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Can't Get It Out Of My Mind: A Systematic Review of Predictors of Intrusive Memories of Distressing Events

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Abstract

Intrusive memories, when persistent and distressing, are theorized to underlie a range of transdiagnostic psychological symptoms and associated impairment. However, little is known about factors predicting the development and persistence of intrusive memories. The aim of this systematic review is to evaluate the literature on pre-event, event-based, and post-event predictors of intrusive memories.

A systematic review was conducted, searching for studies that examined intrusive, event-based memories. One hundred and six articles were identified from PsycInfo, PubMed, and Medline databases. Experimental and prospective studies with clinical (N = 14) and non-clinical (N = 92) samples were critically reviewed, provided the inclusion of an analogue stressor with non-clinical samples, and that intrusive memory frequency and/or distress were assessed as primary dependent variables.

Pre-existing psychopathology and pre-event appraisal style appear to predict intrusive memories (small to medium effects), whereas trait dissociation did not predict intrusive memories. Of studies examining event-based predictors, higher data-driven processing appears to predict intrusive memories with generally large effects. Post-event negative appraisals consistently predicted intrusive memories (medium to large effects), and preliminary evidence suggests higher post-event conceptual processing predicting fewer intrusive memories.

This review synthesizes findings regarding a broad range of pre-event, event-based, and post-event factors that may influence the development of intrusive memories. Methodological issues of current paradigms and the lack of emphasis on memory retrieval processes limit our understanding of what predicts intrusive memory persistence. These limitations are particularly important given that individuals typically seek treatment for distressing intrusive memories once a memory has been fully consolidated, where retrieval processes are of utmost importance.

Keywords

Intrusive memories; intrusive reexperiencing; intrusions; trauma; PTSD

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Intrusive memories are extremely common and normal phenomena; these experiences occur involuntarily after highly emotional events. You may have unexpectedly run into a dear friend you have not seen in years. For several days after this encounter, images of her face and sounds of her joyous shriek as she spots you down the street pop into your head when you least expect them. Each time these memories come into mind, you are reminded of how much you value your relationship, you feel waves of happiness, and are motivated to call her regularly. These same vivid, intrusive memories can also take on a more distressing form if they are memories of an extremely upsetting or dangerous event. You are about to leave for work one morning; you open the door, and your dog escapes. The next thing you know, he is in the middle of the street and your neighbor is slamming on her breaks, beeping her horn as your dog narrowly escapes being hit. In this case, you repeatedly have memories of your dog inches away from the hood of the car popping into your mind while at work. Sometimes the sound of the horn and squealing breaks pop up instead, sometimes images and sounds all at once. You lose focus in the middle of your meetings, your heart races, and have no idea what your tasks are for the week because your mind is elsewhere. When at home, these memories cause you to keep your dog shut in the back room when you leave, with no chance of running out into the street. In both examples, intrusive memories lead to changes in behavior. In the case of intrusive memories related to a distressing event, they are disruptive, in this example causing increased emotional and physical arousal and impaired concentration and functioning at work.

Intrusive re-experiencing is an umbrella term that often is used to refer to a broad range of ways in which the memory of a previously experienced event can resurface, from flashbulb-like images to nightmares, to thoughts accompanied by emotional distress when cued by some type of reminder of the event. More specifically, the term “intrusive memories” is often conceptualized as a particular form of intrusive re-experiencing. Intrusive memories are typically experienced as intense, brief, and vivid image-based recollections of a specific autobiographical event (e.g., Ehlers & Steil, 1995; Brewin & Holmes, 2003; Brewin Gregory, Lipton, & Burgess, 2010). They are predominantly involuntary, often coming to mind without any attempt at deliberate memory retrieval (e.g., Bernsten, 1996), and they often include strong sensory-perceptual elements of the event (e.g., most threatening or salient images, sounds, smells; Conway & Pleydell-Pearce, 2000; Ehlers et al., 2002; Ehlers, Hackmann, & Michael, 2004).

