrieval requires such sensory-perceptual associations (Experiment 1: diary; Experiment 2, 3 & 4: laboratory-based intrusions), but not when compensatory retrieval routes can be recruited. The finding that this effect was stronger for intrusions triggered by sensory-perceptual cues (combined diary analysis) supports the proposal that indeed sensory-perceptual associations were targeted.

The other memory measures, which did not reveal an interference effect, did not require sensory-perceptual associations for successful retrieval (Experiment 1: priming; Experiment 2: attention bias) or were instead able to access alternative (e.g., semantic) routes instead (Experiment 1: free recall; Experiment 1 & 2: single-item recognition) via voluntary retrieval. For the latter, when the use of sensory-perceptual associative cues was encouraged, the dissociation between (involuntary) intrusions and (voluntary) became less reliable (see Discussion of Experiment 4).

This account has difficulties in explaining the main effect of the interference-procedure across sensory-perceptual and abstract cues, i.e., why is retrieval supposed based on 'semantic' links also disrupted? Further, the definition of sensory-perceptual remains vaguely defined (throughout the literature), for example, a razor triggering an intrusive memory of the shaving scene may occur via 'sensory-perceptual' overlap with the objects in memory, but also via a 'conceptual' overlap in terms of themes of injury. This is ambiguous within the trauma film paradigm as it stands, and methodological refinements are needed to clarify the distinction.

Account 2: Memory integration/isolation

A second account is based on the assumption that interference changes mnemonic components linking different episodic memories (trauma film and other past memories) rather than aspects within a specific memory (trauma film only). This process is known as memory integration, a hypothesised process whereby similar experiences becomes increasingly more interconnected, leading to the formation of memory networks stored as overlapping neural representations (Schlichting & Preston, 2015). For example, the memory for the shaving scene may then be connected with other autobiographical memories on injuries and cutting, buying shaving cream, a similar looking guy with athletic build, tooth-brushing in the morning, etc. In fact, existing theoretical proposals (Rubin, 2005, 2011) suggests that traumatic memories become more integrated into one's life narrative, though some clinical theorists disagree (Brewin, 2013).

The overlap between these different traces in turn determines intrusion frequency, i.e., the probability that access to an older (non-film) memory can trigger automatic retrieval of the trauma (film) memory. Such integration processes may have occurred already during encoding (which reactivates previously stored, related memories). Memory cue prior interference leads to the destabilization of this network, with the interference task then competing with resources to maintain such integration. In other words, the trauma film trace becomes less integrated and more 'isolated'. Weakening of this memory integration process means that fewer related memories are available as cues for subsequently triggering intrusions of the film. Compared to a conventional single episodic memory system, this account proposes that rapid memory integration has taken place between a recently encoded episode and previously learned events.

Similar to the sensory-perceptual binding account, this memory integration account does not distinguish between involuntary and voluntary retrieval per se, and suggests that voluntary retrieval can benefit from compensatory mechanisms, e.g., semantic elaboration, to access the less 'well-integrated' memory. Following this explanation, there are interference effects on memory when retrieval requires links with overlapping memories, e.g., intrusive memories cued by daily external reminders that are not exact replica of the film (Experiment 1-4: diary intrusions; Experiment 2-4: laboratory-based intrusions). However, interference effects are less likely when compensatory mechanisms are in place to overcome such trace isolation, including semantic elaboration and strategic search (e.g., with voluntary retrieval) or near-replica cues (Experiment 1: priming; Experiment 2: attention bias). This account predicts that measures of memory integration (between trauma film and other related memories) should reveal an effect of interference.

Several findings are difficult to explain with this account. For instant, it is hard to distinguish whether a triggering cue accesses the trauma film trace via direct overlap with the film trace per se, or alternatively via overlap with an older related memory that is in turn linked to the film trace. It is also unclear when a cue is sufficient to 'compensate' for such disruption. Disentangling these possibilities is difficult with the trauma film paradigm as it stands, because it is unknown which older memories the trauma film memory has been integrated with, making it difficult to quantify the degree of memory integration. Furthermore, memory integration has traditionally been linked to the idea that a newly-encoded memory becomes more semantic and abstracted away over time (weeks and years) and less episodic. However, the 'episodic' nature of (intrusive) trauma film memories (and therefore their integration to wider memories) does not appear to change after interference.

Account 3: Multiple traces

Contrary to the first two accounts relying on single-trace explanations for the trauma film trace, a third type of account proposes that interference indeed changes the contents of memory but in the context of multiple coexisting traces. Such accounts would be consistent with the Multiple Trace Theory (Nadel & Moscovitch, 1997), which argues that an retrieval attempt in itself may lead to the formation of a new hippocampally-dependent episodic trace. However, contrary to the dual-representation theory of PTSD (Brewin, Dalgleish, et al., 1996; Brewin, 2013), the Multiple Trace Theory would assume that these different traces are stored within the same episodic memory system (rather than the intrusive memory trace being stored in a separate long-term perceptual memory system). Also contrary to 'strong' versions of reconsolidation theories (Dudai, 2004), Multiple Trace Theory does not assume permanent changes to the old memory.

Following this account, the availability of at least two different memory traces, one interfered with and one not, might then be able to explain the apparent dissociation between voluntary and involuntary retrieval. Whereas this original trace contributes more strongly to voluntary retrieval (and other involuntary measures with strong cues, i.e., Experiment 1: priming; Experiment 2; attention bias), the second trace (triggered by reminder cues) contribute more strongly to intrusion frequency. However, this second trace is otherwise prevented by the interference task. Critically to support this account, one would need to independently establish that cue-alone is indeed linked to later intrusion frequency.

Another possibility is that the original trace contributes more strongly to all memory measures, but the cue+interference procedure leads to the formation of a new competing trace which reduces the probability of retrieving the original trace (i.e., reducing intrusion frequency). cue-only or interference-only are insufficient to produce trigger the formation of a new trace, because both may be needed to trigger a prediction error (Sevenster et al., 2014). The resulting retrieval competition from this new trace can be overridden by effortful retrieval (e.g., voluntary) or with strong cues (i.e., Experiment 1: priming; Experiment 2; attention bias). To support this account, independent evidence is needed that such retrieval competition indeed occurs.

Critically, neither multiple trace account can readily explain why involuntary and voluntary retrieval utilise different traces and why intrusion frequency is more dependent on changes to the second trace. More importantly, these accounts rely on assumptions about processes occurring during the interference procedure (e.g., reminder cues and competition for resources), which were beyond the scope of the thesis but warrant further investigation.

Consolidation, reconsolidation or *rapid* consolidation?

In addition to the selective interference effect on intrusion frequency, there are two other findings from the current thesis (obtained from manipulations of procedural aspects of the paradigm) that posit challenges to standard consolidation theories.

Timing of the effect on intrusions. The finding that the effect on intrusions are observed almost instantly after interference are unlike typical system-type consolidation effects which are theorized as time-dependent (Squire & Zola-Morgan, 1991), occurring for example after sleep (Walker & van der Helm, 2009), or at least thought to emerge gradually over hours to days (Dudai, 2004; McGaugh, 2000, 2004; Staugaard & Berntsen, 2014). Thus, the traditional concept of time-dependent consolidation appears unable to account for the current early effects on intrusions.

Relatedly, the concept of 'rapid consolidation' (McClelland, 2013; Tse et al., 2007) has been used recently in the literature to describe the finding that rats rapidly acquire new information (single-trial learning) that can be assimilated into neocortical structures if the information is *consistent* with prior learning (schema). However, such accounts have been used to explain successful memory acquisition tested after 24h following a one-shot learning, which is still slower than would be necessary here (effects immediately after interference). While the relationship between prior knowledge and new learning is not straightforward within the trauma film paradigm, it remains possible that some form of rapid consolidation occurs for intrusive memory. This speculation requires further research by mapping directly the neural systems underpinning the encoding, consolidation and retrieval stages relevant to intrusions.

Necessity of pre-interference reminder cues. The second challenge to standard consolidation theories concerns findings that disruption to intrusive memories occurs only if the interference task followed the presentation of reminders. One interpretation, in line with reconsolidation accounts (James, Bonsall, et al., 2015; Nader et al., 2000), is that such film cues were needed to reactivate the memory and render it labile for subsequent modification. This importance of reactivation for exerting interference effects is not readily articulated within consolidation theories, because establishing new memories in itself is expected to disrupts consolidation of a recently encoded memory (Wixted, 2004). Thus, interpreting the importance of cues as reactivation implies that the memory was already consolidated (or rapidly consolidated) 30 min after trauma film viewing, and therefore the effects currently observed are already under the realm of reconsolidation.

An alternative interpretation is that unlike reconsolidation views, film cues serve additional functions beyond reactivation. That is, in addition to rendering the memory labile, film cues may also, for example, orient the interference procedure to more targeted elements within the memory trace. This idea is relevant for more complex memories (Schlichting & Preston, 2015), where specific elements rather than the whole network are deemed as interference targets. Thus, more research needed to understand the role of reminder cues within this interference procedure and consolidation-based manipulations.

Practical Implications

The intrusion/voluntary dissociation indicates that one could stop being haunted by the content of traumatic memories but still summon these memories when necessary, albeit under one's control. These findings are relevant in the context of research seeking to 'erase' trauma memory in humans (e.g., Kroes et al., 2013; Lonergan et al., 2013). The public has long been captivated by the possibility of a 'forgetting pill' that can achieve 'eternal sunshine of the spotless mind'. Even patients with PTSD will often claim that they want to delete their traumas from their minds.

Whether one can erase memory or not is an interesting scientific topic, but whether or not the content of negative memories *should* be eradicated continues to be a controversial topic (Liao & Sandberg, 2008). However, it is undeniable that the preservation of memory is important across many contexts. Erasing memories in trauma survivor may render them unable to provide legal evidence; erasing memories in journalists may affect the integrity of news reports; erasing memory in soldiers may also take away their experiences of courage and resilience. The data in this thesis supports a more nuanced stance to trauma-related research and clinical practice, where the idea of 'erasing' memory can be further unpacked. That is, there are specific pathological properties of the memory that can serve as intervention targets (e.g., intrusiveness), which are critically distinguished from other properties of the memory which we may want to preserve (e.g., voluntary retrieval). Researchers, clinicians, patients and the wider public should be better informed of these nuanced memory differences and the possibility of treating them separately.

Another important finding from this thesis is the lack of time-dependent effect on intrusions. This points to the possibility that the effectiveness of the intervention could be determined early on at an individual level. Such earlier markers, together with other factors, can be used to determine who would and would not benefit from these interventions, and inform clinical decisions where additional support is needed. Moreover, it is nontrivial to find that the intervention is effective only with reminder cues even soon after the events, because one may assume that the trauma is still 'fresh' in mind at that point. Thus, reminder procedures even in the immediate aftermath of trauma cannot be bypassed, although it remains possible that reminder procedures needed at this point may be of a different (or lower) dose than those needed for old established memories (e.g., days after the trauma).

More broadly, the interference procedure used to ameliorate intrusive memories can inform both preventative and treatment interventions. These include clinical domains where intrusive phenomena have been traditionally neglected (e.g., bipolar disoder; Davies, Malik, Pictet, Blackwell, & Holmes, 2012; Holmes et al., 2016), interventions are demanded for the immediate aftermath of trauma (e.g., Horsch et al., 2016; Iyadurai et al., 2016), access to mainstream healthcare services are limited (e.g., youth mental health; Patel, Flisher, Hetrick, & McGorry, 2007), the levels of psychological trauma are rapidly escalating (e.g., refugees, front-line workers), and where public health issues are potentially underrecognised (e.g., media exposure to trauma in the general public, see Appendix 7.1). Such a behavioural intervention using computer games holds promise for translation into a worldwide scalable intervention by leveraging on everyday technology (Kazdin & Rabbitt, 2013).

Key Methodological Limitations of Experiments in this Thesis

The current thesis relied on the use of the trauma film paradigm to study intrusive memories. A common argument against this paradigm concerns its limited ecological validity. While watching a short negative film in the laboratory is indeed not trauma per se, it does induce intrusive memories subsequently in daily life, whose properties (including frequency) are amenable to experimental manipulation. In fact, it allows for the study of more complex forms of episodic memories that is not possible with the other dominant paradigms used in the study of stress-related disorders, such as fear conditioning paradigms (James et al., 2016). Moreover, there is increased recognition that indirect exposure to traumatic events via electronic mediums (e.g., film footages) can result in stress-related symptoms (including intrusive memories) that warrant further scrutiny from a public health perspective, both for exposure in professional contexts, e.g., journalists doing news editing (American Psychiatric Association., 2013) and mainstream media, e.g., lay person watching the news (Holman, Garfin, & Silver, 2014; Silver et al., 2013).

As a paradigm to study episodic memory, one may argue that the trauma film paradigm confers less experimental control compared to paradigms using word or still picture stimuli. Words and still pictures have the relative advantage that encoding/retrieval processes can be even more tightly controlled. For example, it is difficult to specify within the trauma film what are the cue-target contingencies that are readily defined with word/picture paradigms; it is also difficult to ascertain what occurs during the retrieval process, i.e., what is exactly being retrieved when an intrusive memory occurs? Is the intrusion a veridical representation of the film? What part of the film does an intrusion correspond to? Even if a person repeatedly has intrusive memories to the same film, is it the same moment of the film every time? These are issues that might be addressed with simpler stimuli, but on the other hand may be inherent to the study of more complex forms of human memory. Compared to using of real-life stressors, the use of trauma films is more suitable for defining the locus of memory effects. Relevant to this point is the developing better laboratory-based diary analogues as discussed in Chapter 3, so that the retrieval stage (in addition to film encoding) can also be reliable manipulated. Recent developments have already begun to address these issues, for example by combining the trauma film paradigm with fear conditioning to establish clearer cue-response contingences (Kunze, Arntz, & Kindt, 2015; Wegerer et al., 2013), and by methodological advances in quantifying neural 'replay' of memory for film stimuli (Gelbard-Sagiv, Mukamel, Harel, Malach, & Fried, 2008).

Future Directions

There are several ways to test the theoretical proposals suggested in this thesis. While the trauma film paradigm allows for the modulation of intrusive memories (James et al., 2016), the use a complex encoding stimuli (films) may hinder the study of more nuanced mnemonic processes, such as the ones proposed in the section above, including sensory binding and memory integration. One approach is to further adapt the trauma film paradigm so that additional hypothesised memory aspects can also be readily assessed for film material (as attempted in this thesis with an associative memory paradigm). A more readily available alternative is to study the impact of the current interference procedure on another episodic memory paradigm (sufficient to trigger intrusions) which can readily assess aspects of binding and integration.

To elucidate the precise mechanisms underlying this intrusion reduction effect, a complementary approach to testing different aspects of the memory (i.e., the focus in this thesis) is dissecting different aspects of the intervention. This thesis has addressed some of these issues already, for example, by establishing the importance of pre-interference cues and by informing the timing of the effects. However, a more fine-grained investigation is required for further theoretical dissection. With respect to the pre-interference cues: what kinds of cues are needed? Are certain cues better than others? Are these cues indeed rendering the original memory labile (Sevenster, Beckers, & Kindt, 2012), or initiating some other processes as well, e.g., forming new traces/selectively reactivating some aspects of the original trace? For example, a multiple trace account would predict that the degree of reactivation should be linked to subsequent intrusions frequency. Future studies can vary the specificity of reminder the cues (rather than mere presence or absence), the timing between reminders and interference and processing instructions of the cues. With respect to Tetris game-play: what aspects of the game are important for the effect on intrusion frequency? Tetris game-play is assumed to tax visuospatial WM but direct evidence of this assumptions is lacking. Tetris game-play also involves multiple demands, including general attention load and contingent rewards. Thus, future research should assess the contributions of these different features, which could potentially inform the development of new games with therapeutic functions. And critically, is there competition between (reactivation) reminder cues and Tetris game-play (James, Bonsall, et al., 2015)? Understanding this procedure better would clarify its relationship to the intrusion/voluntary dissociation and also inform optimal parameters for clinical translations.

It is also clear that the causes of intrusions, as a form of memory retrieval, require further examination. A detailed qualitative assessment of the phenomenology of intrusive memories (Hackmann et al., 2004) of trauma film materials would help further establish the ecological validity of the paradigm and understand intrusive memories of indirect media-based (rather than direct) exposure to traumatic material, an area with little research (Holman et al., 2014). A closer assessment of intrusions as they occur can also further refine our understanding of their retrieval processes which have been traditionally neglected in this paradigm. The laboratory-based intrusion task could be harnessed in this respect, by facilitating the study of objective (e.g., neural and psychophysiology processes) retrieval markers of an intrusion. This could be both time-linked to the cue it is triggered by, and/or to the exact timing when an intrusion is being experienced. This type of work has begun to emerge (Hellerstedt, Johansson, & Anderson, 2016; Noreika et al., 2015), but not yet for intrusive emotional memories. Compared to reliance on diary measures, such methodological advancement in laboratory-based intrusions would facilitate mechanistic investigation of intrusion development, and could further informed by existing methods in the autobiographical memory literature (Berntsen, Staugaard, & Sørensen, 2013; Schlagman, Kliegel, Schulz, & Kvavilashvili, 2009; Schlagman & Kvavilashvili, 2008; Staugaard & Berntsen, 2014)

The field on intrusive memories should also move beyond studying intrusions as a mere experimental/clinical outcome, and leverage the methods developed in this thesis to investigate intrusive memories as a process, including the impact of intrusions on other aspects of cognition, behaviour and mood in daily life. For instance, the laboratory-based intrusion task can be adapted to investigate how different properties of intrusive memories (e.g., frequency, vividness) vs. voluntary memory as they occur impact on various relevant cognitive outcomes. This line of enquiry can be informed by performance-based methods assessing spontaneous forms of cognition within other (neuro)cognitive psychology domains (Murphy et al., 2013; Robertson et al., 1997). Such line of enquiry can also benefit from ecological momentary assessment methods (Shiffman, Stone, & Hufford, 2008), harnessing technological advances in ambulatory data collection (Trull & Ebner-Priemer, 2013), to understand the role of intrusive memories in moment-to-moment daily functioning, potentially revealing novel theoretical insights (e.g., about cueing processes) that are not apparent with laboratory or diary-based methods used in this thesis and wider involuntary memory research (Berntsen, 2009; Kvavilashvili & Mandler, 2004).

The theoretical proposal arising from this thesis should apply also to intrusive (involuntary) memories deriving from positive, in addition to negative events. Given the widely reported differences between negative and positive memories (Berntsen, Rubin, & Siegler, 2011; Buchanan, 2007; Kensinger, 2009), a study on positive intrusions might further delineate the generalizability and specificity of the current theoretical proposals. One study has found that the interference procedure (reminder cues + Tetris game-play) reduced involuntary memories of a positive film but also reduced recognition memory (Davies et al., 2012). Although this pattern of findings requires replication, it points to the possibility that the relationship between involuntary and voluntary memory may vary from negative to positive materials. Importantly, involuntary memories in daily life are mostly positive (Berntsen, 2009) and their amplification may confers protective functions, and may be useful as an emotional regulation strategy, particularly for clinical domains where the *deliberate* generation of positive cognitions are challenging (e.g., for depressive states; Holmes, Blackwell, Burnett Heyes, Renner, & Raes, 2016).

Chapter Summary: Intrusive Emotional Memories – A Special Form of Memory?

While intrusive memories of affect-laden events have long sparked clinical interest, they have been rarely investigated within mainstream memory research by explicitly linking them to more typically studied forms of memory. From data across four experiments, the present thesis demonstrated that an interference procedure appears to spare memory content while selectively targeting the involuntary (but not voluntary) access to the memory in the form of intrusive memory frequency. Such a pattern of findings is difficult to reconcile with current theories of episodic memory consolidation as they stand, which would expect a general disruption across involuntary/voluntary retrieval of the same memory. Three potential accounts were put forward to explain this dissociation, proposing that the interference procedure led to possible changes in sensory-perceptual binding, memory integration and/or multiple traces. Each of these accounts assumed changes in memory that explains the reduction in intrusion frequency, but leaving compensatory routes that allowed for voluntary retrieval of the same memory content.

The title of this thesis asked the rhetorical question: *are intrusive emotional memories a special form of memory?* The current data converge to highlight that the study of intrusive memories reveals that they are distinct from their deliberate counterparts, prompts the need to revise canonical theories of memory, and underscores the importance of bridging the lab and the clinic via experimental psychopathology. If the study of intrusive memories compels us to expand the scientific landscape around human memory, then they are indeed a special form of memory.

8. References

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9. Appendices

Appendix 2.1: Ethics application covering all experiments within this thesis

UNIVERSITY OF CAMBRIDGE

COUNCIL OF THE SCHOOL OF THE BIOLOGICAL SCIENCES
Cambridge Psychology Research Ethics Committee

Question 1: Title of the study

Notes: The title should be a single sentence

Preventing flashbacks after psychological trauma using cognitive tasks: understanding cognitive and neural mechanisms

Question 2: Primary applicant

Notes: The primary applicant is the name of the person who has overall responsibility for the study. Include their appointment or position held and their qualifications. Primary applicants cannot be research students or junior research assistants. For studies where students and/or research assistants will undertake the research, the primary applicant would normally be their supervisor.

Professor Emily Holmes, DClinPsy, PhD, Programme Leader, MRC CBU

Question 3: Co-applicants

Notes: List the names of all researchers involved in the study. Include their appointment or position held and their qualifications

Professor Richard Henson, PhD, Programme Leader, MRC CBU
Dr Martina Di Simplicio, PhD, Career Development Fellow, MRC CBU
Ms Ella James, BSc, Research Assistant, MRC CBU
Ms Julie Ji, BSc, PhD Student, MRC CBU
Mr Alex Lau-Zhu, BSc, PhD student, MRC CBU
Dr Lalitha Iyadurai, DClinPsy, Department of Psychiatry, University of Oxford
Dr Fritz Renner, PhD, Investigator Scientist, MRC CBU
Dr Renee Visser, PhD, Investigator Scientist, MRC CBU
Ms Katie Dullam, undergraduate student at the University of Cambridge
Ms Elze Landkrron, Visiting student (Masters student at the University of Amsterdam)

Question 4: Corresponding applicant

Notes: Give the name of the person to whom correspondence regarding this application is to be addressed. This person should be the primary applicant or one of the co-applicants. An email address for correspondence must be provided.

Mr Alex Lau-Zhu, email: alex.lauzhu@mrc-cbu.cam.ac.uk
MRC Cognition and Brain Sciences Unit
15 Chaucer Rd Cambridge UK, CB2 7EF

Question 5: In which Department(s) or Research Unit(s) will the study take place?

Notes: Indicate where the study procedures will take place as well as the location for the storage and analysis of data. If the study will use National Health Service facilities, give a contact name and address of the Trust R&D office.

MRC Cognition and Brain Sciences Unit (CBU), 15 Chaucer Road, CB2 2EF

Question 6: What are the start and end dates of the study?

Notes: If exact dates are unavailable, explain why and give approximate dates.

We are applying for an ethics approval for research outlined in the programme proposal led by Professor Emily Holmes, which has been approved by the MRC as part of the quinquennial review process.

We would like to start testing in January 2014 and perform a sequence of experiments over the duration of the programme. The programme commenced last autumn and has been approved until the next quinquennial review (December 2018).

Question 7: Briefly describe the purpose and rationale of the research

Notes: Attach any detailed research proposals, if they have been submitted or will be submitted to a funding body. Make the objectives of the study clear.

This research is part of a continuing programme by the principal investigator that aims to identify and optimise methods to prevent the build-up of flashbacks after trauma. While there are well established treatments for Post-Traumatic Stress Disorder (PTSD) once it is already developed (NICE, 2005), we lack empirically-supported preventative interventions in the immediate aftermatch of a traumatic event, such as a bombing, rape or car crash. A hallmark symptom of PTSD is the recurrent, image-based, distressing intrusive memories of the trauma, commonly known as flashbacks (APA, 2013).

Previously, we have carried out a number of laboratory studies using the "negative film paradigm" as an analogue of a traumatic event using healthy volunteers (e.g. Holmes, Brewin & Hennessy, 2004). The negative film paradigm involves participants viewing a film made up of distressing content, such as the aftermath of car crashes, surgery and road safety adverts. All footage used can be seen in the public domain and as such is of no greater ethical risk than everyday life. For the week after viewing the footage, participants keep a diary in everyday life to monitor any flashbacks to the film. Preliminary work from our lab has demonstrated that performing visuospatial cognitive tasks (e.g. the computer game Tetris) soon after viewing the film reduces the frequency of later analogue flashbacks whereas other (typically verbal) tasks do not (e.g. the computer game Pub Quiz; Holmes, James, Kilford, & Deeprose, 2010). Using the same negative film paradigm, we propose to further examine how best to modify analogue flashback memories using simple cognitive tasks (such as Tetris), and to use neuroimaging to investigate the neural correlates involved in the formation and involuntary recall of flashbacks.

Key questions that we wish to address in a series of experiments using the negative film paradigm are:

- As it is unrealistic for people to engage in a cognitive task during or immediately after negative stimuli, what is the time window in which such task (such as Tetris) is able to reduce later flashback frequency?
- Can we lengthen the time window by "reactivating" the memory, placing the memory into a labile state susceptible for disruption through cognitive tasks? If we can, what kind of cognitive memory reactivation task is most effective in rendering memory into a labile state?
- Which aspects of Tetris are responsible for its beneficial effects on flashbacks? Is it the task's visuospatial nature or other qualities of Tetris?
- Can we develop a cognitive procedure that reduces flashbacks following analogue trauma without compromising memory for facts and events about the analogue trauma?
- What neural substrates are involved in flashbacks formation and their involuntary recall? How are flashback memories different to normal memories that do not return involuntarily?
- In terms of brain systems, why would a cognitive task such as Tetris work? What is the brain system involved in Tetris relative to other tasks? Could understanding the neural mechanisms of these tasks enable us to understand which elements of the memory-related and imagery-related circuitry need to be activated to promote flashback reduction?

Question 8: Who is funding the costs of the study?

Notes: Give the name and address of funding bodies or other sponsorship (other than the University of Cambridge) involved in providing resources for the study.

Medical Research Council

Question 9: Describe the methods and procedures of the study

Notes: Attach any relevant material (questionnaires, supporting information etc.) as appendices and summarise them briefly here (e.g. Cognitive Failures Questionnaire: a standardised self-report measure on the frequency of everyday cognitive slips). Do not merely list the names of measures and/or their acronyms. Include information about any interventions, interview schedules, duration, order and frequency of assessments. It should be clear exactly what will happen to participants.

Previous work from our lab (James et al., 2015) has shown that visuospatial cognitive tasks (e.g. the computer game Tetris) presented soon after participants view the negative film reduces later analogue flashback formation while recognition memory for the film was not affected (Holmes, James, Coode-Bate & Deeprose, 2009; Holmes, James, Kilford & Deeprose, 2010). We would like to further explore whether engaging in a simple cognitive task such as visuospatial Tetris after watching the negative film would have an effect on other forms of memory for the film (e.g. deliberate recall) in addition to reduction in analogue flashbacks.

Experimental procedure

Laboratory studies will be conducted using the negative film paradigm as an analogue of real-life trauma (see Appendix 1 for procedural details of the widely used negative film paradigm, adapted from Holmes & Bourne, 2008). Participants will view a film with distressing content. The content is taken from footages such as those widely available to the public (e.g. car crash seatbelt safety films) and approved in previous ethics applications at Oxford University (e.g. Holmes & James MSD/IDREC/C1/2010/104; Holmes, Bourne, Zhang, Deeprose MSD/IDREC/2006/18).

Behavioural approach

Participants come into the laboratory and they give written informed consent after being taken through the procedure; the nature of the film clips is described to them. Afterwards, they fill out baseline measures (see examples below) followed by watching the film. Following a break, participants perform simple cognitive tasks, such as visuospatial Tetris, or they do nothing and sit quietly to act as a control group. This would allow us to compare the effect of different cognitive tasks on memory for the film.

As in our previous experiments, participants will then be asked to keep a diary in everyday life to monitor any flashbacks to the film. Participants will return at one week for a follow up session in which they will complete measures (see examples below) and a battery of memory tests of both involuntary (unintended recall of the film) versus voluntary memory (deliberate recall of the film). These memory tests will involve the presentation of emotional material, such as stills from the film. Involuntary memory tasks will assess memory without explicitly asking participants to recall the film (e.g. "can you identify what is happening in the scene"?) whist voluntary memory tasks will directly instruct them to refer to the film (e.g. do you recognise this picture as belonging to the film you watched a week ago?"). Responses will either be spoken or manual, record via microphone, keyboard (computer) or using pen and paper.

Participants will undergo the experiment either individually or in a small group. Behavioural experiments using the film paradigm typically last between 60 to 90 minutes for each session.

Subsequent behavioural experiments

A series of behavioural experiments will aim to replicate the same paradigm with minor changes between them taking place. Our overall aim is to optimise conditions to reduce analogue flashbacks.

(1) We aim to vary the timing between film watching and engaging in a cognitive task

Participants would perform simple cognitive tasks such as Tetris following different time intervals after watching the film. Clinically it can be difficult to reach people so soon after a traumatic event. Therefore, it would be a great translational advantage if we could extend the post-film time window to test at which time window memory is still malleable.

One way in which we will manipulate this variable is by asking participants across conditions to play Tetris after different time intervals of film-watching. We aim to vary such interval from minutes, to hours, days or even weeks post-film viewing. This means the whole experiment may consist of more than two experimental sessions: e.g. participant would watch the film on session 1 and leave; they would return for session 2 (e.g. 24 hours later) for the cognitive task intervention and leave again; they return again on another day for session 3 (e.g. one week from the initial session) to hand in the intrusion diary and perform other tasks (e.g. memory tests).

(2) We aim to vary the nature of the memory reactivation task

Our pilot work indicates that 24 hours after viewing a negative film, participants benefited from playing a visuospatial task in relation to reduced flashbacks only if the task was followed by a memory reactivation cue (e.g. film stills from the movie). We aim to further understand whether by varying the nature of the reactivation task we could render certain aspects of the memory more malleable for disruption than others. For example, we seek to vary the specificity of the reactivation by comparing reminders that pinpoint those particular moments within the film that become flashbacks versus more general and contextual reminders.

Following film watching, we would present participants across conditions with different types of memory reactivation tasks before they engage in a cognitive task such as Tetris.

(3) We aim to match other tasks to visuospatial tasks such as Tetris on varying dimensions

While playing visuospatial tasks such as Tetris post-film has shown to reduce flashbacks to the film, we do not fully understand whether the effect is due to them being visuospatial or due to other factors. For instance, the Tetris game is also an adaptive (difficulty increases according to the participants' performance) and cognitively demanding task. By carefully matching different tasks we would be able to understand what the critical features of a task are that provide the beneficial effects on flashbacks reduction.

Following film watching, participants across conditions would engage in cognitive tasks of varying nature.

(4) We aim to assess memory for the film at different time points

The effects on memory may vary depending on when memory is tested. We would like to deliver the battery of memory tests described above at different time intervals, such as within the first experimental session (therefore an experimental session may take up to 3 hours). When a follow-up session is not needed, participants would return the diary booklet by post instead.

(5) We aim to assess the impact of cognitive tasks such as Tetris when performed in other platforms

Most of our studies ask participants to perform cognitive tasks when presented on a computer screen. We aim to test whether the beneficial impact of such tasks translate to other media platforms, such as participants' own devices.

Subsequent experiments using neuroimaging

In terms of brain systems, why would visuospatial tasks such as Tetris work? We also aim to perform fMRI experiments with healthy volunteers using the same film paradigm, i.e. participants would watch the film and perform cognitive tasks such as Tetris following film watching (including rest periods both before and after such active tasks, e.g. 10-30 minutes) while they are in the scanner. Similarly, in the follow up session, they would perform the battery of memory tests as described above while being scanned. Experiments combining the negative film paradigm with neuroimaging techniques (e.g., Bourne, Mackay & Holmes, 2013) have been approved in previous ethics applications (e.g. NHS ethics; Holmes, Mackay, Bourne 07/H0605/127; Oxford University ethics: MSD/IDREC/C1/2012/31).

Conducting the same film paradigm (across testing sessions on multiple days) while performing fMRI would allow us to understand (1) what is the neural signature for those scenes of the film that flashed back versus those that are equally emotional but did not flash back for a particular individual; (2) if we compare the brain systems involved in playing visuospatial tasks such as Tetris versus a control condition, we would understand which elements of the memory-related and imagery-related circuitry need to be activated to promote flashback reduction; (3) and we would understand how these brain systems are implicated when participants recall information from the film.

Before neuroimaging experiments take place, the design, methods, and scientific merit are reviewed at a public meeting where feedback is provided from the Cambridge neuroimaging community. Following this, a formal proposal is evaluated by the Cognition and Brain Sciences Imaging Management Committee, comprised of Cambridge researchers with extensive experience and expertise in functional brain imaging. Formal approval from the committee is required prior to scanning.

Examples of self-reported measures that participants will complete in the experiment (see Appendix 2):

Spontaneous use of imagery scale: A trait measure of an individuals' tendency to engage in spontaneous mental imagery in their day-to-day lives.
Proneness to Intrusive Cognitions Scale: A self-reported rating of how prone participants are to experiencing intrusive cognitions.
Blood phobia: A measure that requires participants to 'indicate if you consider yourself particularly fearful of blood, injury, injections'.
Personal Relevance of Car Crashes: A self-reported measure of how relevant car crashes are in participants' personal history.
Proneness to fainting: A self-reported rating from 1 to 10 on how likely participants are to experience fainting in their day to day life.
Visual Analogue Scale for Mood and Distress Ratings: Pre and post film mood and film distress ratings (e.g. sad, hopeless, depressed, angry, happy) using visual analogue scales.
Film manipulation checks: Ratings of how much attention was paid to the film; how distressing and relevant the film was found.
Impact of Event Scale- Revised: Measures of the impact of the film on participant's lives for a week
Beck Depression Inventory-II (BDI-II): A widely used 21-item self-report measure of depressive symptoms.
State Trait Anxiety Inventory – Trait Version: A measure of trait anxiety.
Traumatic Experience Questionnaire (TEQ): a commonly used self-reported checklist of whether participants have experienced or witnessed a series of traumatic events.

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Holmes, E.A., James, E.L., Kilford E.J., & Deeprose, C. (2010). Key steps in developing a cognitive vaccine against traumatic flashbacks: visuospatial Tetris versus verbal Pub Quiz. *PLoS ONE, 5(11),* e13706. Doi:10.1371/journal.pone.0013706

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National Institute for Health and Clinical Excellence. (2005). *Post-traumatic stress disorder (PTSD): the management of PTSD in adults and children in primary and secondary care.* London National Institute for Health and Clinical Excellence. CG026.

Question 10: What ethical issues does this study raise and what measures have been taken to address them?

Notes: Describe any discomfort or inconvenience that participants may experience. Include information about procedures that for some people could be physically stressful or might impinge on the safety of participants, e.g. noise levels, visual stimuli, equipment; or that for some people could be psychologically stressful, e.g. mood induction procedures, tasks with high failure rate. Indicate what procedures are in place if clinically relevant information arises from the study (e.g. from brain scans or questionnaire responses that might indicate that a participant is at risk).

The main ethical concern relating to film viewing is the potential distress to be caused by the film content:

- The negative film has been shown to induce a transient drop in mood.
- The film also causes analogue flashbacks memories of the film which decrease in frequency over the week. No long- term distress has been reported to date.

A possible inconvenience for participants is that they are required to keep a flashback diary for a week. In our studies carried out so far, they have been happy to do so and to bring it back in the follow up session.

The principal researcher (Emily Holmes) and her research group have extensive experience in conducting experiments using the negative film paradigm. The following measures will be taken to prepare for and support any individual who may experience an adverse reaction:

a. The negative film (e.g. clips of surgical procedures, drink driving adverts, news footage of distressing events) has been used in multiple studies, including recently in an fMRI scanner. Although the film content has been selected to be capable of producing analogue flashbacks, they are taken from footages such as those available from the public domain or designed to help in training emergency workers. These film clips have been approved by both Oxford University ethics (e.g. Holmes & James MSD/IDREC/C1/2010/104; Holmes, Bourne, Zhang, Deeprose MSD/IDREC/2006/18) and NHS ethics (Holmes, Mackay, Bourne 07/H0605/127);
b. All participants will be informed of the distressing nature of the film and the requirement to keep a diary for a week in advance at initial contact, again on the information sheets and before film viewing;
c. Participants will be told that they have the right to terminate film viewing or withdraw from the experiment at any point without explanation or further obligation;
d. The effect of the film viewing on mood and anxiety will be monitored both immediately post-film and at the follow-up session and a researcher is available throughout the experimental procedure.
e. In the unlikely event that a participant becomes distressed and/or is struggling to return to a normal mood after viewing the negative film, the following distress protocol would be followed:
   1) Stop them from doing the activity that is causing distress. i.e., they would stop watching the film.
   2) Offer them a drink (e.g. water or tea) and listen if they wish to talk about their feelings, but do not pressure them to talk;
   3) Offer them the choice of taking a taxi home free of charge;
   4) Offer them a follow-up phone call the next day to check in if necessary;
   5) Ensure they have the details of sources of support.
f. Participants will be informed that they may contact the researchers at any time if they feel unduly distressed (even after the follow-up session).

g. A clinically-qualified member of staff from the team will be available for consultation if any clinical matters arise at any stage in the experimental process (e.g., Emily Holmes – Clinical Psychologist; Simon Blackwell – Clinical Psychologist; Martina Di Simplicio – Psychiatrist). Our research team has written protocols in place to deal with possible risk concerns.
   i. In the case in which participants score 2 or more on the suicidality item of the BDI-II or a total score in the moderately severe to severe range, the researcher will contact an available clinician who will review the questionnaire and talk to the participant to perform a risk assessment. If risk concerns are identified, the clinician would encourage them to contact sources of the support such as their GP, or contact their GP themselves with the participant's consent. The similar procedure would be followed if the TEQ flags up potential issues in relation to ongoing abuse of threat of abuse. If so, a clinician in the team will discuss it with the participant and with their consent, contact the relevant authorities.
   ii. If the clinician judges there to be imminent and high risk to self or other, but the participant does not consent to the relevant authority/healthcare professional being contacted, the clinician would discuss it with other senior colleagues in the team prior to making a decision as to whether it is necessary to break confidentiality.

An additional ethical concern relates to participants returning the diary by post rather than in person. In earlier experiments, participants would return the diary by coming to a follow-up experimental session, at the end of which they would receive further information about the study. In the new studies, participants would be explained that upon receipt of the diary via post by the researcher, they would be sent an email along with confirmation of payment by bank transfer and further information about the study. In addition:

- At the end of the experimental session, participants would be offered the option to schedule a call to discuss the study.
- Participants would also be able to contact the researchers with any questions or concerns they may have, e.g. to schedule a call to discuss the study if they initially did not choose to do so.
- Appendix 9 has been added with an example email sent after receipt of the diary.

Additional consideration for MRI studies:

1. MRI is generally thought to be a safe, non-invasive imaging technique, and there are no known risks or side effects. The scanner can be loud, so participants will be given headphones and earplugs to reduce noise to a comfortable level. As the MR environment is quite confined, people who are uncomfortable in small or confined spaces may not wish to participate. This information will be conveyed to participants when they are contacted to participate in the study.
2. There is a possibility that the combination of fMRI and trauma film might increase stress levels. However, this has been done previously and no adverse effects have been reported (Bourne, Mackay & Holmes 2013; Clark, Holmes, Mackay, in prep). All participants will have an alarm trigger that they can press at any time during the scanning. If pressed, the film will be stopped, replaced with a blank screen and they will be withdrawn from the scanner as quickly as possible.

Question 11: Who will the participants be?

Notes: Describe the groups of participants that will be recruited and the principal eligibility criteria and ineligibility criteria. Make clear how many participants you plan to recruit into the study in total.

Participants will be healthy volunteers, male and female, from 18 years upwards, recruited from the local community. Participants will be ineligible if they have previously taken part in an experiment using the same stimuli, or if they are not fluent in both verbal and written English. Participants will be informed of the inclusion and exclusion criteria at initial contact and on the participant information sheet, given before arrival in the laboratory.

Additional ineligibility criteria for imaging studies if any of the following applies: contraindications to MRI scanning (including but not limited to a history of claustrophobia, certain metallic implants and metallic injury to eye); history of neurological or psychiatric illness; epilepsy; pregnancy.

We determine sample sizes based on formal power calculations. A power analysis based on our previous work (Expt. 1; Holmes et al., 2010) revealed that with a medium effect size when comparing visuospatial tasks Tetris and a control condition (d = 0.75); this means that to replicate this effect with 80% power , 29 participants per each condition will be required. The findings from one particular experiment will inform the sample size required for the subsequent experiment by following this procedure.

Question 12: Describe the recruitment procedures for the study

Notes: Gives details of how potential participants will be identified or recruited. Include all advertising materials (posters, emails, letters etc.) as appendices and refer to them as appropriate. Describe any screening examinations. If it serves to explain the procedures better, include as an appendix a flow chart and refer to it.

Participants will be selected from the MRC CBU volunteer panel (a group of people that have volunteered to take part in psychological research), recruited from University students after consultation with the senior tutor (page 31, CPREC Handbook) or other relevant college liaison; they will also be recruited through advertisement (Appendix 8) in the local community facilities and on the internet. No advertisement will be placed in NHS facilities. All advertising material will state that the study requires the viewing of a negative film.

All fMRI participants will be screened for their fMRI suitability using established questionnaires and guidelines adopted by the MRC Cognition and Brain Sciences Unit (see attached screener in Appendix 3).

Question 13: Describe the procedures to obtain informed consent

Notes: Describe when consent will be obtained. If consent is from ***adult participants****, give details of who will take consent and how it will be done. If you plan to seek informed consent from* ***vulnerable groups*** *(e.g. people with learning difficulties, victims of crime), say how you will ensure that consent is voluntary and fully informed.*

If you are recruiting ***children or young adults*** *(aged under 18 years) specify the age-range of participants and describe the arrangements for seeking informed consent from a person with parental responsibility. If you intend to provide children under 16 with information about the study and seek agreement, outline how this process will vary according to their age and level of understanding.*

How long will you allow potential participants to decide whether or not to take part? What arrangements have been made for people who might not adequately understand verbal explanations or written information given in English, or who have special communication needs?