Within the construct of intrusive memories, several common terms are used, and there is considerable variation in definitions across studies. One term is “flashbulb” memories. Flashbulb memories refer to an almost photographic (e.g., vivid, detailed, brief) memory of a snapshot-like moment of an autobiographical event (e.g., Brown & Kulik, 1977; Conway, 1995). Another commonly used term is “flashbacks.” Beyond the vivid, highly perceptual “here and now” quality of intrusive memories, flashbacks are often considered qualitatively distinct from intrusive memories. Flashbacks involve a feeling of “nowness,” a disconnection from the reality of time and place, where individuals perceive that the distressing event is truly happening to them again (e.g., Ehlers & Clark, 2000; Brewin et al., 2010). Flashbacks can occur following distressing experiences and are thought to reflect more pathological intrusive memories seen in disorders such as posttraumatic stress disorder (PTSD; e.g., Priebe, Kleindienst, Zimmer, Koudela, & Ebner-Priemer, 2013; McNally, 2003;

Bernsten, 2001). There is considerable debate whether flashbacks are simply a particularly vivid form of intrusive memory or whether they are a distinct type of involuntary intrusive memory (McNally, 2003); and, consistent with this, the term “perceptual memory” (e.g., Brewin, 2014) hypothesizes a separate long-term perceptual memory storage system distinct from episodic memory. This lack of clarity is further evidenced in the intrusive memory literature, as some studies use the term “flashback” to describe what most would agree is an intrusive memory rather than assessing the added component of disconnection from time and space. Both the DSM-5 and the proposed ICD-11 shifted the definition of flashbacks to be more inclusive, with a flashback being anything from a very brief disconnection from reality to a more severe, prolonged episode (APA, 2013), as Brewin (2015) discussed recently. With this lack of confluence of terms, accordingly, we will refer to intrusive re-experiencing as a global term that incorporates the full spectrum of ways in which autobiographical memory for a distressing event can be experienced (e.g., images, thoughts, physiological arousal to cues, nightmares). We will refer to intrusive memories as a more specific form of re-experiencing, reflecting involuntary memory of a particular event itself. This definition includes flashbulb memories and flashbacks under this rubric of intrusive memories.

Intrusive memories after highly distressing events are common and their experience is not necessarily pathological (e.g., Bernsten, 2001; Bywaters, Andrade, & Turpin, 2004; Shalev, 1992; Watkins, Grimm, & Kolts, 2004). Typically, these memories naturally diminish over time (McFarlane, 1988; Shalev, 1992; Steil & Ehlers, 2000). However, in a minority of individuals, intrusive memories persist and are considered pathological. Indeed, persistent intrusive memories of the event are a hallmark symptom of PTSD. However, individuals with depression also commonly experience intrusive memories following stressful life events (e.g., death of a loved one) that often lead to depressive episodes (e.g., Williams, Watts, MacLeod, & Mathews, 1997) but do not lead to PTSD. Indeed, distress associated with intrusive memories not only correlates with severity of PTSD symptoms (e.g., Hackmann, Ehlers, Speckens, & Clark, 2004) but also depressive symptoms (e.g., Freeston, Ladouceur, Thibodeau, & Gagnon, 1992; Brewin, Reynolds, & Tata, 1999; Patel et al., 2007). When we consider the broader construct of intrusive re-experiencing, intrusive re-experiencing occurs across many disorders such as specific phobias, social anxiety, panic disorder, and obsessive-compulsive disorder (e.g., Breitholtz, Westling, & Ost, 1998; Lipton, Brewin, Linke, & Halperin, 2010; Speckens, Ehlers, Hackmann, Ruths, & Clark, 2007; Hackmann, Clark, & McManus, 2000; Reynolds & Brewin, 1998; Patel et al., 2007). Of note, intrusive images experienced by individuals with panic disorder, OCD, social phobia and specific phobias tend to be less strongly linked to autobiographical memories of past events, though this does occur (e.g., Breitholtz et al., 1998; Lipton et al., 2010; Hackmann et al., 2000). Highlighting this distinction between intrusive memories of autobiographical events and those related to fears of the future or hypothetical catastrophic outcomes, theorists have long distinguished between mental representations of the *real world* and *imaginary* or *possible* worlds (e.g., Johnson-Laird, 1983; Williams et al., 1997). Intrusive images and thoughts also occur in psychosis, though such thoughts and images may or may not be anchored in the real world. Other intrusive spontaneous thoughts that are not necessarily anchored in autobiographical memory often relate to unattained goals (e.g., Marchetti, Koster, Klinger, & Alloy, 2016) and future fears of unrealistic events (e.g., Lipton

et al., 2010). In sum, while there are clear overlaps in intrusive re-experiencing across a range of psychopathology, not all such forms of re-experiencing represent intrusive memories.