If you are not obtaining consent, explain why not.

Informed consent will be obtained at the start of the experimental procedure. Participants will receive the information sheet for the experiment before attending the session in the laboratory (a generic information sheet is in Appendix 4 for behavioural studies and a generic letter to volunteers is in Appendix 5 for neuroimaging studies). In addition, the experimenters conducting the study will go through the participant information sheet at the start of the experiment and answer any questions before participants are asked to sign an informed consent form (Appendix 6). A volunteer consent form specific to MRI studies is also attached (Appendix 7)

All participants will receive the participant information sheet on initial contact. Participants will be asked to read the information sheet in their own time and to contact the experimenter to arrange a time if they wish to take part in the experiment.

Question 14: Will consent be written?

☒ Yes
☐ No

*Notes: If **yes**, include a consent form as an appendix. If **no**, describe and justify an alternative procedure (verbal, electronic etc.) in the space below.*

Guidance on how to draft Participant Information sheet and Consent form can be found on the Psychology Research Ethics Committee website.

The investigators will verbally review the information form with the volunteer and address any concerns/questions. Consent will be given by the signature of the participant on the appropriate form.

Question 15: What will participants be told about the study? Will any information on procedures or the purpose of study be withheld?

Notes: Include an Information Sheet that sets out the purpose of the study and what will be required of the participant as appendices and refer to it as appropriate. If any information is to be withheld, justify this decision. More than one Information Sheet may be necessary.

Participants will be told at the recruitment stage that the experiment will involve watching negative footage that could potentially be stressful. They will be told that the purpose of the study is to understand people's responses to negative material, which has implications for therapy approaches. At the end of the experiment participants will be debriefed.

Additionally, for MRI experiments, participants will be informed about all scanning procedures beforehand. They will receive detailed information about the tasks they are asked to perform and about the approximate duration of the experiment. People who are unable to understand relevant explanations about the procedure will not be eligible to take part.

Question 16: Will personally identifiable information be made available beyond the research team?

Notes: If so, indicate to whom and describe how consent will be obtained.

No

Question 17: What payments, expenses or other benefits and inducements will participants receive?

Notes: Give details. If it is monetary say how much, how it will be paid and on what basis is the amount determined.

Participants will receive reimbursement for their time and expenses in line with the MRC CBU participant panel payment guidelines: £6 per hour for behavioural experiments and £2.50 travel expenses if within the city boundary or £3.00 if from outside.

When subjects participate in a MRI experiments they will receive £20 per hour plus travel expenses.

Question 18: At the end of the study, what will participants be told about the investigation?

Notes: Give details of debriefings, ways of alleviating any distress that might be caused by the study and ways of dealing with any clinical problem that may arise relating to the focus of the study.

All participants will receive standardised debriefing information at the end of the final session. As noted above, contact details will be provided for an experienced clinical psychologist (Emily Holmes) and participants will be encouraged to contact the researchers at any time during the experiment or afterwards if they feel unduly distressed to provide adequate support. Availability of such support has been provided in previous similar studies and it is reassuring that to date participants have not felt the need to request such support.

It will be pointed out (as is done before the study) that this is basic research without any direct clinical implications. If a brain abnormality is detected by a trained radiographer the participant's GP will be contacted, unless the participant has previously declined to give consent.

The projects will also be monitored by Emily Holmes through regular formal reviews of study progress (e.g. number of participants recruited) and scheduled weekly team meetings. Informal discussions will take place between members of the research team on a daily basis during recruitment and testing periods to ensure that each study session runs smoothly and that any issue can be immediately addressed.

Question 19: Has the person carrying out the study had previous experience of the procedures? If not, who will supervise that person?

Notes: Say who will be undertaking the procedures involved and what training and/or experience they have. If supervision is necessary, indicate who will provide it.

Ian Clark and Ella James have previously conducted similar behavioural experiments using the negative film paradigm at Oxford University. Ian Clark has run experiments combining the negative film paradigm with neuroimaging techniques. Both of them will train the remaining applicants in the experimental procedures. Emily Holmes and Laura Hoppitt will provide supervision for the procedure and any concerns raised by participants. Emily Holmes is a clinical research psychologist who has developed an extensive research programme using the same paradigm. Laura Hoppitt has conducted behavioural experiments involving the presentation of negative films and cognitive testing for over a decade.

The scanning will be carried out by qualified professional radiographers at the MRC CBU. All experimenters will have attended an MRI Safety Course at the MRC CBU and passed a written test. Richard Henson has extensive experience in neuroimaging and will be directly supervising the students.

Question 20: What arrangements are there for insurance and/or indemnity to meet the potential legal liability for harm to participants arising from the conduct of the study?

Notes: Public indemnity insurance would normally be provided by the University's or Medical Research Council's insurance for persons employed by them or working in their institutions. If you do not have an appropriate institutional affiliation, say how you will provide public indemnity insurance, including insurance against non-negligent injury to participants.

Public indemnity insurance is provided by the Medical Research Council.

Question 21: What arrangements are there for data security during and after the study?

Notes: Digital data stored on a computer requires compliance with the Data Protection Act; indicate if you have discussed this with your Departmental Data Protection Officer and describe any special circumstances that have been identified from that discussion. Say who will have access to participants' personal data during the study and for how long personal data will be stored or accessed after the study has ended.

Digital data will be stored in compliance with the Data Protection Act, as set out by MRC CBU procedures. All data will be anonymised on entry. Anonymised data will be kept for 10 years post study completion.

Signatures of the study team (including date)

Notes: The primary applicant and all co-applicants must sign and date the form. Scanned or electronic signatures are acceptable.

Emily Holmes, 02/12/13

Ella James, 02/12/13

Rik Henson, 02/12/13

Heather Mitchell, 02/12/13

Simon Blackwell, 02/12/13

Julie Ji, 02/12/13

Martina Di Simplicio, 02/12/13

Alex Lau Zhu, 02/12/13

Lalitha Iyadurai, 03/06/15

Fritz Renner, 03/06/15

Elze Landkroon, 17.3. 2016

Appendix 2.2: Experimental protocol for Experiment 1

EXPERIMENT 1: Reactivation+Tetris versus Reaction+No-Tetris & New battery of memory tests (Diary, Recognition, Free recall and Priming)

Based on Ella 2010's study

<u>Changes to previous protocol</u>

- Timing between film and Tetris is 30 minutes.
- Participants are tested individually (they could be stacked).
- Two conditions are being compared: Tetris vs. Control (both preceded by a reactivation task)
- The trauma film lasts 12 minutes.
- New memory tests have been introduced (free recall, priming and recognition). The visual recognition test is also different as it has more trials and uses different film stills and foils.
- Diary checking has become the last part of the follow-up session, which is still done individually.
- Participants will not do concurrent intrusion monitoring while playing Tetris or in control. This is to rule out confound of duel task vs. single task in this design.
- Participants will not perform the intrusion provocation task.

<u>Before starting to test</u>

1) Warm up the room!

<u>Before session 1</u>

Have computers set up ready

- Equipment: (Headphones and pens for each participant; stopwatch).
- Encyclopaedia for manual research task should be ready, with both sets of questions inside the hardcover.
- Relevant files at top right of desktop (Tetris, E-Prime for session 1, Matlab for session 2)
- Ensure desktop is as clean as possible. Desktop background to be of neutral single colour.
- Make sure the Tetris program has sound off as default.
- Password for Tetris: (Username: epact1; password: pubquiz / Username: holmesea; password: windmill)
- Information and consent, demographics
- Baseline measures (BDI, STAI, TEQ, SUIS, VAS [Proneness to Intrusive Cognitions; Personal Relevance Car Crash; Blood Phobia; Proneness to Fainting]).
- Diary and diary checklist

After testing

- Save data

<u>Before session 2</u>

Have computer set up ready

- Equipment: headphones, tape recorder, and pens for each participant; stopwatch)
- Ensure desktop is as clean as possible. Desktop background to be of neutral single colour.
- Matlab program running
- Questionnaires ready: Mood VAS, Demand & Compliance, IES, Behaviour change, Debriefing form, Payment Sheet

After testing

- Save data

SESSION 1

1. **(10-15 MIN) INFORMATION AND CONSENT**

[Meet participant in waiting room, give information sheet, checked for consent]

Good morning/afternoon. Thank you for coming.
□ please read this **information sheet** about what is going to happen today.
□ if you are happy please sign the **Consent Form.**
□ if you would like a copy of the Consent Form please let me know.

[Check participant has provided consent and take them to the lab]

Do you have any questions before we move to the lab?

2. **(5MIN) INTRODUCTION**

Thank you for agreeing to take part in this study. Would you mind turning your mobile phone off and leaving it with me before we start as it may create interference with the sound system – thank you.

[Collect phones and check they're turned off]

First, I will like to start by explaining what is going to happen today. This session will consist of a sequence of different activities. Some of these involve using the computer, others will involve using pen and paper; in some of them I will ask you to put the headphones on. When you have finished a task, just wait patiently until I come back to you and give you further instructions.

[Make sure they all have a pen]

You will be reimbursed for the entire duration of the experiment which will consist of 3 ½ hours; 2 hours today and 1 ½ hours at the same time next week.

3. **(10 MIN) BASELINE QUESTIONNAIRES (BDI, STAI, TEQ, Blood Phobia/PIC/Personal Relevance, SUIS)**

Now I will ask you to take some time to fill in the pack of questionnaires

[Give pack of questionnaire to participant]

Don't think about the answers too much, just respond with the first thing that comes to mind. Make sure you read the instructions for each questionnaire before answering the questions. This will take around 10 minutes and please hand them back to me when you are finished. You may start now.

[During game playing following questionnaires completion, experimenter will check for risk]
[Check blood phobia and fainting question, ask for clarification about their ratings, especially if fainting >7, make sure they have eaten, feel ventilated, and have a glass of water, position comfortably].
[Also check for missing answers. Use highlighter to circle missing question and gently remind participants to complete it at the end of the session.]

4. **(6MIN) TETRIS PRACTICE**

Thank you for completing the questionnaires. Now, you are going to have a three minute practice playing the computer game Tetris which you may have heard of it or played it before.

[Experimenter will open Tetris game]

Now I will first explain how to play this game, please only watch the program and listen to my instructions. You will have time to try the game later on; in the meantime, please do not play at all.

> As you can see, the game consists of 7 different shaped blocks which fall from the top of the screen one at a time.
>
> Each time you fill a whole horizontal line with the blocks, with no gaps, that line will disappear and give you points. The aim is to make as many of these lines disappear as possible before the screen is filled completely.
>
> In this particular game **I want you to focus on the three blocks that will be falling immediately after the one being played on the right of the screen.**
>
> **Try and work out in your mind's eye where best to place and rotate these blocks in order to make the most complete lines and get the best score.**
>
> Blocks are moved using the 4 arrow keys.
> Left and right cursor keys are used to move to the left and right;
> Up cursor key is used to rotate the block by 90 degrees clockwise every time you press it;
> Down cursor key is used to speed up the block if you are confident that you have the block at the desired rotation and position.

Do you have any questions?

[Check they had understood the instructions]
[Restart the game for participants by pressing ESCAPE]

Now I would restart the game for you. If you finish a game before time is up, please just restart again and continue playing. You will now have 3 minutes to play and try out Tetris with the instructions that I explained. Ok now press on the 'Restart' button.

[Start stopwatch for 3 minutes. check participant is following with instructions/ not struggling]

5. (1MIN) PRE-FILM MOOD RATINGS

[Close the game for the participant]

Please take some time to fill in a short questionnaire I will hand you now (pre-film mood).

6. (12 MIN) TRAUMA FILM VIEWING

Thanks for playing the game before, now we will move on to something totally different. Do feel free to stretch or stand up, cause the important part of the experiment is about to start. Now you will now see a short film of about 12 minutes.

[Look in participants' eye, check headphones on, sit on their level]

> Please sit still and pay close attention to the film. You will be asked questions about it later.
>
> **I don't want you to watch the film like you normally would. I want you to try and imagine you are there at the scene watching the events unfold in front of your eyes as if you were a REAL bystander, really there immersed and involved.**
>
> **Please pay attention to the film and try not to look away or shut your eyes.**

Check participants' understanding:

[it's very important that you watch the film following these instructions]
[ask participant to summarise back: "do you mind summarising what I just explained"?]
[give them opportunity to ask for questions: "do you have any questions for me before we start?"]
[check for verbal and non-verbal consent]
[if show hesitation: you seem uncertain, what part of my instructions would be the hardest to follow?]

I will also turn off the lights while you watch the film. You may start now.

[Open program and start the film.]
[Experimenter waits outside. Make sure you outside the cubicles/inside the room in case there are any problems].
[DO NOT ask participants about the film or engage with them about the film. Go straight to the next section].
[Turn lights on. Open the door].
[When participant finishes with the film]

Please take some time to fill in a short questionnaire I will hand you no (post-film mood).

7. (30 MIN) FILLER TASKS

Now I am going to ask you to do some tasks for me. In a first task, you will have to answer some questions using the manual provided. The instructions on how to use the manual would be all explained in detail on screen. Please make sure you read all instructions thoroughly before you start the task. I will be back in 10 minutes. You may start now.

[Start timer - do not stop; let it run until 30 minutes]
[After 10 minutes, pick manual task sheet, give music sheet; say:]

10 minutes are up. Now you will move on to another task in which you will listen to some songs and asked to rate how pleasant you find them. This will take around 10 minutes. I will be back after that. You may start now.

[Pick music sheet, give manual task back, and say:]

Now please return to the manual task you were doing beforehand for further 10 minutes. I will be back after that time.

[Press w]

8. (12 MIN) EXPERIMENTAL ALLOCATION

[Screen should ask participant to wait for further instructions]

Please could you close the manual and put aside all the materials and questionnaires inside the manual.

REACTIVATION

Now you will see a selection of pictures from the film you watched earlier. During this time, I want you to sit still and pay close attention to the pictures until further instructions.

[Press S for start the reactivation task]
[Determine if this is Tetris or Control condition]

Tetris

I would like you to play Tetris game that you practised earlier. I would like to emphasise that it is not important the score that you get, but to enjoy yourselves and keep trying all the way through. Do not forget to try and manipulate the blocks to form the most complete lines, and pay attention to the blocks coming up next on the right of the screen, and how they might be rotated to fit best.

[Open Tetris for participant and wait until it loads]

This time you will have 10 minutes to play. You may start now.

Control

There will be now a short break for 10 minutes. During this time please stay seated and do not talk or engage in other tasks, for example using your phone. You can think about anything, with no restrictions during this time. I will let you know when 10 minutes are up so we can move on to the next task. The break starts now.

[Do not interact with participant at all]

9. (1MIN) POST-ALLOCATION MOOD RATIONS

[If Tetris, close the game for them]

Time is up. Please take some time to fill in a short questionnaire I will hand you now (post-film mood).

10. (10 MIN) DIARY INSTRUCTION

[Hand in diary]

This is the last stage of our session today.

[Explanation of intrusive image vs. thought:]
[Pace the explanation as this is critical]

> It may be that over the next few days images or thoughts about the film you have just seen will **pop into your mind without you expecting them to.** This is called an intrusion.
>
> What goes through our minds can either take the form of words and phrases ("verbal thoughts"), or mental images.
>
> Although mental images often take the form of pictures in your mind's eye they can also include any of the five senses, so you can imagine sounds too. We are interested in mental images that are sights and sounds of the film.
>
> Mental images can be very clear, but sometimes they can be fuzzy or fragmented; they can also be brief and very fleeting. We are interested in knowing about all these types of images.

The diary is critical for our study and it is important that you understood. Do you have any questions?

Have you had any intrusions since watching the film?

If you forget about what I just explained, this is summarised inside this diary under 'Introduction'.

[Explanation of filling out diary]:

Now we know what mental images are, let's talk about how you would fill out the diary.

So, if you have any intrusions of the film you have just watched over the next week, please record each one as soon as possible in this diary. Keep the diary in your bag or next to your bed, and please start filling it in from right after this session. It's really important that you keep it as accurately as possible.

On page 2 and page 3, fill in one of the little boxes every single time you have an intrusion. I for image, T for thought or IT if it was both. You may have the same one over and over again. That's ok just make a note every time it happens.

On page 2, there is an example box in grey that is at the top right corner. In this example, you can see that the day is divided into three day periods:

In the morning, the person did not experience any intrusion, so they wrote 0 and cross it off.
In the afternoon, the person experienced two intrusive images
In the evening, the person experienced one intrusion which was both an image and a thought at the same time.

Make sure that you have completed each of the three time periods (Morning, Afternoon and Evening/Night) as they occur. If you are unable to complete the diary at the time when you experience an intrusion please make sure you have completed each time period at least once a day.

Next, fill in the details of each intrusion you have had on page 4. Put down the day and time, and whether it was an image, thought or both. We then need to know the content of the intrusion. This can be brief but we need to be able to match any intrusions you have to the film so please be as clear as possible.

There are some examples on page 4. As you can see, the participant recorded an intrusion on (Day 1, 1 pm, it was an intrusive image, a brief description of the content of that intrusion which was 'I saw the scene of two people waiting for their flight', it was triggered by the participant 'opening a passport', and on a scale from 0-10, it caused a distress level of 3).

For every little box you fill in for an intrusion, there should be a matching line describing briefly its content.

If you are unsure of any of the details, please just make a note in the diary anyway and we will go over it with you later when you return.

Day 1 is today, please go back to page 2 and fill in the date for DAY1 which is [DATE OF THE WEEK] XXX. Please also complete the dates for DAY2-7, which should be…Please go to page 7 and write down the time and date of our next session [PROVIDE DATE].

My details are also on the diary – if you have any questions, please get in contact with me. This diary is vital for the study as we won't be able to get any results without it. It is sentential that you return the diary in our session next week.

Remember, if you don't have any intrusions; please still return it as we are interested in those results too.

Do you have any questions?

[Summarising]:

So to summarise:

Mental images can be pictures in your mind but also sounds of the film.
Mental images may be fuzzy, very brief or almost like a flash in your mind's eye.
Even if you have several intrusions that are the same moment of the film, please record each individual one in the diary.
Although brief, make sure that the description of your intrusion can allow me to match it to a specific film clip.

Now please read through this **checklist** that summarises what we just talked about in relation to filling your intrusions about the film in the next week before our follow up session.

[give them the checklist, and make sure they have marked yes on all items, else clarify any questions].

11. (5MIN) DEBRIEF

Thank you very much for coming today. I will see you in our next session next week on XXX at the same time. Please do not discuss today's sessions with anyone.

[Escort each participant out]
[Make notes on lab book]

End of session 1

SESSION 2

1. **(5 MIN) WELCOME BACK**

Welcome back. Today will be the second session of this study. Could I have your diaries back please? Could you please complete a brief questionnaire about your mood right now?

[Participants will fill baseline mood VAS]

Thank you. You will now perform a variety of computer tasks and this would last around 1 hour. Some of these will involve using the tape recorder and the headphones, others will involve looking at pictures and making decisions using keypresses.

[Open Matlab file]

The first task involves you using this tape recorder and recording your own voice while you are speaking out loud. The way in which you would use this tape recorder is explained in detailed on screen; please make sure that you read the instructions thoroughly before you start the task.

2. **(15 MIN) FREE RECALL**
3. **(20 MIN) PRIMING TASK**
4. **(20 MIN) RECOGNITION TASK**
5. **(15 MIN) DIARY CHECKING + QUESTIONNAIRES (demand, compliance, behaviour change, IES)**

I would like you to go through some questionnaires that I will hand in now. For each questionnaire, please read the instructions carefully before you start completing it.

[Give participants questionnaire pack, IES, compliance and demand, behaviour change]

We have come to the last part of our session today. I will now go through the diary you have completed with you.

[Go through diary checking protocol below]

Check diary is completed correctly. Complete any missing information, with the participants help if necessary:

- Is there a description for every single box checked with an intrusion?
    - If not ask participants if they can remember and describe the intrusion that went with the checked box.
    - If they can't remember, make a mark. This will not be included for the analysis as we cannot assure it is an intrusion of the film.

- Are all the intrusion descriptions clear?
    - If they are unclear or you don't recognise them ask for more details until you can identify it with the film sequence.

    - Avoid asking leading questions, and stick to open questions. E.g., can you tell me more? Or if they mention 'car crash': can you tell me more about the car crash?
    - If the intrusion is linkable to a film clip then it cannot be included for analysis.

If an intrusion description is unclear, ask:

- Can you tell me more details about this intrusion?
- What else do you see or hear? (colours, objects, shapes, sounds)
- Any other detail, however fleeting?
- Show stills – is it one of these?

6. (5 MIN) DEBRIEF

[Give debrief sheet to participants]

We have now come to an end of our session today and you have completed this study. Thank you very much for taking part. Please read this debriefing information that lets you know the purpose of today's experiment. If you have any questions then please do ask, I will be happy to answer them. If you have any concerns about having taking part of the experiment, you can contact the principal investigator of this study whose details are on the information sheet. If you are happy with all of the information provided then please sign this form saying you have received the debriefing information. For your reimbursement please fill out this form.

[Ask the participant to sign end of the experiment form and give full payment]
[Make note on lab book]

End of session 2

END OF PROTOCOL

Appendix 2.3: Detailed description of trauma film clips

TOTAL DURATION [12min, 7sec film duration]

Between each clip is a blank, black screen for duration of 3 – 6 sec.

1) ***'It's 30 for a reason'*** (2005): Road safety campaign.
In this television advertisement a young girl is leaning against a tree with blood dripping out of her ear. Her child like voice explains that this is a result of a car hitting her at 40mph as her bones crack back into place and the clip moves backwards in time to just after she was hit.
Complete advert duration: 26sec.
Trauma-film clip duration: 20 sec / 00:00 (start of advert) to 00:20
Link**:** https://www.youtube.com/watch?v=HeUX6LABCEA

2) ***The Big Shave*** (1967). Film/McGraw-Hill Films.
A man is shaving and cutting himself, apparently without noticing, until he is covered in blood.
Complete film duration: 6min.
Trauma-film clip duration: 2min (end of film sequence).
Link**:** https://www.youtube.com/watch?v=AlwOrKsmYUg

3) **DOE: Anti-Drink/Drive [Shame]** (2000). Anti-drink/drive road safety campaign.
This television advertisement shows a car with a drunk driver at the wheel, crashing through a fence sideways after losing control of the vehicle, and thereby rolling over and killing a child playing football in his garden.
Complete advert duration: 1min03sec.
Trauma-film clip duration: 50sec / 00:00 (start of advert) to 00:50
Link**:** http://www.tv-ark.org.uk/mivana/mediaplayer.php?id=af0e8ed6b2b1c9a53d91fce9fe7db506 &media=doeantidrinkdriveshame2000&type=mp4 or http://www2.tv-ark.org.uk/pifs/pifs_a-f.html [then search for 'shame']

4) **Lasik Eye Surgery**. Eye surgery procedure
Video showing an eyeball undergoing the process of Lasik eye surgery. The edited trauma-film clip shows start of the video with 3 rings burned on the eye, followed by eyeball moving (looking down) and then scraping off of the top layer of the eye with a thin metal implement.
Complete surgery clip duration: unknown.
Trauma-film clip duration: 1 min
Link**:** http://www.yourguideto.org.uk/laser-eye-surgery/laser-eye-surgery-video.htm

5) **THINK! No Seatbelt, No Excuse. Always wear a seatbelt.** Road safety campaign.
In this road safety television advertisement a young man and his girlfriend are picked up in a car by some friends. We see that while everybody else has buckled their seatbelt, one boy has not. The car stops to turn right, and is involved in a collision. The result is that the boy's body (who did not wear a seatbelt) causes the death of himself and his two friends, and his collision with his girlfriend causes her brain damage.
Complete advert duration: 1min 12sec.
Trauma-film clip duration: 1min04sec / 00:00 (start of advert) to 01:04
Link: https://www.youtube.com/watch?v=e6Qhmdk4VNs

6) **Ghosts of Rwanda** (2004) Film documentary by Frontline, Australia of the Genocide in Rwanda
Documentary (promotion clip) Duration: 1.06 min
Trauma-film clip duration: 57sec / 00:09 (opening shots of documentary) to 00:57
Link: https://www.youtube.com/watch?v=SVtN99_f4dE

7) **Drink and Drowning 'alcohol and water don't mix'** (1990) Public Information film [BFI]
This television advertisement was shown as a warning against drinking alcohol before going swimming. The advert shows a group of friends chatting on the beach, interspersed with scenes of one of the men drowning after consuming alcohol.
Complete clip duration: 3min20sec.
Trauma-film clip duration: 19sec / 00:37 (from start of film) to 00:56

Link: http://www.tv-ark.org.uk/mivana/mediaplayer.php?id=156af0e6dd10fc66a82fc9bfe1ff9ccb &media=drinkanddrowning1990&type=mp4 or http://www2.tv-ark.org.uk/pifs/pifs_a-f.html [then search for 'drink and drowning']

8) **The Faster the Speed, The Bigger the Mess**. Road safety campaign (from Ireland)
This television advertisement shows a man speeding, overturning and pinning a girl to her dead boyfriend against a wall.
Complete advert duration: 1min.
Trauma-film clip duration: 40sec / 00:00 (from of advert) to 00:40
Link: https://www.youtube.com/watch?v=Lw8GPiiOCpI

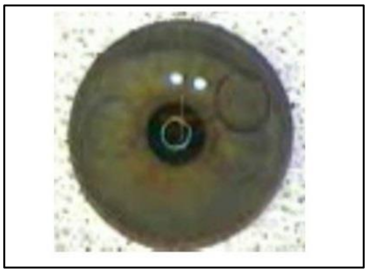
9) **Orthopaedic Management of Compound Wounds** [Online video clip] Originally retrieved October 13th 2006. A Royal College of Surgeons of Edinburgh training video. Film clip and voiceover of a leg wound being cleaned with graphic images of the skin and bone in close up
Video training duration: NA.
Trauma-film clip duration: 1min32sec
Link: This clip is no longer available online. See description provided above to locate a similar substitute clip

10) **DOE: Pay Attention - Texting** (2002). Road safety campaign
In this television road safety advert a teenage boy and girl flirt with each other as they leave school. As he sends a text to her he steps into the road and is hit by a van; the clip shows the impact of the van on the boy and finishes with the girl's face at the funeral.
Advert duration: 41sec.
Trauma-film clip duration: 41sec / 0:00 (start of advert) to 00:41
Link: http://www.tv-ark.org.uk/mivana/mediaplayer.php?id=5a110fe4b6933fc6a9c9af12c631a773 &media=doepayattentiontexting2002&type=mp4 or http://www2.tv-ark.org.uk/pifs/pifs_a-f.html [search for 'Pay Attention']

11) **Circus elephant rampage**.
Shows home video footage of an elephant attacking people at the circus in Hawaii. The elephant tramples on several trainers in a circus tent; it then leaves the tent and rampages down a street.
Clip duration: 3min19sec.
Trauma-film clip duration: 1min39 sec / 0:00 (start of footage) to 1:39
Link: https://www.youtube.com/watch?v=FWURBYDS_1U

Links to UK public information film archives with various different clips that are in the public domain: (some of which have been provided here [e.g., clips 3, 7 and 10]) can be found at the following links:
http://www.nationalarchives.gov.uk/films/
http://www.tv-ark.org.uk

Appendix 2.4: Still pictures used in the reminder cues task across experiments



Appendix 2.5: Self-reported measures used across experiments

Baseline questionnaires

Beck Depression Inventory Second Edition (BDI-II; Beck, Steer, & Brown, 1996) assessed current depressive symptoms using 21 items, each measured on a scale from 0-3. Higher scores indicate higher levels of depression. The BDI-II shows good internal validity (a = .81; Beck, Steer & Garbin, 1988).

State-Trait Anxiety Inventory-Trait version (STAI-T; Spielberger, C. D., Gorsuch, R. L., Lushene, R., Vagg, P. R., & Jacobs, 1983) measured current trait anxiety using 20 anxiety-related items which participants rate on a 4 point scale - almost never, sometimes, often or almost always. The STAI-T shows good internal validity (a = .90; Speilberger, Reheiser, Owen, & Sydeman, 2004).

Traumatic Experience Questionnaire (TEQ) adapted from the Criterion A list of the Posttraumatic Diagnostic Scale (Foa, 1995), was used to assessed prior trauma history. Participants indicated whether they have experienced or witnessed each of the 12 traumatic events.

Spontaneous Use of Imagery (SUIS; Reisberg, Pearson, & Kosslyn, 2003) measured trait tendency to engage in one's day-to-day life using 12 items, each measured on a 5 point scale from never to always. The SUIS shows excellent internal consistency (a = .98; Reisberg et al., 2003).

Impact of Event Scale-Revised (IES-R; Weiss & Marmer, 1997) was completed to assess PTSD symptomatology one-week after film viewing. Each of the 24 items were rated on a 5-point scale.

Mood and distress ratings

Mood pre- and post- film. Visual analogue scales (VAS) were used to assess negative mood (sadness, depression and hopelessness), anchored from 0 (not at all) to 10 (extremely). Participants were instructed to rate according to their feelings ' at the moment'.

Film distress. Participants indicated the degree to which they felt distressed following film viewing using a single anchored by 0 (not at all) and 10 (extremely).

Manipulation checks

Film relevance. Participants rated the relevant they found the film using a 11-point scale ranging from 0 (not at all) to 10 (extremely).

Film attention. Participants were asked 'how much attention did you pay to the film you just watched' using a 11-point scale ranging from 0 (not at all) to 10 (extremely).

Demand ratings. Participants rated the extent to which they predicted that Tetris-playing may reduce intrusive images to the film using a single VAS scale, which ranged from -10 (extreme decrease), to 0 (no impact) to 10 (extreme increase).

Diary accuracy. Participants rated the extent to which they thought they had accurately completed the diary using a single VAS scale, which ranged from 1 (not at all accurate) to 10 (extremely accurate).

Appendix 2.6: Filler tasks used in the 30-min break across experiments

Music filler task

Participants listened to classical music excerpts and rated them on a Likert-scale from 1 'not at all pleasant' to 9 'extremely pleasant' (as used in Holmes et al., 2009, 2010; Deeprose et al., 2012; James et al., 2015). The music was played using E-Prime 2.0 and via headphones. The duration of this filler task was 10 min.

Knowledge search task

Participants were presented with a list of questions which they had to search the answer for using the encyclopaedia *Enquire Within Upon Everything* (Bremner, 1988). They were told they could answer the questions in any other they wished. This task was performed twice with each lasting 10 min.

Appendix 2.7: Baseline, mood and compliance measures for Experiment 1

Baseline, Task Manipulation and Compliance Measures for each Experimental Condition in Experiment 1

	Interference (n = 23)		No-interference (n = 23)		Independent group comparisons		
	n		n		χ^2	df	p
Gender (females)	15		13		0.37	1	.763
	M	SD	M	SD	t	df	p
Age	27.39	6.87	27.91	7.17	0.25	44	.802
BDI-II	6.61	6.51	8.26	6.40	0.87	44	.390
STAI-T	37.87	8.69	38.96	9.83	0.40	44	.693
TEQ	1.61	1.73	1.48	1.38	0.28	44	.778
SUIS	39.74	5.37	39.26	8.98	0.22	44	.827
Attention paid to the film	9.26	1.21	9.43	0.73	0.59	44	.559
Personal relevance of film	3.91	3.25	4.35	2.89	0.48	44	.634
Demand of Tetris playing	- 1.26	3.70	-1.83	3.30	0.55	44	.587
Diary accuracy	8.35	1.97	8.39	1.08	0.09	44	.926

Note. BDI-II = Beck Depression Inventory; STAI-T = State Trait Anxiety Inventory – Trait; TEQ = Traumatic Experience Questionnaire; SUIS = Spontaneous Use of Imagery Scale.

Pre- and Post-Film Negative Mood Scores in Experiment 1

	Interference (n = 23)		No-interference (n = 23)		Repeated-measures ANOVA
	M	SD	M	SD	Group: F(1,44) = 0.13,
Pre-film negative mood	1.38	1.91	2.72	3.93	p = .716.
Post-film negative mood	9.32	7.88	8.96	7.04	Time: F(1,44) = 46.24,
					p < .001.
					G × T: F(1,34) = 0.67,
					p = .419.

Note. Each negative mood is a composite score summing score on three Visual Analogue Scales on sad, depressed and hopeless moods.

Appendix 2.8: Method for norming of still images used in memory measures

Aim

A normative study was conducted to determine the emotionality levels associated with both film and foil stills to inform the development of memory tasks in this thesis using such stills.

Participants

Ten participants from the MRC Cognition & Brain Sciences Unit volunteer panel were recruited.

Apparatus and Stimuli

The full set had 369 still image, half belonging to different scenes of the trauma film and half belong to various foil sources. This stimuli for norming were presented using MATLAB 2009 and Psychtoolbox.

Procedure

The stimuli were presented in two stages. In the first stage, each trial consisted of a central fixation cross followed by the presentation of an image for 500ms only. Participants had to rate them for their instant *impact* on a 9-point rating scale, with 9 representing the highest impact (Ewbank, Barnard, Croucher, Ramponi, & Calder, 2009; Murphy, Hill, Ramponi, Calder, & Barnard, 2010). More specifically, participants were told:

You will be presented with a series of images very briefly. Please consider each picture as a whole. Just judge whether you feel the content of the image created AN INSTANT SENSE OF IMPACT ON YOU PERSONALLY. Try not to think in detail about the picture or its content in terms of particular properties like particular positive or negative feelings it might invoke in you, how distinctive the image is or how many thoughts and ideas it leads to. We just want an estimate of its overall immediate impact, irrespective of what it is that might underlie its impact on you personally (i.e., whether its positive, negative or neither).

Remember, it is your own PERSONAL reaction we are interested in, not how you think people in general should feel. Just glance at the picture and make an instant judgement ratings each picture on a scale from 1 to 9. Where (1) means complete indifference and (9) means an intense impact.

In the second stage, all images were presented again and stayed on screen until participants rated them for arousal, negative and positive valence, also on a 9-point rating scale. The order of these three ratings scales were randomised for each image. The definition of each scale was as follows:

> AROUSAL SCALE: at the higher end of the this scale (9) you feel stimulated, excited, frenzied, jittery, wide-awake, aroused; At the lower extreme of the arousal scale (1) you feel completely calm, relaxed, sluggish, sleepy in response to the picture.

POSITIVE SCALE: at the higher extreme of this scale (9) you feel completely positive, pleased, satisfied, contended, hopeful in response to the picture. At the lower end (1) you do not feel these at all.

NEGATIVE SCALE: at the higher extreme of this scale (9) you feel completely unpositive, annoyed, unsatisfied, melancholic, despaired, bored in response to the picture. At the lower end (1) you do not feel these at all.

Each of these stages were divided into three blocks with self-timed rests in between. The instructions emphasised a personal judgment rather than how people in general would respond to these images. Images within each stage was randomised for each participant.

Scoring

For each still image, and emotionality rating was obtained per participant. Given the interest in emotional processing of negative (traumatic) material for the current thesis, high emotionality was defined as a combination of high impact, high arousal and high negative valence. Thus, the emotionality index was calculated by averaging ratings on impact, arousal, negative valence and the reversed score of positive valence.

Appendix 2.9: Free recall administration and scoring protocols

Self-administered interview protocol for free recall in Experiment 1

Preparation:

- This protocol was presented using MATLAB 2007.
- A tape recorder is needed.
- **BOLD** characters were presented as such to the participants for emphasis.
- The interview protocol has four phases:
    - Explanation of how to use the tape recorder
    - Free recall (adapted from Levine et al 2002)
    - Specific probing (adapted from Levine et al 2002).
    - End of the task

PHASE 1: SETTING UP THE TAPE RECORDER

[Slide 1]

Please look at the tape recorder in your desk.

To help with scoring, we will be audiotaping your responses. Otherwise, your responses will be kept completely confidential and your tape will be assigned a subject number and stored in a secure place.

Press Enter to continue

[Slide 2]

On the left hand side of the tape recorder you can switch it on by pulling the Power on/off button down.

Please pull it down to switch it on.

Press Enter to continue.

[Slide 3]

There is a red button in the tape recorder. When pressed it will start recording.

Press the red button.

You can just leave it at the desk near you.

Press Enter to continue.

PHASE 2: FREE RECALL

[Slide 4]

I am going to ask you to tell me about **all the film clips** that you saw in the session last week. Please respond by speaking out loud naturally and at your normal speed as if you were talking to someone.

You can start with any film clip you wish.

I want you to provide **as much detail** as you can about the film clips. Our interest is in how you describe each of them.

Remember, please provide **as much detail** as you can, including **perceptual** (e.g., objects, colours, sounds) and **emotional** details.

Press ENTER for more instructions

[Slide 5]

You may find it strange to speak out loud by yourself without any feedback.

You can **take as long as you need**. However, the maximum time allocated for this will be 10 minutes. After 10 minutes, this slide will automatically move to the next one.

In case you finish before the allocated 10 minutes, You could press Enter to continue.

Press Enter to start with this task.

[Slide 6]

You may **START NOW** while being recorded. Remember to describe **all the film clips**.

Remember, please provide **as much detail** as you can, including **perceptual** (e.g., objects, colours, sounds) and **emotional** details.

- Please DO NOT PRESS ANY KEY. This slide will skip automatically **after 10 minutes.**
- If you finish before the maximum of 10 minutes, then do press ENTER to proceed.

PHASE 3: SPECIFIC PROBING

[Slide 7]

Please stop speaking. Now we will move on to a new task.

Let's see if this list can trigger any memories for each of the film clips you watched last week.

Each cue will be prompted by a sound. For each cue presented, **read it out loud** and think of the film clip it refers to. For each film, tell me more about it **that you haven't mentioned before.**

You have 2 mins max. allocated for each cue, after which it will skip automatically to the next one. If you finish before the 2 mins, just press Enter to move on to the next slide.

If you cannot recall any further details, just say out loud "I cannot think of anything else" and Press Enter to move on to the next slide.

Please put the headphones on now.

Press Enter for the first cue.

[Slide 8]
Drunk Driver & Boy in a Garden
1. Read it out loud and think of the film clip it refers to.
2. Tell me more about it **that you haven't mentioned before.**
3. Please provide **as much detail** as you can, including **perceptual** (e.g., objects, colours, sounds) and **emotional** details.
When you're done, press ENTER.

[Slide 9]

Elephant
1. Read it out loud and think of the film clip it refers to.
2. Tell me more about it **that you haven't mentioned before.**
3. Please provide **as much detail** as you can, including **perceptual** (e.g., objects, colours, sounds) and **emotional** details.
When you're done, press ENTER.

[Slide 10]
Man Shaving
1. Read it out loud and think of the film clip it refers to.
2. Tell me more about it **that you haven't mentioned before.**
3. Please provide **as much detail** as you can, including **perceptual** (e.g., objects, colours, sounds) and **emotional** details.
When you're done, press ENTER.

[Slide 11]
Africa
1. Read it out loud and think of the film clip it refers to.
2. Tell me more about it **that you haven't mentioned before.**
3. Please provide **as much detail** as you can, including **perceptual** (e.g., objects, colours, sounds) and **emotional** details.
When you're done, press ENTER.

[Slide 12]
Girl Lying in a Road
1. Read it out loud and think of the film clip it refers to.
2. Tell me more about it **that you haven't mentioned before.**
3. Please provide **as much detail** as you can, including **perceptual** (e.g., objects, colours, sounds) and **emotional** details.
When you're done, press ENTER.

[Slide 13]
Texting & Crossing the Road
1. Read it out loud and think of the film clip it refers to.
2. Tell me more about it **that you haven't mentioned before.**
3. Please provide **as much detail** as you can, including **perceptual** (e.g., objects, colours, sounds) and **emotional** details.
When you're done, press ENTER.

[Slide 14]
Drowning
1. Read it out loud and think of the film clip it refers to.
2. Tell me more about it **that you haven't mentioned before.**
3. Please provide **as much detail** as you can, including **perceptual** (e.g., objects, colours, sounds) and **emotional** details.
When you're done, press ENTER.

[Slide 15]
Knee Operation
1. Read it out loud and think of the film clip it refers to.
2. Tell me more about it **that you haven't mentioned before.**
3. Please provide **as much detail** as you can, including **perceptual** (e.g., objects, colours, sounds) and **emotional** details.
When you're done, press ENTER.

[Slide 16]
Friends & No Seatbelt

1. Read it out loud and think of the film clip it refers to.
2. Tell me more about it **that you haven't mentioned before.**
3. Please provide **as much detail** as you can, including **perceptual** (e.g., objects, colours, sounds) and **emotional** details.
When you're done, press ENTER.

[Slide 17]
Eye Surgery
1. Read it out loud and think of the film clip it refers to.
2. Tell me more about it **that you haven't mentioned before.**
3. Please provide **as much detail** as you can, including **perceptual** (e.g., objects, colours, sounds) and **emotional** details.
When you're done, press ENTER.

[Slide 18]
Speeding & Couple Against a Wall
1. Read it out loud and think of the film clip it refers to.
2. Tell me more about it **that you haven't mentioned before.**
3. Please provide **as much detail** as you can, including **perceptual** (e.g., objects, colours, sounds) and **emotional** details.
When you're done, press ENTER.

PHASE 4: END OF THE TASK

[Slide 19]

End! You could take the headphones off.

Now please press the Red button on the tape recorder to stop the recording.

On the left hand side of the tape recorder you can switch it off by pulling the Power on/off button down again.

Please pull it down to switch it off

When you're ready, press Enter to continue

END OF PROTOCOL

Scoring protocol for free recall in Experiment 1

Preparation:

- This protocol was adapted from the Autobiographical Interview by Levine et al (2002) to assess retrieved episodic details for memory for film footage.
- Before scoring, all free recall verbalization must be transcribed.
- A scoring sheet is used to tally the final outcome and is included at the end of the protocol.

Overview

- We consider only quantitative ratings (number of details per category) but not qualitative ratings (subjective ratings of the experimenter) for the present study as the former shows higher inter-rater reliability.

First step: segmenting transcript into constituent details

- A segment, or detail, is an information bit; it is a unique occurrence, observation, fact, statement, or thought. This will usually be a grammatical clause -- a sentence or part of a sentence that independently conveys information (i.e., a subject and a predicate), although a single clause may contain more than one detail. For each clause, consider whether its constituent parts convey additional information. If so, the parts can be separated and scored as separate segments. For example, the statement "he had an old, brown fedora" would receive two perceptual details because the term "old" significantly alters the meaning of the brown fedora, which on its own would receive one detail.