Despite a large body of literature examining predictors of intrusive memories following a distressing event, a systematic review of this literature is lacking. Temporally, there are likely pre-existing vulnerability factors, event-related factors, and post-event factors that are all important to consider in understanding what predicts the development and persistence of intrusive memories over time. If we are able to better understand factors that lead to the development and maintenance of intrusive memories over time, we can better tailor preventative and therapeutic interventions targeting intrusive memories to make these interventions more effective, efficient, and more easily able to be disseminated.

Prominent Theoretical Models of Intrusive Memories

According to the prominent models, intrusive memories are thought to form based on the way the event is encoded in memory (e.g., Conway & Pleydell-Pearce, 2000; Foa, Sketekee, & Rothbaum, 1989; Brewin et al., 2010). In general, memories of emotional events tend to be more persistent and vivid (e.g., Christianson, 1992), which makes sense evolutionarily, given that emotional memories were often critical for survival. Thus, there may be unique neurobiological underpinnings of emotional memory encoding not seen in the encoding of other kinds of memory that allows these memories to persist longer and be more readily available for retrieval. Indeed, Phelps (2004) suggests an interaction between the amygdala and hippocampal lobe occurs during the encoding of emotional memory, wherein the amygdala is able to modulate the encoding and storage processes. Fittingly, when a memory undergoing consolidation is emotional in nature and the amygdala is more activated, the degree of amygdala activation during encoding is positively correlated with later memory recall (e.g., McGaugh, 2004). In other words, an individual higher in stress or distress as an event is being encoded, according to these theories of stress and memory, will likely encode a more persistent, durable memory due to greater amygdala activation modulating hippocampal encoding processes (e.g., Cahill & McGaugh, 1998; McGaugh, 2004; McGaugh, 2014; Phelps, 2004).

In a specific theoretical account of intrusive memories incorporating both cognitive and neurobiological processes, Brewin and colleagues (2010) and Brewin and colleagues (1996) emphasize two different theorized types of memory representations. Sensory representations, or S-reps, are perceptual, sensory images that can only be retrieved involuntarily once a traumatic memory is encoded. In contrast, during encoding, contextualized representations (C-reps) correlate with where conscious attention is focused, and can be retrieved both involuntarily and voluntarily. C-reps can also be communicated and reappraised, unlike S-reps. In this model, when an emotional memory is encoded, both C-reps and S-reps are longer lasting than those of a neutral memory. For individuals who experience an extremely distressing event but recover naturally, the S-rep has a corresponding C-rep, which then allows for the memory to be filed in the autobiographical memory “library”, thus available for voluntary retrieval with a relatively low likelihood of involuntary retrieval. However, for some, the very durable S-rep may be cued for retrieval by

a particular affective state or environmental cue associated with the original memory, thus causing involuntary retrieval. C-reps are thought to modulate this retrieval process, but the process can also occur in the alternate order. Intrusive memories may also arise when a C-rep involuntarily activates a corresponding S-rep, which then provides the vivid sensory and emotional components of the involuntarily retrieved memory. Brewin and colleagues (2010), in their revised theory that accounts for intrusive images across a wide range of psychological disorders, make a distinction between perceptual and episodic long-term memory storage and point to evidence of reduced bilateral inferior temporal cortex volume and lower activation of the parahippocampal gyrus (medial temporal lobe) in patients with flashbacks, arguing that these areas of the brain are implicated in processing of contextual visual and spatial information.

With a similar emphasis on sensory-perceptual encoding of emotional memories as Brewin and colleagues, Ehlers and Clark's (2000) and Ehlers and colleagues' (2004) model emphasize the roles of data-driven processing and lack of self-referent processing. According to their cognitive theory, intrusive memories develop in individuals who are primarily encoding sensory-perceptual details without the broader context and conceptual organization that helps make sense of the event as it is happening. In other words, an event encoded primarily as fragmented sensory details (e.g., a loud bang, an image of a face, darkness, and the sound of sirens) is much more likely to re-emerge as an intrusive memory than a memory of the same event encoded in a more conceptual, organized manner (i.e., "I walked into my house one night and was confronted by an armed robber. As he threatened me, he fired his gun into mid-air. I fled, called 911, and felt relief as the cops arrived."). This data-driven processing leads to the lack of self-referent processing, in that individuals are unable to place a memory with little conceptual detail/organization into their broader autobiographical memory library. Further, sensory perceptual details of immediately before and during the event, often poorly discriminated from other parts of the memory, are understood by the individual as "warning signals" (Ehlers et al., 2004) and will easily cue intrusive memories and other trauma responses. If an individual then negatively appraises an intrusive memory (e.g., "This must mean I am going crazy" or "I have permanently changed for the worse"), this likely leads to increases in negative emotions and subsequent maladaptive coping behaviors like thought suppression, avoidance of reminders that may cue intrusive memories, etc. that ultimately maintain intrusive memories long-term. Within this model, Ehlers and colleagues did not posit specific neurobiological mechanisms implicated in the development and persistence of intrusive memories.