Second step: categorizing details into internal versus external events

- Levine distinguishes between internal and external details in autobiographical memory recall. *Internal details* pertain to the unfolding of the event itself. *External details* pertain to facts or semantic information that is not part and not specific to the main event. Therefore, only internal details will be counted as these directly pertain to the content of the film.

- When in doubt, the rule of thumb is to give 'benefit of the doubt' to those that could be <u>reasonably</u> internal, not just <u>possibly</u>. (Levine doesn't give more explanation on these distinctions).

- Recollected quotes (e.g., "When he saw me he said, 'I can't believe how much weight you lost. You look great!") are generally scored as event details. They are generally not segmented as other text in the protocol because they represent a single event (someone saying something). However, extensive quotes or quotes reflecting discrete recollections may be scored as separate details.

Third step: categorizing internal events further into theoretically interesting subcategories

- Levine further subcategorises internal details into events, time, place, perceptual, and emotion/thought details. We are only interested in three types of information that were theoretically relevant to the present study (event, perceptual and emotion experienced at the time of film viewing). Only one type of external detail, emotion experienced at the time of film recall, were included as these are theoretically relevant to the present study. We did not include thought details when counting emotion details, contrary to Levine.

  a. *Event detail*: it refers to the unfolding of the story. It could include happenings, individuals present (up to 5), and their physical/emotional actions/reactions. E.g., "it was sunny"; "she was scared".
  b. *Perceptual detail*: it includes any olfactory, auditory, tactile, taste, and visual details. It also includes spatial-temporal descriptions. E.g., "there was a <u>blue</u> car".

c. *Emotion details*: it includes emotional states, E.g., "It was horrible". Inferences about others' emotions are considered event details.

- Only accurate details are scored (this applies to event and perceptual details only as emotional details are subjective reports). There is no guideline on accuracy as AI has only been used on autobiographical memories reported by the subject. Accuracy becomes extremely relevant to assess retrieval of film content. When assessing accuracy, room will be given for ambiguous interpretation of events and objects. When in doubt, discrepancies between raters will be resolved by looking back to the film and reaching and agreed decision.

  a. During Free Recall phase, as long as a detail mentioned belongs to any part of the film, it will be scored as accurate.
  b. During Specific Probing, details will be scored only if they are accurate and belong to the specific film clip being probed.

- When several possible outcomes are mentioned for one particular detail (e.g., this shirt was green or blue or black), it will be scored as an accurate detail as long as one of the options are 'reasonably' accurate.

- For emotional details, the rule of thumb is that different words represent different emotions. The same word can also be used to describe different emotions as long as they are associated to different events or moments of a film. (Be more liberal when scoring emotional details as the same emotion can be experienced during different moments of film watching or different underlying emotions may be expressed using the same word).

- One detail cannot be classified in two categories. Priorities are given to the more specific category (i.e., between event or perceptual detail, perceptual category should be chosen). While Levine differentiates between objects that are part of the unfolding of an event as 'event' details, while objects that are part of the landscape as 'perceptual' details, we count both as perceptual as these are directly relevant to our theoretical interest.

- Score as a separate detail when it significantly alters the meaning.

- Do not give information that is not there, even if implied. Only score of detail is mentioned.

- Negative events, absences/failures to do something are still scoreable, as they reject subject's recollection.

- Allowances may be made for individual differences in discourse style. For example, if a subject repeatedly uses the word "nice", perceptual details would not be scored for every use of this word (as in Levine).

- "Many scoring decisions are judgement calls. Scorers will be somewhat influenced by their own knowledge and experience with the subject matter. Score according to your knowledge. If two people could reasonably score a detail more than one way, simply score it the way that seems best rather than agonize over it" (as in Levine).

END OF PROTOCOL

Scoring sheet

Participant Number:												
	1. Drunken driver			2. Elephant			3. Shaving			4. Africa		
	FR	**SP**	**T**	**FR**	**SP**	**T**	**FR**	**SP**	**T**	**FR**	**SP**	**T**
Event detail												
Percept												
Emotion												
internal-encoding												
external-recall												
Total (w emotion)												
Total (w/o emotion)												
	5. Girl Lying Road			6. Texting			7. Drowning			8. Knee Operation		
	FR	**SP**	**T**	**FR**	**SP**	**T**	**FR**	**SP**	**T**	**FR**	**SP**	**T**
Event detail												
Percept												
Emotion												
internal-encoding												
external-recall												
Total (w emotion)												
Total (w/o emotion)												
	9. No Seatbelt			10. Eye Surgery			11. Against Wall			**ENTIRE MOVIE**		
	FR	**SP**	**T**	**FR**	**SP**	**T**	**FR**	**SP**	**T**	**FR**	**SP**	**T**
Event detail												
Percept												
Emotion												
internal-encoding												
external-recall												
Total (w emotion)												
Total (w/o emotion)												
#films recalled in FR												
#films recalled in SP												
times up FR?												
times up SP?												

Note. FR = free recall; SP = specific probing; T= total; w = with; w/o = without.

Appendix 3.1: Experimental protocol for Experiment 2

EXPERIMENT 2: Reactivationn+Tetris versus Reactivation +No-Tetris & + New battery of memory tests (Diary, Recognition, Laboratory-based Intrusions, Attention Bias)

Based on Alex's 2013/4 Exp 1

<u>Changes to previous protocol</u>

- Timing between film and Tetris is 30 minutes.
- Participants are tested individually (they could be stacked).
- Two conditions are being compared: Tetris vs. Control (both preceded by an reactivation task)
- The trauma film lasts 12 minutes.
- New memory tests have been introduced (free recall, priming and recognition). The visual recognition test is also different as it has more trials and uses different film stills and foils.
- Diary checking has become the last part of the follow-up session, which is still done individually.
- Participants will not do concurrent intrusion monitoring while playing Tetris or in control. This is to rule out confound of duel task vs. single task in this design.
- Participants will not perform the intrusion provocation task.

<u>Before starting to test</u>

2) Warm up the room!

<u>Before session 1</u>

Have computers set up ready

- Equipment: (Headphones and pens for each participant; stopwatch).
- Encyclopaedia for manual research task should be ready, with both sets of questions inside the hardcover.
- Relevant files at top right of desktop (Tetris, E-Prime for session 1, Matlab for session 2)
- Ensure desktop is as clean as possible. Desktop background to be of neutral single colour.
- Make sure the Tetris program has sound off as default.
- Password for Tetris: (Username: epact1; password: pubquiz / Username: holmesea; password: windmill)
- Information and consent, demographics
- Baseline measures (BDI, STAI, TEQ, SUIS, VAS [Proneness to Intrusive Cognitions; Personal Relevance Car Crash; Blood Phobia; Proneness to Fainting]).
- Diary and diary checklist

After testing

- Save data

<u>Before session 2</u>

Have computer set up ready

- Equipment: headphones, tape recorder, and pens for each participant; stopwatch)
- Ensure desktop is as clean as possible. Desktop background to be of neutral single colour.
- Matlab program running
- Questionnaires ready: Mood VAS, Demand & Compliance, IES, Behaviour change, Debriefing form, Payment Sheet

After testing

- Save data

SESSION 1

1. **(10-15 MIN) INFORMATION AND CONSENT**

[Meet participant in waiting room, give information sheet, checked for consent]

Good morning/afternoon. Thank you for coming.

□ please read this **information sheet** about what is going to happen today.
□ if you are happy please sign the **Consent Form.**
□ if you would like a copy of the Consent Form please let me know.

[Check participant has provided consent and take them to the lab]

Do you have any questions before we move to the lab?

2. **(5MIN) INTRODUCTION**

Thank you for agreeing to take part in this study. Would you mind turning your mobile phone off and leaving it with me before we start as it may create interference with the sound system – thank you.

[Collect phones and check they're turned off]

First, I will like to start by explaining what is going to happen today. This session will consist of a sequence of different activities. Some of these involve using the computer, others will involve using pen and paper; in some of them I will ask you to put the headphones on. When you have finished a task, just wait patiently until I come back to you and give you further instructions.

[Make sure they all have a pen]

You will be reimbursed for the entire duration of the experiment which will consist of 3 ½ hours; 2 hours today and 1 ½ hours at the same time next week.

3. **(10 MIN) BASELINE QUESTIONNAIRES (BDI, STAI, TEQ, Blood Phobia/PIC/Personal Relevance, SUIS)**

Now I will ask you to take some time to fill in the pack of questionnaires

[Give pack of questionnaire to participant]

Don't think about the answers too much, just respond with the first thing that comes to mind. Make sure you read the instructions for each questionnaire before answering the questions. This will take around 10 minutes and please hand them back to me when you are finished. You may start now.

[During game playing following questionnaires completion, experimenter will check for risk]
[Check blood phobia and faiting question, ask for clarification about their ratings, especially if fainting >7, make sure they have eaten, feel ventilated, and have a glass of water, position comfortably].
[Also check for missing answers. Use highlighter to circle missing question and gently remind participants to complete it at the end of the session.]

4. (6MIN) TETRIS PRACTICE

Thank you for completing the questionnaires. Now, you are going to have a three minute practice playing the computer game Tetris which you may have heard of it or played it before.

[Experimenter will open Tetris game]

Now I will first explain how to play this game, please only watch the program and listen to my instructions. You will have time to try the game later on; in the meantime please do not play at all.

> As you can see, the game consists of 7 different shaped blocks which fall from the top of the screen one at a time.
>
> Each time you fill a whole horizontal line with the blocks, with no gaps, that line will disappear and give you points. The aim is to make as many of these lines disappear as possible before the screen is filled completely.
>
> In this particular game **I want you to focus on the three blocks that will be falling immediately after the one being played on the right of the screen.**
>
> **Try and work out in your mind's eye where best to place and rotate these blocks in order to make the most complete lines and get the best score.**
>
> Blocks are moved using the 4 arrow keys.
> Left and right cursor keys are used to move to the left and right;
> Up cursor key is used to rotate the block by 90 degrees clockwise every time you press it;
> Down cursor key is used to speed up the block if you are confident that you have the block at the desired rotation and position.

Do you have any questions?

[Check they had understood the instructions]
[Restart the game for participants by pressing ESCAPE]

Now I would restart the game for you. If you finish a game before time is up, please just restart again and continue playing. You will now have 3 minutes to play and try out Tetris with the instructions that I explained. Ok now press on the 'Restart' button.

[Start stopwatch for 3 minutes. check participant is following with instructions/not struggling]

5. (1MIN) PRE-FILM MOOD RATINGS

[Close the game for the participant]

Please take some time to fill in a short questionnaire I will hand you now (pre-film mood).

6. (12 MIN) TRAUMA FILM VIEWING

Thanks for playing the game before, now we will move on to something totally different. Do feel free to stretch or stand up, cause the important part of the experiment is about to start. Now you will now see a short film of about 12 minutes.

[Look in participants' eye, check headphones on?, sit on their level]

> Please sit still and pay close attention to the film. You will be asked questions about it later.
>
> **I don't want you to watch the film like you normally would. I want you to try and imagine you are there at the scene watching the events unfold in front of your eyes as if you were a REAL bystander, really there immersed and involved.**
>
> **Please pay attention to the film and try not to look away or shut your eyes.**

Check participants' understanding:
[its very important that you watch the film following these instructions]
[ask participant to summarise back: "do you mind summarising what I just explained"?]
[give them opportunity to ask for questions: "do you have any questions for me before we start?"]
[check for verbal and non-verbal consent]
[if show hesitation: you seem uncertain, what part of my instructions would be the hardest to follow?]

I will also turn off the lights while you watch the film. You may start now.

[Open program and start the film.]
[Experimenter waits outside. Make sure you outside the cubicles/inside the room in case there are any problems].
[DO NOT ask participants about the film or engage with them about the film. Go straight to the next section].
[Turn lights on. Open the door].
[When participant finishes with the film]

Please take some time to fill in a short questionnaire I will hand you no (post-film mood).

7. (30 MIN) FILLER TASKS

Now I am going to ask you to do some tasks for me. In a first task, you will have to answer some questions using the manual provided. The instructions on how to use the manual would be all explained in detail on screen. Please make sure you read all instructions thoroughly before you start the task. I will be back in 10 minutes. You may start now.

[Start timer - do not stop; let it run until 30 minutes]
[After 10 minutes, pick manual task sheet, give music sheet; say:]

10 minutes are up. Now you will move on to another task in which you will listen to some songs and asked to rate how pleasant you find them. This will take around 10 minutes. I will be back after that. You may start now.

[Pick music sheet, give manual task back, and say:]

Now please return to the manual task you were doing beforehand for further 10 minutes. I will be back after that time.

[Press w]

8. (12 MIN) EXPERIMENTAL ALLOCATION

[Screen should ask participant to wait for further instructions]

Please could you close the manual and put aside all the materials and questionnaires inside the manual.

REACTIVATION

Now you will see a selection of pictures from the film you watched earlier. During this time I want you to sit still and pay close attention to the pictures until further instructions.

[Press S for start the reactivation task]
[Determine if this is Tetris or Control condition]

Tetris

I would like you to play Tetris game that you practised earlier. I would like to emphasise that it is not important the score that you get, but to enjoy yourselves and keep trying all the way through. Do not forget to try and manipulate the blocks to form the most complete lines, and pay attention to the blocks coming up next on the right of the screen, and how they might be rotated to fit best.

[Open Tetris for participant and wait until it loads]

This time you will have 10 minutes to play. You may start now.

Control

There will be now a short break for 10 minutes. During this time please stay seated and do not talk or engage in other tasks, for example using your phone. You can think about anything, with no restrictions during this time. I will let you know when 10 minutes are up so we can move on to the next task. The break starts now.

[Do not interact with participant at all

9. (1MIN) POST-ALLOCATION MOOD RATIONS

[If Tetris, close the game for them]

Time is up. Please take some time to fill in a short questionnaire I will hand you now (post-film mood).

10. (20 MIN) LAB MONITORING INSTRUCTIONS

(5min) EXPLAIN PARAMETERS OF EXPERIMENTAL TASK + PRACTICE TRIAL

The next task examines concentration, which requires you to carry out a vigilance task on the computer. In this task, you are going to see the numbers 1 to 9 on the screen, one at a time. Your job is to press the "GO" key as soon as you see a number other than 3, and not press anything when you see the number 3.

At the same time, on some trials you will also see a background image, but you don't have to do anything with these. Just focus on the number task. I will walk you through these so you know what it looks like and how you should do the task.

Do you have any questions?

[Experimenter conducts digit task walkthrough]

(1min) EXPLAIN NATURE OF THOUGHTS DURING TASK

Now, because this task could become quite monotonous, you might find that occasionally your attention might wander off. An mental image from the film may pop into your mind spontaneously, out of the blue. We call this an intrusive image-based memory.

Although imaged-based memories from the film can be extremely vivid and clear, they can also often be quite fuzzy and quite brief, like a quick flash.

We are interested in all kind of intrusive image-based memories from the film only.

Is that clear?

[Check participant understanding, provide further examples if necessary]

Whenever an image-based memory from the film pops up, I would like you to complete one row of this sheet. First you will have to briefly describe the content of the image so we can check it is related to the film. Then, you will have to provide 3 ratings on a 5 point scale. First, how distressing was the image? Second, how vivid was the image? Finally, to what extend did you feel you were seeing the film now?

[Go through example]

Just answer these questions, as best as you can based on your gut feeling, there is no need to overthink your answers. Is that clear?

[Go through example on sheet]

(3min) REPORTING OF INVOLUNTARY THOUGHTS WALKTHROUGH

I want you to press the '2' key every time you notice an intrusive image of the film popping into your mind during the task. The screen will go blank and you will have to write down a few details about the image that you just experienced. Let's walk through an example together.

[Experimenter conducts digit task walkthrough again]

Imagine you have an intrusive image now.

[and demonstrate how to stop ask to report intrusion]
[Go through a pretend intrusion reporting]

Once you have finished reporting the details of the image, then just go back to the task by pressing Return.

[Participant resume practice trials until finished]

You should press the key each time you notice an intrusive image from the film, even if it's the same image you've had before. But if something doesn't come to mind, there's no need to search for anything. Is that clear?

Remember: press the GO key whenever you see a digit, unless it is a 3; stop the task whenever you notice an image from the film popping into your mind spontaneously. Any questions before we start with the task?

[Ensure any questions are fully addressed before moving onto experimental trials]
[When participants finish with the task (5-6 min approx)]

There will now be a short break of 2 minutes where I want you to close your eyes. You can think about anything, with no restrictions. If images from the film happen to spontaneously pop into your mind during this period, I'd like you to make a part on this piece of paper while keeping your eyes closed. Any questions before we start? Please hold this pen. Remember to make a mark whenever an image from the film pops into mind spontaneously. The break starts now.

[Set stopwatch to 2 minutes and start counting down]
[Ask participant to tell you the content of the intrusions and thoughts, distress rating and perspective.]

11. ATTENTION TASK INSTRUCTION (25 MIN)

In this task you will first be presented with a fixation cross in the centre of the screen. This fixation cross will disappear, and a pair of images will be briefly presented. One of the face images will appear just to the left, and the other will appear just to the right, of where the fixation cross was shown.

Immediately after the image pair disappears a small probe will be shown. This probe will be either one or two dots. Your task will be to indicate whether this probe consists of one or two dots. If the probe consists of one dot, then press the '1' button on your number keypad. If the probe consists of two dots, then press the '2' button on your keypad.

<u>Please fixate on the central cross until the dot appears.</u> Then respond as quickly as possible, without undue speed causing you to make avoidable mistakes.

Once you have made your response the screen will be cleared, and the next trial will begin.

12. (10 MIN) DIARY INSTRUCTION

[Hand in diary]

This is the last stage of our session today.

[Explanation of intrusive image vs. thought:]
[Pace the explanation as this is critical]

It may be that over the next few days images or thoughts about the film you have just seen will **pop into your mind without you expecting them to.** This is called an intrusion.

What goes through our minds can either take the form of words and phrases ("verbal thoughts"), or mental images.
Although mental images often take the form of pictures in your mind's eye they can also include any of the five senses, so you can imagine sounds too. We are interested in mental images that are sights and sounds of the film.

Mental images can be very clear, but sometimes they can be fuzzy or fragmented; they can also be brief and very fleeting. We are interested in knowing about all these types of images.

The diary is critical for our study and it is important that you understood. Do you have any questions?

If you forget about what I just explained, this is summarised inside this diary under 'Introduction'.

[Explanation of filling out diary]:

Now we know what mental images are, let's talk about how you would fill out the diary.

So, if you have any intrusions of the film you have just watched over the next week, please record each one as soon as possible in this diary. Keep the diary in your bag or next to your bed, and please start filling it in from right after this session. It's really important that you keep it as accurately as possible.

On page 2 and page 3, fill in one of the little boxes every single time you have an intrusion. I for image, T for thought or IT if it was both. You may have the same one over and over again. That's ok; just make a note every time it happens.

On page 2, there is an example box in grey that is at the top right corner. In this example, you can see that the day is divided into three day periods:

> In the morning, the person did not experience any intrusion, so they wrote 0 and cross it off.
> In the afternoon, the person experienced two intrusive images
> In the evening, the person experienced one intrusion which was both an image and thought at the same time.

Make sure that you have completed each of the three time periods (Morning, Afternoon and Evening/Night) as they occur. If you are unable to complete the diary at the time when you experience an intrusion please make sure you have completed each time period at least once a day.

Next, fill in the details of each intrusion you have had on page 4. Put down the day and time, and whether it was an image, thought or both. We then need to know the content of the intrusion. This can be brief but we need to be able to match any intrusions you have to the film so please be as clear as possible.

There are some examples on page 4. As you can see, the participant recorded an intrusion on (Day 1, 1 pm, it was an intrusive image, a brief description of the content of that intrusion which was 'I saw the scene of two people waiting for their flight', it was triggered by the participant 'opening a passport', and on a scale from 0-10, it caused a distress level of 3).

For every little box you fill in for an intrusion, there should be a matching line describing briefly its content.

If you are unsure of any of the details, please just make a note in the diary anyway and we will go over it with you later when you return.

Day 1 is today, please go back to page 2 and fill in the date for DAY1 which is [DATE OF THE WEEK] XXX. Please also complete the dates for DAY2-7, which should be…Please go to page 7 and write down the time and date of our next session [PROVIDE DATE].

My details are also on the diary – if you have any questions, please get in contact with me. This diary is vital for the study as we won't be able to get any results without it. It is sentential that you return the diary in our session next week.

Remember, if you don't have any intrusions; please still return it as we are interested in those results too.

Do you have any questions?

[Summarising]

So to summarise:

> Mental images can be pictures in your mind but also sounds of the film.
> Mental images may be fuzzy, very brief or almost like a flash in your mind's eye.
> Even if you have several intrusions that are the same moment of the film, please record each individual one in the diary.
> Although brief, make sure that the description of your intrusion can allow me to match it to a specific film clip.

Now please read through this **checklist** that summarises what we just talked about in relation to filling your intrusions about the film in the next week before our follow up session.

[give them the checklist, and make sure they have marked yes on all items, else clarify any questions].

13. **(5MIN) DEBRIEF**

Thank you very much for coming today. I will see you in our next session next week on XXX at the same time. Please do not discuss today's sessions with anyone.

[Escort each participant out]
[Make notes on lab book]

End of session 1

SESSION 2

1. **(5 MIN) WELCOME BACK**

Welcome back. Today will be the second session of this study. Could I have your diaries back please? Could you please complete a brief questionnaire about your mood right now?

[Participants will fill baseline mood VAS]

2. **(15 MIN) LAB INTRUSION TASK**

Thank you. You will now perform the vigilance task that you did last week in which you had to press a key every time you saw a digit. I will go through a practice trial again with you.

[Go through instructions again as last week, check section 10]

3. **(20 MIN) RECOGNITION TASK**

Now you will move on to a different task.

Here, you will be presented with pictures and you will have to say whether you recognise them being from the film you have seen before or not. If you say yes, then you will have to indicate whether you REMEMBER the picture from the film or whether you just KNOW on some other basis that the picture was from the film. Please go through the instructions carefully and ask me any question until you understand the instructions fully.

4. **(15 MIN) DIARY CHECKING + QUESTIONNAIRES (demand, compliance, behaviour change, IES)**

I would like you to go through some questionnaires that I will hand in now. For each questionnaire, please read the instructions carefully before you start completing it.

[Give participants questionnaire pack, IES, compliance and demand, behaviour change]

We have come to the last part of our session today. I will now go through the diary you have completed with you.

[Go through diary checking protocol below]

Check diary is completed correctly. Complete any missing information, with the participants help if necessary:

- Is there a description for every single box checked with an intrusion?

- If not ask participants if they can remember and describe the intrusion that went with the checked box.
- If they can't remember, make a mark. This will not be included for the analysis as we cannot assure it is an intrusion of the film.

- Are all the intrusion descriptions clear?
    - If they are unclear or you don't recognise them ask for more details until you can identify it with the film sequence.
    - Avoid asking leading questions, and stick to open questions. E.g., can you tell me more? Or if they mention 'car crash': can you tell me more about the car crash?
    - If the intrusion is linkable to a film clip then it cannot be included for analysis.

If an intrusion description is unclear, ask:

- Can you tell me more details about this intrusion?
- What else do you see or hear? (colours, objects, shapes, sounds)
- Any other detail, however fleeting?
- Show stills – is it one of these?

5. (5 MIN) DEBRIEF

[Give debrief sheet to participants]

We have now come to an end of our session today and you have completed this study. Thank you very much for taking part. Please read this debriefing information that lets you know the purpose of today's experiment. If you have any questions then please do ask, I will be happy to answer them. If you have any concerns about having taking part of the experiment, you can contact the principal investigator of this study whose details are on the information sheet. If you are happy with all of the information provided then please sign this form saying you have received the debriefing information. For your reimbursement please fill out this form.

[Ask the participant to sign end of the experiment form and give full payment]
[Make note on lab book]

End of session 2

END OF PROTOCOL

Appendix 3.2: Example of pictures used in attention bias task for each level of source (film vs. foil) and emotionality (emotional vs. neutral) in Experiment 2

Film/Emotional



Film/Neutral


Foil/Emotional



Foil/Neutral



Appendix 3.3: Baseline, mood and compliance measures for Experiment 2

Baseline, Task Manipulation and Compliance Measures for each Experimental Condition in Experiment 2

	Interference (n = 18)		No-interference (n = 18)		Independent group comparisons		
	n		n		χ^2	df	p
Gender (females)	10		9		0.11	1	.738
	M	SD	M	SD	t	df	p
Age	26.39	7.24	24.94	7.00	0.61	34	.547
BDI-II	5.50	3.47	6.72	4.60	0.90	34	.374
STAI-T	35.11	9.92	39.22	8.23	1.35	34	.185
TEQ	1.39	1.75	1.00	1.09	0.80	34	.429
SUIS	39.56	5.58	40.06	6.26	0.25	34	.802
Attention paid to the film	9.17	0.71	9.22	1.00	0.19	34	.849
Personal relevance of film	3.44	2.46	3.83	2.90	0.44	34	.667
Demand of Tetris playing	- 2.94	4.52	-1.83	3.47	0.83	34	.414
Diary accuracy	8.94	1.00	8.06	1.16	2.46	34	.019

Note. BDI-II = Beck Depression Inventory; STAI-T = State Trait Anxiety Inventory – Trait; TEQ = Traumatic Experience Questionnaire; SUIS = Spontaneous Use of Imagery Scale.

Pre- and Post-Film Negative Mood Scores in Experiment 2

	Interference (n = 18)		No-interference (n = 18)		Repeated-measures ANOVA
	M	SD	M	SD	Group: $F(1,34) = 4.01$, $p = .053$.
Pre-film negative mood	1.84	1.32	4.07	3.95	
Post-film negative mood	7.66	4.85	10.42	6.54	Time: $F(1,34) = 48.18$, $p < .001$. G × T: $F(1,34) = 0.09$, $p = .761$.

Note. Each negative mood is a composite score summing score on three Visual Analogue Scales on sad, depressed and hopeless moods.

Appendix 3.4: Treatment of outliers in Experiment 2

Participant number	Group	Measure	Outlier score	Changed score
508	Interference	Frequency of diary intrusions (day 1 to 7)	15	7
402	No-interference	Recognition accuracy	-0.29	0.22
518	Interference	Frequency of laboratory intrusions (day 1)	30	13

Appendix 4.1: Experimental protocol for Experiment 3

EXPERIMENT 3: Reactivation + Tetris versus Reactivation + No-Tetris versus Tetris-only & Lab-based intrusion task (original and modified to include manipulations for retrieval loads)

Based on Alex's 2014/5 Exp 2

Changes to previous protocol

- Timing between film and Tetris is 30 minutes.
- Participants are tested individually (they could be stacked).
- Three conditions are being compared: Tetris vs. Control (both preceded by an reactivation task) and Tetris only
- The trauma film lasts 12 minutes.
- Lab-based intrusion task from exp 2 – only difference is that participants won't report intrusions on a sheet
- Lab-based intrusion task modified – 4 different versions which required no online intrusion estimate, but rather retrospective.
- Participants provide card details at the beginning of the experiment
- Diary will be posted back. No follow-up session.
- Participants would be told they will receive a debriefing email upon receipt of the diary by post, or alternatively they could arrange a phone chat.

Before starting to test

3) Warm up the room!

Before session 1

Have computers set up ready

- Equipment: (Headphones and pens for each participant; stopwatch).
- Encyclopaedia for manual research task should be ready, with both sets of questions inside the hardcover.
- Relevant files at top right of desktop (Tetris, E-Prime, All MATLAB files)
- Ensure desktop is as clean as possible. Desktop background to be of neutral single colour.
- Make sure the Tetris program has sound off as default.
- Password for Tetris: (Username: epact1; password: pubquiz / Username: holmesea; password: windmill)
- Information and consent, demographics
- Baseline measures (BDI, STAI, TEQ, SUIS, VAS [Proneness to Intrusive Cognitions; Personal Relevance Car Crash; Blood Phobia; Proneness to Fainting]).
- Diary, diary checklist, demand/compliance ratings sealed,
- Free postage envelop
- Bank transfer document
- Tape recorder for verbal load
- Moar box for visuospatial load

After testing

- Save data

SESSION 1

1. **(10-15 MIN) INFORMATION AND CONSENT**

[Meet participant in waiting room, give information sheet, checked for consent]

Good morning/afternoon. Thank you for coming.

□ please read this **information sheet** about what is going to happen today.
□ if you are happy please sign the **Consent Form.**
□ if you would like a copy of the Consent Form please let me know.

[Check participant has provided consent and take them to the lab]

Do you have any questions before we move to the lab?

2. **(5MIN) INTRODUCTION**

Thank you for agreeing to take part in this study. For this study you will be paid by bank transfer, and it could take up to 4 weeks. Is that still ok with you? Would you mind turning your mobile phone off and leaving it with me before we start as it may create interference with the sound system – thank you.

[Collect phones and check they're turned off]

First, I will like to start by explaining what is going to happen today. This session will consist of a sequence of different activities. Some of these involve using the computer, others will involve using pen and paper; in some of them I will ask you to put the headphones on. When you have finished a task, just wait patiently until I come back to you and give you further instructions.

[Make sure they all have a pen]

You will be reimbursed for the entire duration of the experiment which will consist of 3 hours plus for carrying the diary over the week for which we would reimburse you with an additional payment equivalent to 1 hour participation.

3. **(10 MIN) BASELINE QUESTIONNAIRES (BDI, STAI, TEQ, Blood Phobia/PIC/Personal Relevance, SUIS)**

Now I will ask you to take some time to fill in the pack of questionnaires

[Give pack of questionnaire to participant]

Don't think about the answers too much, just respond with the first thing that comes to mind. Make sure you read the instructions for each questionnaire before answering the questions. This will take around 10 minutes and please hand them back to me when you are finished. You may start now.

[During game playing following questionnaires completion, experimenter will check for risk]
[Check blood phobia and faiting question, ask for clarification about their ratings, especially if fainting >7, make sure they have eaten, feel ventilated, and have a glass of water, position comfortably].
[Also check for missing answers. Use highlighter to circle missing question and gently remind participants to complete it at the end of the session.]

4. (6MIN) TETRIS PRACTICE

Thank you for completing the questionnaires. Now, you are going to have a three minute practice playing the computer game Tetris which you may have heard of it or played it before.

[Experimenter will open Tetris game]

Now I will first explain how to play this game, please only watch the program and listen to my instructions. You will have time to try the game later on; in the meantime please do not play at all.

> As you can see, the game consists of 7 different shaped blocks which fall from the top of the screen one at a time.
>
> Each time you fill a whole horizontal line with the blocks, with no gaps, that line will disappear and give you points. The aim is to make as many of these lines disappear as possible before the screen is filled completely.
>
> In this particular game **I want you to focus on the three blocks that will be falling immediately after the one being played on the right of the screen.**
>
> **Try and work out in your mind's eye where best to place and rotate these blocks in order to make the most complete lines and get the best score.**
>
> Blocks are moved using the 4 arrow keys.
> Left and right cursor keys are used to move to the left and right;
> Up cursor key is used to rotate the block by 90 degrees clockwise every time you press it;
> Down cursor key is used to speed up the block if you are confident that you have the block at the desired rotation and position.

Do you have any questions?

[Check they had understood the instructions]
[Restart the game for participants by pressing ESCAPE]

Now I would restart the game for you. If you finish a game before time is up, please just restart again and continue playing. You will now have 3 minutes to play and try out Tetris with the instructions that I explained. Ok now press on the 'Restart' button.

[Start stopwatch for 3 minutes. check participant is following with instructions/ not struggling]

5. (1MIN) PRE-FILM MOOD RATINGS

[Close the game for the participant]

Please take some time to fill in a short questionnaire I will hand you now (pre-film mood).

6. (12 MIN) TRAUMA FILM VIEWING

Thanks for playing the game before, now we will move on to something totally different. Do feel free to stretch or stand up, cause the important part of the experiment is about to start. Now you will now see a short film of about 12 minutes.

[Look in participants' eye, check headphones on?, sit on their level]

Please sit still and pay close attention to the film. You will be asked questions about it later. **I don't want you to watch the film like you normally would. I want you to try and imagine you are there at the scene watching the events unfold in front of your eyes as if you were a REAL bystander, really there immersed and involved.** **Please pay attention to the film and try not to look away or shut your eyes.**

Check participants' understanding:
[its very important that you watch the film following these instructions]
[ask participant to summarise back: "do you mind summarising what I just explained"?]
[give them opportunity to ask for questions: "do you have any questions for me before we start?"]
[check for verbal and non-verbal consent]
[if show hesitation: you seem uncertain, what part of my instructions would be the hardest to follow?]

I will also turn off the lights while you watch the film. You may start now.

[Open program and start the film.]
[Experimenter waits outside. Make sure you outside the cubicles/inside the room in case there are any problems].
[DO NOT ask participants about the film or engage with them about the film. Go straight to the next section].
[Turn lights on. Open the door].
[When participant finishes with the film]

Please take some time to fill in a short questionnaire I will hand you no (post-film mood).

7. (30 MIN) FILLER TASKS

Now I am going to ask you to do some tasks for me. In a first task, you will have to answer some questions using the manual provided. The instructions on how to use the manual would be all explained in detail on screen. Please make sure you read all instructions thoroughly before you start the task. I will be back in 10 minutes. You may start now.

[Start timer - do not stop; let it run until 30 minutes]
[After 10 minutes, pick manual task sheet, give music sheet; say:]

10 minutes are up. Now you will move on to another task in which you will listen to some songs and asked to rate how pleasant you find them. This will take around 10 minutes. I will be back after that. You may start now.

[Pick music sheet, give manual task back, and say:]

Now please return to the manual task you were doing beforehand for further 10 minutes. I will be back after that time.

[Press w]

8. (12 MIN) EXPERIMENTAL ALLOCATION

[Screen should ask participant to wait for further instructions]

Please could you close the manual and put aside all the materials and questionnaires inside the manual.

REACTIVATION + TETRIS

[Open Reactivation task]

Now you will see a selection of pictures from the film you watched earlier. During this time I want you to sit still and pay close attention to the pictures until further instructions.

[Press S for start the reactivation task]
[Open Tetris]

I would like you to play Tetris game that you practised earlier. I would like to emphasise that it is not important the score that you get, but to enjoy yourselves and keep trying all the way through. Do not forget to try and manipulate the blocks to form the most complete lines, and pay attention to the blocks coming up next on the right of the screen, and how they might be rotated to fit best.

[Open Tetris for participant and wait until it loads]

This time you will have 10 minutes to play. You may start now.

REACTIVATION + CONTROL

[Open Reactivation task]

Now you will see a selection of pictures from the film you watched earlier. During this time I want you to sit still and pay close attention to the pictures until further instructions.

[Press S for start the reactivation task]

There will be now a short break for 10 minutes. During this time please stay seated and do not talk or engage in other tasks, for example using your phone. You can think about anything, with no restrictions during this time. I will let you know when 10 minutes are up so we can move on to the next task. The break starts now.

TETRIS ONLY

[Open Tetris]

I would like you to play Tetris game that you practised earlier. I would like to emphasise that it is not important the score that you get, but to enjoy yourselves and keep trying all the way through. Do not forget to try and manipulate the blocks to form the most complete lines, and pay attention to the blocks coming up next on the right of the screen, and how they might be rotated to fit best.

[Open Tetris for participant and wait until it loads]

This time you will have 10 minutes to play. You may start now.

[Do not interact with participant at all]

9. **(1MIN) POST-ALLOCATION MOOD RATIONS**

[If Tetris, close the game for them]

Time is up. Please take some time to fill in a short questionnaire I will hand you now (post-film mood).

10. **(15 MIN) LAB INTRUSIONS – ORIGINAL**

(5min) EXPLAIN PARAMETERS OF EXPERIMENTAL TASK + PRACTICE TRIAL

The next task examines concentration, which requires you to carry out a vigilance task on the computer. In this task, you are going to see the numbers 1 to 9 on the screen, one at a time. Your job is to press the "GO" key <u>as soon as</u> you see a number other than 3, and not press anything when you see the number 3. I will walk you through these so you know what it looks like.

[Experimenter conducts digit task walkthrough]

(1min) EXPLAIN NATURE OF THOUGHTS DURING TASK

At the same time, on every trial you will also see an image at the background, but you don't have to do anything with these. Just focus on the number task. Now, because this task is quite monotonous, you might find that occasionally your attention might wander. An intrusive memory from the film, in the form of a mental image, may pop into your mind, out of the blue, and not at times when you are deliberately thinking about it. We call this an intrusive image-based memory of the film.

Although mental images can be extremely vivid and clear, like you're experiencing it for real, it can also often be quite fuzzy and quite brief, like a quick flash. Most mental images take the form of pictures in your mind's eye, but they can actually include any of the five senses, so you can imagine sounds too.

Is that clear?

[Check participant understanding, provide further examples if necessary]

(2min) REPORTING OF INVOLUNTARY THOUGHTS WALKTHROUGH

So we are interested in knowing about the intrusive image-based memories of the film you have seen earlier that pop into your mind during the task.
And you should press it each time you notice it, even if it's the same image-based memory you've had before. But if something doesn't come to mind, there's no need to search for anything.
So I want you to press the '2' key every time you notice an intrusive image-based memory popping into your mind during the task.

[Ensure any questions are fully addressed before moving onto practice trial]

11. (60 MIN) LAB INTRUSIONS – MODIFIED (CHECK COUNTERBALANCING ORDER)

PRACTICE NEW VERSION

We will now move on to the next task. It is very similar to the one you just did: you are going to see the numbers 1 to 9 on the screen, one at a time. Your job is to press the "GO" key every time you see a digit, unless it is a 3. From now on, the GO key will be the MouseKey using your NON-DOMINANT HAND **as soon as** you see a digit.

Compared to the previous task, one main difference now is that you WILL NOT have to make any responses if you experience and intrusive image-based memory; Just focus on carrying out this vigilance task by pressing the MouseKey accordingly. Instead, in this new version of the task, you will be prompted with some questions after a certain amount of time. I will take you through an example.

[take through practice walkthrough]

PRACTICE VERBAL COUNTING BACKWARDS

Now, you are given the task of counting backwards out loud in 2s. For example, if I ask you to start from the number 120, you will say: 119, 117, 116, 115 and so for… I will give you a number, and then you will be asked to count backwards out loud in 2s. I will give you feedback of your performance.

Caveat: **It is more important that you are accurate on each response. It is not a competition about speed. The most important thing is to keep doing it steadily and continuously without stopping, but you do not have to rush.**

Do you have any questions?

Number: ***576***

Criterion stage [1 minute]: at least 10 numbers consecutively correct.

Answer: 576; 575; 574; 573; 572; 571; 570; 569; 568; 566 (criterion); 565; 564
After 1-minute has passed say:

Stop. [if not criterion, repeat this stage]

Overpractised stage: (5 minutes): *576*

Please do this again now for 5 minutes. Remember: **It is more important that you are accurate on each response. It is not a competition about speed. The most important thing is to keep doing it steadily and continuously without stopping, but you do not have to rush.**

[start tape]
After 5-minute has passed say:

Stop.

PRACTICE VISUOSPATIAL COMPLEX TAPPING

Open a word/excel document

Now, you are given the task of tapping a pattern of keys on a box continuously using your dominant hand. The computer is wired up to record every correct sequence. I will show you the whole pattern first, and then you will be asked to follow for 1 minute.

Caveat: **It is more important that you are accurate on each response. It is not a competition about speed. The most important thing is to keep doing it steadily and continuously without stopping, but you do not have to rush.**

Show sequence: **JYPVA**

Criterion stage 1: (1 minute): at least 10 patterns tapped consecutively correct while able to see the box

After 1-minute has passed say:
Stop. [if not criterion, repeat this stage]

Criterion stage 2: (1 minute): at least 10 patterns tapped consecutively correct while box concealed (while seeing visual feedback)

Now you will be asked to do the tapping with the box is **hidden out of sight**. Try to hold the pattern in mind and visualise it, this will help you to remember the pattern in your mind's eye. I will give you feedback of your performance after 1 minute.

[Participants can see their performance on screen]

After 1-minute has passed say:
Stop. **[if not criterion, repeat this stage]**

Overpracticed stage 1: (5 minutes) not looking at screen.

That was really good. Please do this again now for 4 minutes. Remember: **It is more important that you are accurate on each response. It is not a competition about speed. The most important thing is that you keep doing it steadily and continuously without stopping, but you do not have to rush.**

TASK COUNTERBALANCING INSTRUCTIONS

LOW LOAD VERSION

Now you will perform the vigilance task again. Remember to press MouseKey every time you see a digit AS SOON AS YOU CAN, unless it is a 3. THIS IS ALL YOU HAVE TO DO. Do you have any questions?

VERBAL VERSION:

Now you will perform the vigilance task again. Remember to press the MouseKey every time you see a digit AS SOON AS YOU CAN, unless it is a 3. IN ADDITION, at the same time, you will have to count out loud backwards in 2s as you practised before. Please pay attention to the instructions on the screen which will tell you which number to start counting from, when to start counting and also when to stop. Remember that your responses will be tape recorded. Attending to the digits and counting backwards may be difficult, but please try your best. It is more important that you are accurate on each response. It is not a competition about speed. The most important thing is to keep doing it steadily and continuously without stopping, but you do not have to rush. Do you have any questions? *[Researcher would say participant's number out loud to record participant's number of the tape recorder]*

VISUOSPATIAL VERSION:

Now you will perform the vigilance task again. Remember to press MouseKey every time you see a digit AS SOON AS YOU CAN, unless it is a 3, using your NON-DOMINANT HAND. IN ADDITION, at the same time, you will have to tap pattern of keys on the hidden box as you practised before. *[check if they remember the pattern]* Please try to hold the pattern in your mind and visualise it. This will help you to remember the sequence in your mind's eye. Read the task instructions carefully which would tell you when to start and when to stop tapping. Remember the computer will also record your responses on this tapping task. Attending to the digits and tapping the pattern may be difficult but please try your best. It is more important that you are accurate on each response. It is not a competition about speed. The most important thing is to keep doing it steadily and continuously without stopping, but you do not have to rush. Do you have any questions?

12. (10 MIN) DIARY INSTRUCTION

[Hand in diary]

This is the last stage of our session today.