Alternatively, retrieval-based models suggest that greater access to the explicit memory of an event predicts intrusive memories and other PTSD symptoms, rather than the manner of the event encoding (e.g., Conway, 2005; Rubin, Bernsten, & Bohni, 2008). According to these retrieval-based models, the more information encoded, regardless of modality of encoding, will lead to increased voluntary and involuntary memories following the event. Further, because emotional memories are more readily available for retrieval, these memories will be better rehearsed than neutral memories, making them increasingly more likely for future retrieval. In addition, and specific to involuntary distressing memories, retrieval is typically accompanied by an intense emotional response (fear, anger, sadness, etc.). If a memory is retrieved and paired with intense emotional responding, this then further increases the

salience and strength of the memory as it is restored to long-term memory, and increases likelihood of future retrieval. Neurobiologically, it is thought that when an emotional memory is retrieved, brain areas that were activated during initial encoding are reactivated and produce an affective state comparable to that during memory encoding (Buchanan, 2007). Specifically, activation of the amygdala and medial prefrontal cortex typically occurs, as well as hypothalamic and brainstem activation, eventually leading to a range of responses (i.e., physiologic, autonomic). It is worth noting that the experience of an affective state can serve as a cue for memory retrieval (e.g., the feeling of fear cuing an intrusive memory of a rape) in addition to an external reminder (e.g., a man who resembles the perpetrator) serving as the initial retrieval cue. In both cases, the neurobiological activity is thought to closely resemble that of encoding.

Ironic control theory, while not specifically emphasizing intrusive memories, posits mechanisms through which thought suppression leads to an increased, rather than decreased, frequency of an unwanted thought or image (Wegner, 1994). According to Wegner and colleagues (1987), thought suppression requires both a plan to suppress a thought, as well as the actual carrying out of this plan, by “suppressing all manifestations of the thought, including the original plan” (p. 5). Based on ironic control theory, the mechanism through which thought suppression is thought to occur is via two mental processes: an operating process and a monitoring process. The operating process functions to achieve the intended mental state (e.g., not worrying about a test, pushing away memories of a car accident) by searching for relevant mental content. During thought suppression, the operating process is working to successfully suppress the unwanted thought or image by searching for alternative material unrelated to the unwanted thought or image. This would distract from the unwanted thought or image. Simultaneously, the monitoring process is scanning for mental content that goes against the intended mental state, in order to determine whether the operating process is required. In the case of thought suppression, the operating process is often undermined due to cognitive load (e.g., multitasking, any current distraction), and the monitoring process, thought to be less effortful, kicks in, thus bringing into consciousness the unwanted thought (i.e., the mental content inconsistent with the intended mental state) by increasing their activation (Wegner, 1992; 1994). Accordingly, intrusive memories are thought to be the product of either an undermined operating process and/or a failed monitoring process.

Taken together, prominent models of memory intrusions vary in the weight they place on potential encoding or retrieval processes and the specific mechanisms by which intrusive memories are formed and maintained.

Possible Predictors of Intrusive Memories

Pre-event vulnerability factors, peri-event-related factors, and post-event factors are potential candidates for key predictors of the development and persistence of intrusive memories. In this next section, key constructs commonly reported in the larger literature will be introduced and defined for the subsequent systematic review. Particular attention will be paid to the relationship of these constructs to psychopathology, particularly PTSD, depression, and anxiety. Indeed, large meta-analyses have consistently pointed to the relative

importance of during event and post-event factors over pre-event factors in the development of PTSD (e.g., Brewin et al., 2000; Ozer, Best, Lipsey, & Weiss, 2003; Trickey et al., 2012). It should be noted that below is a not a comprehensive list of potential factors predicting intrusive memories or a review of pre-, during, or post-mechanisms underlying intrusive memories, rather a brief overview of factors commonly implicated in the literature to date.

Pre-existing factors

Factors such as pre-existing psychopathology (e.g., Laposa & Alden, 2008; Regambal & Alden, 2009), biological vulnerabilities (e.g., Cheung & Bryant, 2015; Soni, Curran, & Kamboj, 2013), perceptual priming (e.g., Ehlers et al., 2006; Sundermann, Hauschildt, & Ehlers, 2013), tendency to use mental imagery (e.g., Davies & Clark, 1998a; Morina, Liebold, & Ehring, 2013), negative beliefs and appraisals (Lang, Moulds, & Holmes, 2009; Woud, Postma, Holmes, & Mackintosh, 2013), and working memory capacity (Hagenaars & Putnam, 2011; Wessel, Overwijk, Verwoerd, & de Vrieze, 2008) likely affect the development of intrusive memories. In particular, the presence of prior trait anxiety, depression, or dissociation may make an individual more likely to later experience memory intrusions. Similarly, pre-existing biological vulnerabilities may include being female, specific genetic variants or polygenetic risks, the chronic use of alcohol or drugs, and higher levels of stress and related noradrenergic activity.

Individuals may also vary in how they generally encode and process information. Perceptual priming is a form of implicit memory that is characterized by an individual being more likely to recognize perceptual parts of a memory such as sounds, smells, or touch due to previous exposure to those elements (Schacter, 1992). These perceptual traces are thought to acquire the ability to elicit involuntary memory retrieval (Ehlers & Clark, 2000). Individuals may vary in their general use of a more perceptually-oriented processing style, making them more vulnerable to later intrusive memories. Similarly, individuals who tend to use or are good at mental imagery, that is, being able to vividly developing pictures in their mind without environmental stimuli, may be more vulnerable to intrusive memories, given that intrusive memories are often image-based memories of an event. Individuals may also differ in their general appraisal style. Individuals with more negative appraisal styles may be more vulnerable to developing intrusive memories. This general negative appraisal style may include beliefs about oneself (e.g., “I am a bad person.”), the world or situations (e.g., “The world is a dangerous place.”), or the presence of psychiatric symptoms (e.g., “This must mean I am going crazy.”) and may alter how new information is processed and remembered. Finally, individuals also vary in their working memory capacity. Working memory is an executive function through which we hold and process information (e.g., Diamond, 2013), and working memory capacity is the amount of information that can hold in working memory at a particular time. Those with lower working memory capacity may be more vulnerable to later intrusive memories, given decreased cognitive control and ability to let go of information that is no longer relevant.

Event-related factors

The above pre-event factors may subsequently alter how a new event is initially encoded and processed but also event characteristics themselves may alter processing styles. More severe

or life threatening events may be more likely to elicit memory intrusive memories. Related, higher peri-traumatic levels of physiological arousal during an event or its immediate aftermath may increase development of intrusive memories, particularly events that result in higher negative emotional arousal (e.g., Hall & Bernsten, 2008) and increased noradrenergic activity (e.g., Cheung, Garber, & Bryant, 2015; Nicholson, Bryant, & Felmingham, 2014). Similarly, higher peri-traumatic dissociation, reflecting a disconnection between what is occurring and the person experiencing it, may also alter what is encoded. This dissociative processing may shift attention and lead to an inability to properly integrate available information about an event in a way that makes sense (Ozer et al., 2003), making later intrusive memories more likely (e.g., Holmes, Brewin, & Hennessy, 2004; Mairean & Ceobanu, 2016).

Events that are more perceptually processed may be more vulnerable to later intrusive memories (e.g., Bourne, Frasquilho, Roth, & Holmes, 2010; Holmes et al., 2004). Specifically, the term data-driven processing refers to heightened sensory-perceptual processing, where information that can be processed using the five senses is primarily being encoded. In contrast, the term conceptual processing refers to chronological, contextual processing of information, where individuals can make meaning of what is happening, and organize it in a way that makes sense (Roediger, 1990). Data-driven and conceptual processing are thought to occur simultaneously, yet the strength of one type of processing versus the other can vary from person to person and situation to situation. Similarly, events that are decontextualized may be more vulnerable to later intrusive memories (e.g., Krans, Pearson, Maier, & Moulds, 2016; Pearson, Ross, & Webster, 2012). Contextual information refers to time, place, etc., as well as information about what happened leading up to and during a distressing event. It is thought that contextual information helps with memory integration, elaboration, and allows for new learning and shifts in perspective (e.g., Liberzon & Sripada, 2007; Garfinkel et al., 2014). Importantly, context as factual information taken in by a third-person observer is quite distinct from context information from an autobiographical event that allows for changes in meaning and understanding.