[Explanation of intrusive image vs. thought:]
[Pace the explanation as this is critical]

> *It may be that over the next few days images or thoughts about the film you have just seen will* **pop into your mind without you expecting them to.** *This is called an intrusion.*
>
> *What goes through our minds can either take the form of words and phrases ("verbal thoughts"), or mental images.*
>
> Although mental images often take the form of pictures in your mind's eye they can also include any of the five senses, so you can imagine sounds too. We are interested in mental images that are sights and sounds of the film.
>
> Mental images can be very clear, but sometimes they can be fuzzy or fragmented; they can also be brief and very fleeting. We are interested in knowing about all these types of images.
>
> The diary is critical for our study and it is important that you understood. Do you have any questions?
>
> If you forget about what I just explained, this is summarised inside this diary under 'Introduction'.

[Explanation of filling out diary]:

Now we know what mental images are, let's talk about how you would fill out the diary.

So, if you have any intrusions of the film you have just watched over the next week, please record each one as soon as possible in this diary. Keep the diary in your bag or next to your bed, and please start filling it in from right after this session. It's really important that you keep it as accurately as possible.

On page 2 and page 3, fill in one of the little boxes every single time you have an intrusion. I for image, T for thought or IT if it was both. You may have the same one over and over again. That's ok just make a note every time it happens.

On page 2, there is an example box in grey that is at the top right corner. In this example, you can see that the day is divided into three day periods:

In the morning, the person did not experience any intrusion, so they wrote 0 and cross it off.
In the afternoon, the person experienced two intrusive images
In the evening, the person experienced one intrusion which was both an image and a thought at the same time.

Make sure that you have completed each of the three time periods (Morning, Afternoon and Evening/Night) as they occur. If you are unable to complete the diary at the time when you experience an intrusion please make sure you have completed each time period at least once a day.

Next, fill in the details of each intrusion you have had on page 4. Put down the day and time, and whether it was an image, thought or both. We then need to know the content of the intrusion. This can be brief but we need to be able to match any intrusions you have to the film so please be as clear as possible.

There are some examples on page 4. As you can see, the participant recorded an intrusion on (Day 1, 1 pm, it was an intrusive image, a brief description of the content of that intrusion which was 'I saw the scene of two people waiting for their flight', it was triggered by the participant 'opening a passport', and on a scale from 0-10, it caused a distress level of 3).

For every little box you fill in for an intrusion, there should be a matching line describing briefly its content.

If you are unsure of any of the details, please just make a note in the diary anyway and we will go over it with you later when you return.

Day 1 is today, please go back to page 2 and fill in the date for DAY1 which is [DATE OF THE WEEK] XXX. Please also complete the dates for DAY2-7, which should be…Please go to page 7 and write down the time and date of our next session [PROVIDE DATE].

My details are also on the diary – if you have any questions, please get in contact with me. This diary is vital for the study as we won't be able to get any results without it. It is sentential that you return the diary in our session next week.

Remember, if you don't have any intrusions; please still return it as we are interested in those results too.

Do you have any questions?

[Summarising]:

So to summarise:

- Mental images can be pictures in your mind but also sounds of the film.
- Mental images may be fuzzy, very brief or almost like a flash in your mind's eye.
- Even if you have several intrusions that are the same moment of the film, please record each individual one in the diary.
- Although brief, make sure that the description of your intrusion can allow me to match it to a specific film clip.

Now please read through this **checklist** that summarises what we just talked about in relation to filling your intrusions about the film in the next week before our follow up session.

[give them the checklist, and make sure they have marked yes on all items, else clarify any questions].

At the end of one-week, I will send you a reminder email that you can complete this sealed questionnaires and also return the diary. Postage will be free. Upon receipt of the diary by me you will receive an email confirming payment via bank transfer. I will also send you information about the study then. If you would like to schedule a phone call in which I can tell you more about the study you could let me know now or anytime from now.

[Escort participant out of the room]

END OF PROTOCOL

Appendix 4.2: Baseline, mood and compliance measures for Experiment 3

Baseline, Task Manipulation and Compliance Measures for each Experimental Condition in Experiment 3

	Cue+ Interference (*n* = 19)		Cue + No-interference (*n* = 19)		Interference only (*n* = 19)		One-way ANOVA		
	n		*n*		*n*		χ^2	*df*	*p*
Gender (females)	11		13		10		1.02	2	.597
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*	*df*	*p*
Age	27.26	7.81	25.32	5.40	28.05	6.90	0.82	2,54	.445
BDI-II	4.95	5.34	4.68	4.67	5.37	5.77	0.08	2,54	.992
STAI-T	36.32	8.35	33.53	8.07	35.89	10.55	0.52	2,54	.595
TEQ	0.58	0.77	1.32	1.20	0.74	1015	2.56	2,54	.087
SUIS	35.84	9.91	36.68	8.89	39.37	7.83	0.81	2,54	.450
Attention paid to the film	9.53	0.96	9.53	0.61	9.37	0.76	0.25	2,54	.778
Personal relevance of film	3.00	2.40	4.37	2.89	3.68	2.47	1.32	2,54	.276
Demand of Tetris playing	-1.32	2.96	-1.42	3.19	-1.65	3.62	0.05	2,52	.953
Diary Accuracy	8.21	2.15	8.68	1.38	8.87	1.20	0.77	2,51	.469

Note: BDI-II = Beck Depression Inventory; STAI-T = State Trait Anxiety Inventory – Trait; TEQ = Traumatic Experience Questionnaire; SUIS = Spontaneous Use of Imagery Scale. The first two groups were equivalent to those in the other experiments.

Pre- and Post-Film Negative Mood Scores in Experiment 3

	Cue+ Interference (*n* = 19)		Cue + No-interference (*n* = 19)		Interference only (*n* = 19)		Repeated-measures ANOVA
	M	*SD*	*M*	*SD*	*M*	*SD*	Group: $F(2,54)$ = 0.07, p = .937.
Pre-film negative mood	1.87	3.21	1.54	2.37	2.11	2.49	Time: $F(2,54)$ = 49.92, p < .001.
Post-film negative mood	8.57	7.26	8.32	6.20	7.55	5.28	G × T: $F(2,54)$ = 0.24, p = .792.

Note. Each negative mood is a composite score summing score on three Visual Analogue Scales on sad, depressed and hopeless moods.

Appendix 4.3: Treatment of outliers in Experiment 3

Participant number	Group	Measure	Outlier score	Changed score
616	Interference	Frequency of laboratory intrusions – modified version (retrospective estimates, no load)	72	16

Appendix 5.1: Experimental protocol for Experiment 4

EXPERIMENT 4: Reactivation+Tetris versus Reactivation+No-Tetris & New memory tests (laboratory-based intrusions and recognition, both cued with film or foil cues)

Based on Alex's 2015 Exp 3

<u>Changes to previous protocol</u>

- Timing between film and Tetris is 30 minutes.
- Participants are tested individually (they could be stacked).
- Two conditions are being compared: Reactivation+Tetris vs. Reactivation+No-task Control
- The trauma film lasts 12 minutes.
- Lab-based intrusion task from exp 3 –participants won't report intrusions on a sheet but will report them online. Two versions of the task: uncued vs cued. Uncued always procedes cued. New change: responses to 3 is 'go' instead of 'no go'.
- Novel memory measure introduced: cued recognition.
- Participants provide card details at the beginning of the experiment
- Diary will be posted back. No follow-up session.
- Participants would be told they will receive a debriefing email upon receipt of the diary by post, or alternatively they could arrange a phone chat.

<u>Before starting to test</u>

- Warm up the room!
- Two rooms need to be booked. One for main testing, another one to assess 'uncued' intrusions by taking them to a different laboratory setting.

<u>Before session 1</u>

Have computers set up ready

Room 1: Main experimental room

- Equipment: (Headphones and pens for each participant; stopwatch).
- Encyclopaedia for manual research task should be ready, with both sets of questions inside the hardcover.
- Relevant files at top right of desktop (Tetris, E-Prime, All MATLAB files)
- Ensure desktop is as clean as possible. Desktop background to be of neutral single colour.
- Make sure the Tetris program has sound off as default.
- Password for Tetris: (Username: epact1; password: pubquiz / Username: holmesea; password: windmill)
- Information and consent, demographics
- Baseline measures (BDI, STAI, TEQ, SUIS, VAS [Proneness to Intrusive Cognitions; Personal Relevance Car Crash; Blood Phobia; Proneness to Fainting]).
- Diary, diary checklist, demand/compliance ratings sealed,
- Free postage envelop
- Bank transfer document

Room 2: Room to assess 'uncued intrusions

- Make sure MATLAB file is ready to run

After testing

- Save data from Room 1 (cued intrusions & cued recognition) and 2 (uncued intrusions)

SESSION 1

1. (10-15 MIN) INFORMATION AND CONSENT

[Meet participant in waiting room, give information sheet, checked for consent]

Good morning/afternoon. Thank you for coming.

□ please read this **information sheet** about what is going to happen today.
□ if you are happy please sign the **Consent Form.**
□ if you would like a copy of the Consent Form please let me know.

[Check participant has provided consent and take them to the lab]

Do you have any questions before we move to the lab?

2. (5MIN) INTRODUCTION

Thank you for agreeing to take part in this study. For this study you will be paid by bank transfer, and it could take up to 4 weeks. Is that still ok with you? Would you mind turning your mobile phone off before we start as it may create interference with the sound system – thank you.

[Collect phones and check they're turned off]

First, I will like to start by explaining what is going to happen today. This session will consist of a sequence of different activities. Some of these involve using the computer, others will involve using pen and paper; in some of them I will ask you to put the headphones on. When you have finished a task, just wait patiently until I come back to you and give you further instructions.

[Make sure they all have a pen]

You will be reimbursed for the entire duration of the experiment which will consist of 3 hours plus for carrying the diary over the week for which we would reimburse you with an additional payment equivalent to 1 hour participation.

3. (10 MIN) BASELINE QUESTIONNAIRES (BDI, STAI, TEQ, Blood Phobia/PIC/Personal Relevance, SUIS)

Now I will ask you to take some time to fill in the pack of questionnaires

[Give pack of questionnaire to participant]

Don't think about the answers too much, just respond with the first thing that comes to mind. Make sure you read the instructions for each questionnaire before answering the questions. This will take around 10 minutes and please hand them back to me when you are finished. You may start now.

[During game playing following questionnaires completion, experimenter will check for risk]
[Check blood phobia and faiting question, ask for clarification about their ratings, especially if fainting >7, make sure they have eaten, feel ventilated, and have a glass of water, position comfortably].
[Also check for missing answers. Use highlighter to circle missing question and gently remind participants to complete it at the end of the session.]

4. (6MIN) TETRIS PRACTICE

Thank you for completing the questionnaires. Now, you are going to have a three minute practice playing the computer game Tetris which you may have heard of it or played it before.

[Experimenter will open Tetris game]

Now I will first explain how to play this game, please only watch the program and listen to my instructions. You will have time to try the game later on; in the meantime please do not play at all.

> As you can see, the game consists of 7 different shaped blocks which fall from the top of the screen one at a time.
>
> Each time you fill a whole horizontal line with the blocks, with no gaps, that line will disappear and give you points. The aim is to make as many of these lines disappear as possible before the screen is filled completely.
>
> In this particular game **I want you to focus on the three blocks that will be falling immediately after the one being played on the right of the screen.**
>
> **Try and work out in your mind's eye where best to place and rotate these blocks in order to make the most complete lines and get the best score.**
>
> Blocks are moved using the 4 arrow keys.
> Left and right cursor keys are used to move to the left and right;
> Up cursor key is used to rotate the block by 90 degrees clockwise every time you press it;
> Down cursor key is used to speed up the block if you are confident that you have the block at the desired rotation and position.
>
> Do you have any questions?

[Check they had understood the instructions]
[Restart the game for participants by pressing ESCAPE]

Now I would restart the game for you. If you finish a game before time is up, please just restart again and continue playing. You will now have 3 minutes to play and try out Tetris with the instructions that I explained. Ok now press on the 'Restart' button.

[Start stopwatch for 3 minutes. check participant is following with instructions/ not struggling]

5. (1MIN) PRE-FILM MOOD RATINGS

[Close the game for the participant]

Please take some time to fill in a short questionnaire I will hand you now (pre-film mood).

6. (12 MIN) TRAUMA FILM VIEWING

Thanks for playing the game before, now we will move on to something totally different. Do feel free to stretch or stand up, cause the important part of the experiment is about to start. Now you will now see a short film of about 12 minutes.

[Look in participants' eye, check headphones on?, sit on their level]

> Please sit still and pay close attention to the film. You will be asked questions about it later.
>
> **I don't want you to watch the film like you normally would. I want you to try and imagine you are there at the scene watching the events unfold in front of your eyes as if you were a REAL bystander, really there immersed and involved.**
>
> **Please pay attention to the film and try not to look away or shut your eyes.**

Check participants' understanding:
[its very important that you watch the film following these instructions]
[ask participant to summarise back: "do you mind summarising what I just explained"?]
[give them opportunity to ask for questions: "do you have any questions for me before we start?"]
[check for verbal and non-verbal consent]
[if show hesitation: you seem uncertain, what part of my instructions would be the hardest to follow?]

I will also turn off the lights while you watch the film. You may start now.

[Open program and start the film.]
[Experimenter waits outside. Make sure you outside the cubicles/inside the room in case there are any problems].
[DO NOT ask participants about the film or engage with them about the film. Go straight to the next section].
[Turn lights on. Open the door].
[When participant finishes with the film]

Please take some time to fill in a short questionnaire I will hand you no (post-film mood).

7. (30 MIN) FILLER TASKS

Now I am going to ask you to do some tasks for me. In a first task, you will have to answer some questions using the manual provided. The instructions on how to use the manual would be all explained in detail on screen. Please make sure you read all instructions thoroughly before you start the task. I will be back in 10 minutes. You may start now.

[Start timer - do not stop; let it run until 30 minutes]
[After 10 minutes, pick manual task sheet, give music sheet; say:]

10 minutes are up. Now you will move on to another task in which you will listen to some songs and asked to rate how pleasant you find them. This will take around 10 minutes. I will be back after that. You may start now.

[Pick music sheet, give manual task back, and say:]

Now please return to the manual task you were doing beforehand for further 10 minutes. I will be back after that time.

[Press w]

8. **(12 MIN) EXPERIMENTAL ALLOCATION**

[Screen should ask participant to wait for further instructions]

Please could you close the manual and put aside all the materials and questionnaires inside the manual.

REACTIVATION + TETRIS

[Open Reactivation task]

Now you will see a selection of pictures from the film you watched earlier. During this time I want you to sit still and pay close attention to the pictures until further instructions.

[Press S for start the reactivation task]
[Open Tetris]

I would like you to play Tetris game that you practised earlier. I would like to emphasise that it is not important the score that you get, but to enjoy yourselves and keep trying all the way through. Do not forget to try and manipulate the blocks to form the most complete lines, and pay attention to the blocks coming up next on the right of the screen, and how they might be rotated to fit best.

[Open Tetris for participant and wait until it loads]

This time you will have 10 minutes to play. You may start now.

REACTIVATION + CONTROL

[Open Reactivation task]

Now you will see a selection of pictures from the film you watched earlier. During this time I want you to sit still and pay close attention to the pictures until further instructions.

[Press S for start the reactivation task]

There will be now a short break for 10 minutes. During this time please stay seated and do not talk or engage in other tasks, for example using your phone. You can think about anything, with no restrictions during this time. I will let you know when 10 minutes are up so we can move on to the next task. The break starts now.

[Do not interact with participant at all]

9. **(1MIN) POST-ALLOCATION MOOD RATIONS**

[If Tetris, close the game for them]

Time is up. Please take some time to fill in a short questionnaire I will hand you now (post-film mood).

10. **(15 MIN) LAB INTRUSIONS – UNCUED**

Now we are going to move to a different room and do something completely different. Please follow me.

[Go to new room]

(5min) EXPLAIN PARAMETERS OF EXPERIMENTAL TASK + PRACTICE TRIAL

The next task examines concentration, which requires you to carry out a vigilance task on the computer. In this task, you are going to see the numbers 1 to 9 on the screen, one at a time. Your job is to press the "GO" key **<u>as soon as</u>** you see number 3, and not press anything when you see any other number. I will walk you through these so you know what it looks like.

[Experimenter conducts digit task walkthrough]

EXPLAIN NATURE OF THOUGHTS DURING TASK

At the same time, on every trial you will also see an image at the background, but you don't have to do anything with these. Just focus on the number task. Now, because this task is quite monotonous, you might find that occasionally your attention might wander. An intrusive memory from the film, in the form of a mental image, may pop into your mind, out of the blue, and not at times when you are deliberately thinking about it. We call this an intrusive image-based memory of the film. Although mental images can be extremely vivid and clear, like you're experiencing it for real, it can also often be quite fuzzy and quite brief, like a quick flash. Most mental images take the form of pictures in your mind's eye, but they can actually include any of the five senses, so you can imagine sounds too. Is that clear?

[Check participant understanding, provide further examples if necessary]

REPORTING OF INVOLUNTARY THOUGHTS WALKTHROUGH

So we are interested in knowing about the intrusive image-based memories of the film you have seen earlier that pop into your mind during the task. And you should press it each time you notice it, even if it's the same image-based memory you've had before. But if something doesn't come to mind, there's no need to search for anything. So I want you to press the '2' key every time you notice an intrusive image-based memory popping into your mind during the task.

[Ensure any questions are fully addressed before moving onto practice trial]

11. (15 MIN) LAB INTRUSIONS – CUED

Now we are going back to the room we were before. Please follow me.

[Go back to previous room]

Now I would like you to repeat the task you have just done one more time. Remember to always press '1' for every time you see number 3. If any intrusive image-memories from the film pop up into your mind, press 2.

12. (40 MIN) CUED RECOGNITION

Now we are going to move on to a different task.

This task also examines concentration. On each trial you will see a pair of pictures on the screen, one followed by another one. We will call it picture 1 and picture 2. It is important you keep in mind this discussion because you will be asked to react differently to each of them. For the first picture, you will see that it has a number on top. Press 1 or 'go' **as soon as** you see the number 3. Soon afterwards. You will see a second picture. This picture is quite blurred. I want you pay close attention to this picture and identify whether this picture, in its 'original' nonblurred format, came from the film you just saw today. If it came from the film indeed, I want you to press '2' for YES, if it did not, press '3' for NO. Remember to make these decisions as fast and as accurate as you can.

Do you have any questions?

Do you mind repeating the instructions back to me?

So this would be repeated for a while, would last around 30 minutes. We will now do a short practice.

13. (10 MIN) DIARY INSTRUCTION

[Hand in diary]

This is the last stage of our session today.

[Explanation of intrusive image vs. thought:]
[Pace the explanation as this is critical]

> It may be that over the next few days images or thoughts about the film you have just seen will **pop into your mind without you expecting them to.** This is called an intrusion.
>
> What goes through our minds can either take the form of words and phrases ("verbal thoughts"), or mental images.
>
> Although mental images often take the form of pictures in your mind's eye they can also include any of the five senses, so you can imagine sounds too. We are interested in mental images that are sights and sounds of the film.
>
> Mental images can be very clear, but sometimes they can be fuzzy or fragmented; they can also be brief and very fleeting. We are interested in knowing about all these types of images.
>
> The diary is critical for our study and it is important that you understood. Do you have any questions?

If you forget about what I just explained, this is summarised inside this diary under 'Introduction'.

[Explanation of filling out diary]:

Now we know what mental images are, let's talk about how you would fill out the diary.

So, if you have any intrusions of the film you have just watched over the next week, please record each one as soon as possible in this diary. Keep the diary in your bag or next to your bed, and please start filling it in from right after this session. It's really important that you keep it as accurately as possible.

On page 2 and page 3, fill in one of the little boxes every single time you have an intrusion. I for image, T for thought or IT if it was both. You may have the same one over and over again. That's ok just make a note every time it happens.

On page 2, there is an example box in grey that is at the top right corner. In this example, you can see that the day is divided into three day periods:

In the morning, the person did not experience any intrusion, so they wrote 0 and cross it off.
In the afternoon, the person experienced two intrusive images
In the evening, the person experienced one intrusion which was both an image and a thought at the same time.

Make sure that you have completed each of the three time periods (Morning, Afternoon and Evening/Night) as they occur. If you are unable to complete the diary at the time when you experience an intrusion please make sure you have completed each time period at least once a day.

Next, fill in the details of each intrusion you have had on page 4. Put down the day and time, and whether it was an image, thought or both. We then need to know the content of the intrusion. This can be brief but we need to be able to match any intrusions you have to the film so please be as clear as possible.

There are some examples on page 4. As you can see, the participant recorded an intrusion on (Day 1, 1 pm, it was an intrusive image, a brief description of the content of that intrusion which was 'I saw the scene of two people waiting for their flight', it was triggered by the participant 'opening a passport', and on a scale from 0-10, it caused a distress level of 3).

For every little box you fill in for an intrusion, there should be a matching line describing briefly its content.

If you are unsure of any of the details, please just make a note in the diary anyway and we will go over it with you later when you return.

Day 1 is today, please go back to page 2 and fill in the date for DAY1 which is [DATE OF THE WEEK] XXX. Please also complete the dates for DAY2-7, which should be…Please go to page 7 and write down the time and date of our next session [PROVIDE DATE].