Post-event factors

Memory consolidation, reconsolidation, and retrieval processes are also important to consider, given that memories are not simply encoded and then unable to be altered. Recent work has focused on the potential role of memory reconsolidation (e.g., Parsons & Ressler, 2013), as well as stress levels during memory retrieval (e.g., Smeets, Otgaar, Candel, & Wolf, 2008) as possible drivers of intrusive memory persistence.

How personally relevant a memory is may affect the strength of the memory and later retrieval. Vantage perspective is one specific construct related more to retrieval rather than encoding, where individuals who retrieve distressing memories from an observer perspective may be more likely to report factual and descriptive information, whereas individuals who experience the memory from a field perspective may be more likely to report highly distressing information such as emotional and physical details of the experience (McIsaac & Eich, 2004). This later field perspective may make individuals more vulnerable to memory intrusions.

Post-event negative appraisals of the event itself and of the intrusive memories themselves may also increase the likelihood of future intrusive memories. Typically, negative appraisals are thought to lead to increased distress, which increases retrieval strength and the likelihood of a future intrusive memory, and may lead to avoidance behaviors (e.g., Ehlers & Steil, 1995; Starr & Moulds, 2006). Indeed, a general pre-event negative appraisal style, discussed earlier, may predispose an individual to negatively appraising the specific distressing event and related intrusive memories.

Finally, cognitive avoidance strategies such as rumination and thought suppression may exacerbate intrusive memories. Rumination is considered to be a response that involves focusing on distress in a repeated and passive manner (Nolen-Hoeksema, 1991), in a way where new learning or shifts in perspective is unlikely to occur. Further, when individuals ruminate, they think about the possible causes and consequences of their symptoms. A second and perhaps more overt cognitive avoidance strategy, thought suppression, is defined as a conscious attempt to stop thinking about a specific thought. Periods of thought suppression are typically followed by a "rebound effect," which is a later resurgence of the thought or image at a higher frequency than previously experienced (Wegner, Schneider, Carter, & White, 1987; Wenzlaff & Wegner, 2000).

Although potential factors increasing the likelihood of intrusive memories are grouped into pre-, during, and post-event factors, undoubtedly these factors interact with one another to influence how information is processed, what was encoded, and how the event is remembered.

Summary

Intrusive memories are integral to theoretical accounts of PTSD, depression, anxiety disorders, and general memory models. A large body of literature exists that examines what may predict intrusive memories, based on theoretical accounts of what predicts the development and maintenance of PTSD. Pre-existing vulnerabilities (e.g., pre-existing psychopathology, negative beliefs, perceptual priming, and biological factors), event-based processes (e.g., sensory vs. chronological processing, peritraumatic dissociation), and post-event factors (e.g., cognitive appraisals, rumination, thought suppression) may all be relevant when considering who is most likely to develop intrusive memories. However, a notable gap in the intrusive memory literature is a systematic review of what predicts the occurrence of these memories, both in the immediate aftermath of distressing events and over the longer term.

Review of Predictors of Intrusive Memories

A systematic review of predictors of intrusive memories is particularly critical given multiple factors that are mechanistically implicated in the genesis and persistence of memory intrusions. Much of the research to date on what predicts intrusive memories has been conducted using experimental manipulations with analogue events (i.e., distressing film paradigm, valenced picture sets), while much of the research examining the relationship between intrusive memories and psychiatric disorders has looked at clinical samples who have already experienced trauma. In order to gain a better, more comprehensive

understanding of intrusive memories, the integration of clinical and analogue studies is necessary. At the present time, the high number of predictors and the variability of study designs argues that a synthesis of the extant literature is needed and that a meta-analysis would be combining veritable “apples” and “oranges” from a small number of studies of varying designs for analyses, including substantial variability in the definition of the key dependent variable across studies (e.g., intrusive memories after 5 min vs. 1 week, frequency vs. distress of intrusive memories). Notably, there is a lack of prospective clinical studies examining intrusive memories; the clinical studies that do examine intrusive memories specifically tend to be cross-sectional, limiting causal interpretations. Also important to note is the distinction between intrusive memory *development* and intrusive memory *persistence;* intrusive memory development refers to the initial presence of intrusive memories soon following a distressing event, whereas intrusive memory persistence refers to the presence of intrusive memories longer-term. Unfortunately, the vast majority of studies to date emphasize intrusive memory development over persistence, so our understanding of what predicts intrusive memories is largely focused on what predicts intrusive memory development.

Better understanding of the relative contribution of pre-existing vulnerabilities, specific event-related processing, or post-event processing factors in the occurrence and maintenance of intrusive memories may help in designing interventions to prevent their persistence over time and better tailoring interventions that target unwanted intrusive memories. This systematic review examined consistency of findings across prospective clinical and analogue experimental studies regarding pre-event vulnerabilities, event-based predictors, and post-event predictors of intrusive memories following a distressing event. Extrapolating from prior meta-analytic studies of predictors of PTSD where there is more consistent evidence for event-based (e.g., trauma severity) and post-event (e.g., lack of social support) factors predicting the development of PTSD and weaker and less consistent evidence for pre-trauma factors (e.g., pre-existing psychopathology, prior trauma exposure; Ozer et al., 2003, 2008; Brewin et al., 2000; Trickey et al., 2012), we hypothesized that event-based and post-event factors would be more consistently associated with intrusive memories than would pre-event factors. Specifically, with regard to event-based factors, we hypothesized that lower peritraumatic dissociation and higher conceptual processing would predict lower intrusive memories, based on peritraumatic dissociation being a strong predictor of PTSD (e.g., Ozer et al., 2003) and theories implicating contextual information processing (e.g., Bouton, 1993). With regard to post-event factors, we hypothesized that lower rumination and less negative cognitive appraisals would lead to lower intrusive memories, based on the broader theoretical and empirical literatures linking appraisals and rumination to the maintenance of overall PTSD and depression symptoms (e.g., Ehlers & Clark, 2000; van den Hout & Engelhard, 2004; Clohessy & Ehlers, 1999; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008).

Method

A search of peer-reviewed empirical articles from the following databases was conducted: PsycInfo, PubMed, Medline, and the Cochrane Database. Key terms that were included were: (*intrusive memories* OR *intrusive reexperiencing* OR *intrusions*) AND (*posttraumatic*

stress disorder OR *PTSD* OR *post-traumatic stress disorder* OR *post traumatic stress disorder* OR *MDD* OR *depression* OR *major depression* OR *major depressive disorder* OR *generalized anxiety disorder* OR *GAD* OR *dysthymia* OR *panic disorder* OR *agoraphobia* OR *social anxiety disorder* OR *social phobia* OR *specific phobia* OR *obsessive compulsive disorder* OR *OCD*). No date of publication restrictions were used. Articles were limited to those published in English that were peer-reviewed empirical articles; dissertations, book chapters, books, and case studies were not included. Additional articles were identified by careful examination of reference lists of studies selected using the search terms above. The search date was January 16, 2017.

Inclusion, exclusion, and design of selected studies

We selected studies that included adult participants 18 years of age and over that reported at least one relationship between at least one independent variable and intrusive memories. We included studies that were either experimental or prospective, with either clinical or non-clinical samples. Inclusion of both clinical and non-clinical studies allowed for the exploration of whether findings from more tightly controlled experimental studies using analogue events hold when examining real-world events in clinical samples. For clinical samples, inclusion criteria were limited to studies of individuals with mood, anxiety, and traumatic stressor-related disorders, as these categories of disorders most commonly report intrusive memories. Due to reality testing concerns, psychotic disorders were not included. We did not include cross-sectional studies or clinical treatment trials. Cross-sectional studies do not allow for causal inferences to be made, and treatment outcome studies were similarly excluded because of the focus on predicting the occurrence of intrusive memories, rather than the remittance of intrusive memories. Studies were excluded if they did not include a specific assessment of intrusive memories, given that was the key dependent variable of interest. As stated above, flashbulb memories and flashbacks were considered forms of intrusive memories. Studies that only included a self-report or interview measure of broader re-experiencing symptoms (e.g., subcluster score of re-experiencing in PTSD), without specificity for intrusive memories, were excluded. We differentiated between intrusive *memories* related to some prior event and other forms of intrusive memories (such as characteristic of obsessions) due to spontaneous memory processes being distinct from intrusive thoughts and intrusive future-oriented worry. Included studies examined event-based intrusive memories, either from a real-world event or an analogue distressing event, given that predictors of other types of intrusive memories may differ from those of event-based intrusive memories. If the event was a real-world negative event, it did not have to meet DSM definition of a traumatic event traumatic event but could be any negative life event that led to intrusive memories of the event. We chose not to limit studies to DSM traumatic events given that intrusive memories develop following a range of negative experiences (e.g., Gold, Marx, Soler-Baillo, & Sloan, 2005; Smyth, Hockemeyer, Heron, Wonderlich, & Pennebaker, 2008).