My details are also on the diary – if you have any questions, please get in contact with me. This diary is vital for the study as we won't be able to get any results without it. It is sentential that you return the diary in our session next week.

Remember, if you don't have any intrusions; please still return it as we are interested in those results too.

Do you have any questions?

[Summarising]:

So to summarise:

- Mental images can be pictures in your mind but also sounds of the film.
- Mental images may be fuzzy, very brief or almost like a flash in your mind's eye.
- Even if you have several intrusions that are the same moment of the film, please record each individual one in the diary.
- Although brief, make sure that the description of your intrusion can allow me to match it to a specific film clip.

Now please read through this **checklist** that summarises what we just talked about in relation to filling your intrusions about the film in the next week before our follow up session.

[give them the checklist, and make sure they have marked yes on all items, else clarify any questions].

At the end of one-week, I will send you a reminder email that you can complete this sealed questionnaires and also return the diary. Postage will be free. Upon receipt of the diary by me you will receive an email confirming payment via bank transfer. I will also send you information about the study then. If you would like to schedule a phone call in which I can tell you more about the study you could let me know now or anytime from now.

[Escort them out of the room]

END OF PROTOCOL

Appendix 5.2: Baseline, mood and compliance measures for Experiment 4

Baseline, Task Manipulation and Compliance Measures for each Experimental Condition in Experiment 4

	Interference (*n* = 18)		No-interference (*n* = 18)		Independent group comparisons		
	n		*n*		χ^2	*df*	*p*
Gender (females)	12		15		1.33	1	.248
	M	*SD*	*M*	*SD*	*t*	*df*	*p*
Age	25.11	2.40	23.56	4.12	1.39	34	.175
BDI-II	5.00	6.16	4.39	3.26	0.37	34	.712
STAI-T	35.89	11.32	35.44	8.31	0.13	34	.894
TEQ	0.72	0.96	0.39	0.70	1.19	34	.241
SUIS	39.67	7.51	39.44	9.35	0.08	34	.938
Attention paid to the film	9.39	0.70	9.44	0.62	0.25	34	.802
Personal relevance of film	3.89	2.30	4.78	2.49	1.14	34	.273
Demand of Tetris playing	- 2.89	2.70	-1.22	4.48	1.35	34	.167
Diary accuracy	9.44	0.98	8.89	1.23	1.50	34	.144

Note. BDI-II = Beck Depression Inventory; STAI-T = State Trait Anxiety Inventory – Trait; TEQ = Traumatic Experience Questionnaire; SUIS = Spontaneous Use of Imagery Scale.

Pre- and Post-Film Negative Mood Scores in Experiment 4

	Interference (*n* = 18)		No-interference (*n* = 18)		Repeated-measures ANOVA
	M	*SD*	*M*	*SD*	Group: $F(1,34) = 0.01$, $p = .937$.
Pre-film negative mood	2.17	3.56	3.30	4.10	
Post-film negative mood	9.54	7.28	8.66	5.54	Time: $F(1,34) = 54.95$, $p < .001$. G × T: $F(1,34) = 1.38$, $p = .249$.

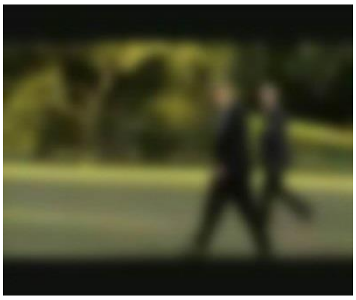
Note. Each negative mood is a composite score summing score on three Visual Analogue Scales on sad, depressed and hopeless moods.

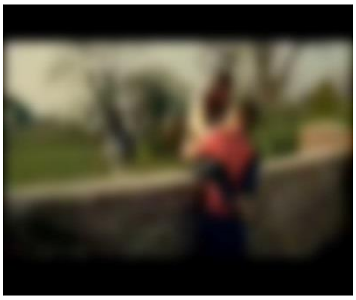
Appendix 5.3: Film and foil cues used in Experiment 4

Film cues



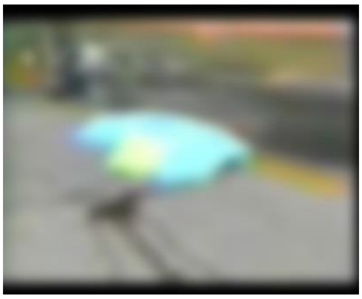




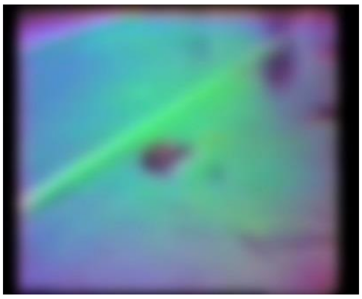

Foil cues









Appendix 6.1: Layout of diary used across experiments

Thank you for completing the diary. Your participation is very much appreciated. Don't forget to return the completed diary on the dates below, then you will then be given payment and information about the purpose of the study.

Thank you

Follow up Session Appointment Card

Session 1
Date____________ Time_______________
Session 2
Date____________ Time_______________

If you have any questions or problems, please do not hesitate to contact me at alex.lauzhu@mrc-cbu.cam.ac.uk

If you would like to discuss anything related to the experiment or your reactions to it, please do not hesitate to contact the responsible Investigator, at any point in the week after the film or beyond. Prof Emily Holmes can be contacted at at the Medical Research Council Cognition & Brain Sciences, Cambridge CB2 7EF, emily.holmes@mrc-cbu.cam.ac.uk.

p8

PARTICIPANT DIARY

Participant No:

1. Date started :

2. Return :

p1

Instructions: How to use the Diary

❖If over the next week you experience <u>any</u> **intrusions <u>about the film</u> you have just watched**, I would be very grateful if you could note them down in this diary.

❖What goes through our minds can either take the form of words and phrases ("**verbal thoughts**"), or it can be like mental pictures ("**images**") in your minds eye. Although mental 'images' often take the form of pictures they can actually include any of the five senses, so you can imagine sounds too. Please note down all intrusions in this diary.

❖For each intrusion, mark 'I'(mental image), 'T'(though) or 'IT' (image and thought) on pages 3 and 4 for the corresponding time of day, or write down that you have had Zero in that time frame. Then <u>for every single intrusion</u> you have had fill in the details of the content on pages 5, 6 and 7. **Please write an entry for each intrusion even if you have several the same or intrusions that occur one after the other.**

❖If you are, on occasion, unable to record details as they happen, please make sure you record that an intrusion has occurred.

❖Remember, **intrusions for the film can be very short/fleeting and fragmented**. We still would like to know about them in the diary!

PLEASE KEEP THIS DIARY – IT IS VITAL FOR THE EXPERIMENT. THANK YOU

Distress: How distressed were you at the intrusion? 1 (not at all distressing) 2 3 4 5 (extremely distressing)

Vividness: How vivid was this intrusion? 1 (very weak and fleeting) 2 3 4 5 (clear as normal vision)

Nowness: Did you experience this intrusion as 'in the present'? 1 (does not feel like now at all again) 2 3 4 5 (experiencing the film again)

Date and Time of intrusion	Was it an image (I), thought (T) or both (IT)?	What was the content of the intrusion? (e.g. subject matter)	What, if anything, triggered the intrusion?	Distress	Vividness	Nowness

Date and Time of intrusion	Was it an image (I), thought (T) or both (IT)?	What was the content of the intrusion? (e.g. subject matter)	What, if anything, triggered the intrusion?	**Distress:** How distressed were you at the intrusion? 1 (not at all distressing) 2 3 4 5 (extremely distressing) **Vividness:** How vivid was this intrusion? 1 (very weak and fleeting) 2 3 4 5 (clear as normal vision) **Nowness:** Did you experience this intrusion as 'in the present'? 1 (does not feel like now at all) 2 3 4 5 (experiencing the film again)		
				Distress	Vividness	Nowness

p6

Mark each intrusion as 'I' for image, 'T' for thought or 'IT' if it is a combination of both. Otherwise write '0' or cross out for that timeframe.

Example Day 0					
Morning	0				
Afternoon	I	I			
Evening & Night	IT				

Day 1 Date:					
Morning					
Afternoon					
Evening & Night					

Day 2 Date:					
Morning					
Afternoon					
Evening & Night					

Day 3 Date:					
Morning					
Afternoon					
Evening & Night					

Please remember to fill in the content for each intrusion indicated.
Thank you

p3

Day 4 Date:					
Morning					
Afternoon					
Evening & Night					

Day 5 Date:					
Morning					
Afternoon					
Evening & Night					

Day 6 Date:					
Morning					
Afternoon					
Evening & Night					

Day 7 Date:					
Morning					
Afternoon					
Evening & Night					

For each intrusion, mark 'I'(**mental image**), 'T'(**thought**) or 'IT' (**image & thought**) on pages 3 and 4 for the corresponding time of day, or **write down that you have had Zero** in that time frame. Then for every single intrusion you have had fill in the details of the content on pages 5, 6 and 7.

Please remember to fill in the content page for every intrusion indicated.

Thank you!

Content Page

Intrusions of the film can include **mental images**, (that is 'see' or 'hear' in your minds eye) and/or **verbal thought**, (thoughts about using verbal language when we talk) or combination of both image plus verbal thoughts. Please use additional paper if you run out of lines

Date and Time of intrusion	Was it an image (I), thought (T) or both (IT)?	What was the content of the intrusion? (e.g. subject matter)	What, if anything, triggered the intrusion?	**Distress:** How distressed were you at the intrusion? 1 (not at all distressing) 2 3 4 5 (extremely distressing)	**Vividness:** How vivid was this intrusion? 1 (very weak and fleeting) 2 3 4 5 (clear as normal vision)	**Nowness:** Did you experience this intrusion as 'in the present'? 1 (does not feel like now at all) 2 3 4 5 (experiencing the film again)
				Distress	Vividness	Nowness
Day 1 1pm	I	I saw the scene of two people waiting for their flight	Opening my passport	2	4	2
Day 1 4pm	T	I could hear the rumble of the airplane landing in my mind	Seeing an airplane	1	2	4
Day 1 11pm	IT	I saw the scene of two people waiting for their flight, and I thought it is nice to go on holidays with your partner	Out of the blue	2	3	2

Appendix 6.2: Protocol for cue classification system

Diary Cue Classification Protocol (Based on Mace, 2004)

For each involuntary image to the film, identify the corresponding trigger reported. This trigger could be classified in two different ways: A) internal, external and mixed; and B) abstract, sensory/perceptual and state.

A. Internal/external

1. **Internal** cues were defined as having an internal source only, such as a bodily sensation or state (e.g., pain, being cold or hungry), an emotional state (e.g., feeling happy, sad, or fearful), and a thought.
2. **External** cues were defined as all cues experienced externally in the environment (i.e., all sensory and perceptual experiences, including activities such as playing sports).
3. **Mixed** cues were defined as any combination of an internal and external cue (e.g., a thought combined with a perceptual experience or activity).
4. **No cues**: sometimes involuntary memories appear to have any eliciting cues (see Berntsen, 1996). Involuntary memories without any apparent eliciting cue were simply classified as unknown, and thus not included in the analyses.

B. Cue types

1. **Abstract** cues: all thought or linguistic referents to the original episode.
Involuntary memories are evoked by **thoughts** (e.g., when thinking about the zoo evokes a memory of a past trip to it), various elements of **language** (e.g., when hearing someone talk about the zoo evokes a past trip to it).

All thoughts, the words or phasing heard spoken by another (i.e., in conversation, on the television, or on the radio or other audio media), or the words or phrasing used in written language (i.e., printed in all types of texts, on billboards, on street signs, or in e-mails).

2. **Sensory/perceptual** cues: all fundamental sensory/perceptual referents to the original episode.
Involuntary memories are evoked by **sensory** experiences (e.g., when the smell of perfume evokes the memory of an acquaintance), **perceptual** experiences (e.g., when the sight of a common object or place evokes a memory).

All raw sensory experiences (i.e., any sound, smell or taste), fundamental perceptions (i.e., the perception of any person, place, object, weather condition, or piece of music), and activities (i.e., any sort, such as horseback riding, riding on a train, being stuck in a traffic jam, playing sports, etc.).

3. **State** cues were defined as all physiological or emotional states referents to the original episode.
Involuntary memories are evoked by **physiological** states (e.g., when hunger evokes a specific memory of being hungry), and **mood** states (e.g., when feeling sad evokes a specific memory of feeling sad).

Any mood, feeling, or physiological state, such as being cold or hot, hungry, intoxicated, or feeling pain or other bodily sensations.

Appendix 6.3: Treatment of outliers in combined diary analyses

Exploratory analysis 1

Participant number	Group	Measure	Outlier score	Changed score
1018, Experiment 4	Interference	Frequency of diary intrusions triggered with sensory-perceptual cues	10	6

Exploratory analysis 3

Participant number	Group	Measure	Outlier score	Changed score
406, Experiment 1	Interference	Frequency of diary intrusions (day 2)	4	2
412, Experiment 1	Interference	Frequency of diary intrusions (day 1)	7	2
508, Experiment 2	Interference	Frequency of diary intrusions (day 2)	4	2
508, Experiment 2	Interference	Frequency of diary intrusions (day 6)	2	0
518, Experiment 2	Interference	Frequency of diary intrusions (day 1)	6	2
603, Experiment 3	Interference	Frequency of diary intrusions (day 3)	3	1
616, Experiment 3	Interference	Frequency of diary intrusions (day 3)	3	1
617, Experiment 3	Interference	Frequency of diary intrusions (day 1)	6	2
617, Experiment 3	Interference	Frequency of diary intrusions (day 7)	9	1
618, Experiment 3	Interference	Frequency of diary intrusions (day 6)	2	0
1015, Experiment 4	Interference	Frequency of diary intrusions (day 4)	3	1
1018, Experiment 4	Interference	Frequency of diary intrusions (day 5)	2	0

Appendix 7.1: A short policy article on contemporary media exposure to trauma developed during the PhD

Contemporary Media Exposure to Psychological Trauma: Negative Impact on Public Health

Executive Summary:

1. Media exposure to psychological trauma has been linked to enduring mental health outcomes in the general public, beyond those directly afflicted.
2. Media exposure is at its highest, particularly with social media.
3. Policy needs development in three areas: increasing awareness in the general public; increasing awareness in broadcasters and journalists; developing public health programs.

Devastating collective psychological traumas, such as the ongoing *Syrian Conflict*, the *Boston Marathon Bombing* and the *9/11 Terrorist Attacks,* can spread visually via repeated media broadcasting, turning from local events into real-time global phenomena. For example, ten thousand individuals directly witnessed the *9/11 Attacks*, but millions more worldwide viewed the events both live and in the aftermath.

Challenging prevailing assumptions, recent research hints that media exposure to psychological trauma could potentially lead to enduring and widespread mental health outcomes beyond those directly afflicted.

The media is pervasive

Media exposure is at its highest. In the UK, access to news via smartphones increased from 28% to 42% in the last year [1]. Social media in particular can enhance exposure of unedited material with traumatic content, such as the tragic video depicting the beheading of a British aid worker by the Islamic State extremists.

Clinical symptoms after trauma

A hallmark symptom of mental health disorders related to post-traumatic distress [2] is re-experiencing the trauma, such as in the form of recurrent images, thoughts or nightmares. Other typical symptoms include increased arousal (e.g. sleeping difficulties and irritability) and persistent high levels of low mood. These symptoms can impair daily functioning.

Media exposure to trauma is linked to clinical symptoms in the general public

A widely researched collective psychological trauma has been the *9/11 Attacks*. In one study [3] watching 12 or more hours of 9/11 anniversary news coverage 1 year post-event was associated with increased likelihood of being diagnosed with a stress-related disorder. However, it remained possible that those with more severe symptoms chose to watch more distressing footages.

A more recent study investigated responses soon after trauma [4]. Six or more daily hours of media exposure to the *Boston Marathon Bombing* was associated with higher acute stress response 2 to 4 weeks post-bombing. Such indirect exposure was linked to more severe symptoms than directly witnessing the bombing.

More compelling evidence comes from a study tracking the pattern of stress response for a longer period of time [5]. Higher frequency of early television exposure to footage linked to *9/11*

Attacks and the Iraq War predicted increased acute psychological stress even 2 and 3 years later. Further, exposure to 4 or more hours daily predicted 33% increase in reports of physical health ailments. These effects remained even after ruling out pre-existing mental health and general television watching.

Some may be particularly vulnerable to media exposure

Television exposure to *9/11 Attacks* was associated with acute psychological stress symptoms and functional impairments in children based in the UK, assessed 6 months post-event [6]. Further, patients with pre-existing psychiatric disorders also appear to display similar vulnerabilities [7].

Analogue studies provide consistent findings

Exposure to traumatic footage in laboratory settings has been linked to high levels of anxiety , increased physiological stress reactions and developing aversive memories [8]. Hence, repeated exposure by contemporary media may keep such traumatic images in one's mind, accumulating long-lasting mental health symptoms.

POLICY IMPLICATIONS

Policy needs development in three areas:

1. Increasing awareness in the general public

Media coverage plays an important role in informing the public. However, media outlets (e.g. YouTube, Twitter) beyond traditional platforms can spread undesirable exposure. We need to communicate to the public the importance of limiting exposure.

Messages in everyday setting, such as schools and stores can serve as avenues for delivering psychoeducation. For instance, the American Red Cross delivered a successful campaign encouraging Bostonians to limit their exposure to media coverage of the Marathon Bombing [4]. Further, guidelines for parents can also be developed, such as those by the New York University Child Study Center [9]. At present, the UK is lagging behind in these regards.

2. Increasing awareness in journalists and broadcasters

It is indeed difficult to establish strict rules given the idiosyncratic nature of each event. However, media outlets can benefit from periodically updated guidelines informed by ongoing scientific findings, as to best achieve the balance between 'information' and 'clinical distress'.

A successful precedent is in the area of media images of suicide associated with copycat behaviours [10]. This can provide a platform for writing about the recent surge of knowledge in the area of media-based trauma more broadly.

3. Developing public health programs

Wellbeing approaches following media-based trauma need development. Such initiatives may involve low intensity strategies (e.g. self-help protocols) specifically targeted at this type of exposure, and integrated within existing health infrastructure (e.g., Improving Access to Psychological Therapies Services).

Word count: 736 words

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Appendix 7.2: Dissemination during PhD period

Papers

Di Simplicio, M., Renner, F., Blackwell, S., Mitchell, H., Stratford, H., Watson, P., Myers, N., Nobre, A.C., **Lau-Zhu, A.**, & Holmes, E.A. (2016) An investigation of mental imagery in bipolar disorder: exploring "the mind's eye". *Bipolar Disorders*. (Accepted).

James, E.L., **Lau-Zhu, A.**, Clark, I., Visser, R., Hagernaars, M. & Holmes, E.A. (2016). The trauma film paradigm as an experimental psychopathology model of psychological trauma: intrusive memories and beyond. *Clinical Psychology Review*, *47*, 106-142.

James, E.L., **Lau-Zhu, A.**, Tickle, H., Horsch, A. & Holmes, E.A. (2015). Playing the computer game Tetris prior to viewing traumatic film material and subsequent intrusive memories: Examining proactive interference. *Journal of Behavioural Therapy and Experimental Psychiatry*. (In Press).

Kamboj, S., Langhoff, C., Pajak, P., **Lau-Zhu, A.**, Chevalier, A., & Watson, S. (2015). Bowel and bladder-control anxiety: A preliminary description of a viscerally-centered phobic syndrome. *Behavioural and Cognitive Psychotherapy*, *43(2)*,142-57.

Conference papers/posters

Lau-Zhu, A., Henson, R., & Holmes, E.A. (2016, September). A cognitive-task therapeutic to reduce intrusive (but not deliberate) memories of psychological trauma: What are the mechanisms of action? In Wild, J. (Chair), *How can basic research inform resilience and treatment interventons for Posttraumatic Stress Disorder?* Symposium conducted at the 46th European Association of Behavioural and Cognitive Therapies Annual Conference, Stockholm, Sweden.

Lau-Zhu, A., Henson, R., & Holmes, E.A. (2016, July). Involuntary and voluntary memories of trauma: dissociable routes to consolidation? In **Lau-Zhu, A.**, & Holmes, E.A. (Chairs), *Intrusive emotional memories: A special form of memory challenging mainstream theories?* Symposium organised by **Lau-Zhu, A.** and conducted at the 6th International Conference on Memory, Budapest, Hungary.

Lau-Zhu, A., Henson, R., & Holmes, E.A. (2016, June). *Involuntary intrusions and voluntary memory of trauma films: dissociable routes to consolidation?* Poster presented at 'Travelling in Time' Conference, Centre of Autobiographical Memory Research, Aarhus, Denmark.

Lau-Zhu, A., Henson, R., & Holmes, E.A. (2015, July). *Disrupting intrusions while sparing voluntary memory of experimental trauma: therapeutic promise and theoretical puzzle*. Poster presented at the 43th British Association of Behavioural and Cognitive Psychotherapies Annual Conference, Coventry, UK. [Best Poster Award]

Lau-Zhu, A., James, E.L, Clark, I., Hoppit, L. & Holmes, E.A. (2014, July). *Reducing involuntary image-based memories after analogue trauma using visuospatial tasks: Applying ideas from working memory to emotional psychopathology*. Poster presented at the International Working Memory Conference, Cambridge, UK.

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