Using the results from the original search terms, articles were identified. Articles were excluded examining the title, abstract, or full text version based on the following criteria: not in English; participants were under the age of 18; if a clinical study, did not include participants with a mood, anxiety, or traumatic-stressor related disorder; were case studies,

dissertations, or other non-empirical articles; did not include an assessment of event-based intrusive memories; not prospective or experimental; or did not examine an association between at least one independent variable and intrusive memories. A consort diagram of the study selection process with specific numbers of studies excluded based on each criterion is shown in Figure 1. Excluded studies and the primary reason for their exclusion are presented in Table 1.

A summary of included study characteristics can be found in Table 2 (Pre-event Predictors), Table 3 (Peri-event Predictors), and Table 4 (Post-event Predictors). In Tables 2, 3, and 4, under “Sample,” we list whether any exclusion criteria were used in non-clinical analogue studies. Under “Study Design,” we list whether the study was a randomized or prospective study. In the “Independent Variables” column, we list any measures used to assess particular constructs, and also any conditions or groups being compared. The “Intrusion Variables Reported” lists the intrusive memory variables that were used as dependent variables in a given study. Importantly, many studies assessed intrusive memory distress, but simply used that data to decide whether to include a given intrusive memory in the intrusive memory frequency count, rather than using intrusive memory distress as a dependent variable. In such cases, distress is not listed as it is not a dependent variable. The “Intrusion Assessment Timing” column lists “During” and “7 Day,” as these are the most commonly used timepoints for assessments. “During” refers to during the experimental session. If a study uses other assessment timing, this is specified here as well. The “Intrusion Measurement” column includes an “Other column”, where assessments that are not intrusive memory monitoring or intrusive memory diaries are listed.

Results

We first examine pre-existing factors that may predict intrusive memories. We then review factors during the event itself, and end with an examination of post-event predictors of intrusive memories. In total, 106 articles were included in this review; of those 106 studies, 14 studies included clinical samples of some kind (e.g., trauma-exposed, PTSD, depression, dysphoria, etc.). Within each section, studies using clinical samples will be discussed first, followed by analogue studies.

Pre-event Predictors of Intrusive Memories

While no clinical studies have looked at pre-event characteristics as potential vulnerabilities for developing intrusive memories, thirty-seven analogue studies have done so. Pre-event characteristics include pre-existing traits and psychopathology (Bomyea & Amir, 2012; Davies & Clark, 1998a; Hagenaars, van Minnen, Holmes, Brewin, & Hoogduin, 2008; Hagenaars & Krans, 2011; Halligan, Clark, & Ehlers, 2002; Holmes, Brewin, & Hennessy, 2004; Kamboj et al., 2014; Kubota, Nixon, & Chen, 2015; Laposa & Alden, 2008; Logan & O’Kearney, 2012; Mairean & Ceobanu, 2016; Marks & Zoellner, 2014; Regambal & Alden, 2009; Schaich, Watkins, & Ehring, 2013; White & Wild, 2016; Williams & Moulds, 2007a), pre-existing biological factors (Bisby, Brewin, Leitz, & Curran, 2009; Bisby, King, Brewin, Burgess, & Curran, 2010; Cheung & Bryant, 2015; Ferree, Kamat, & Cahill, 2011; Hawkins & Cougle, 2013; Rombold et al., 2016a; Rombold et al., 2016b; Soni, Curran, & Kamboj,

2013; Wegerer, Kerschbaum, Blechert, & Wilhelm, 2014), contextual cues (Ehlers, Michael, Chen, Payne, & Shan, 2006; Michael & Ehlers, 2007; Meyer et al., 2013; Sundermann, Hauschildt, & Ehlers, 2013), appraisal tendencies (Brown, Joscelyne, Dorfman, Marmar, & Bryant, 2012; Lang, Moulds, & Holmes, 2009; Wilksch & Nixon, 2010; Woud, Postma, Holmes, & Mackintosh, 2013), attentional control and working memory capacity (Hagenaars & Putnam, 2011; James, Lau-Zhu, Tickle, Horsch, & Holmes, 2016; Verwoerd, Wessel, de Jong, Nieuwenhuis, & Huntjens, 2011; Wessel, Overwijk, Verwoerd, & de Vrieze, 2008) and use of general mental imagery (Davies & Clark, 1998a; Krans, Naring, Speckens, & Becker, 2011; Morina, Leibold, & Ehring, 2013).

Pre-existing traits and psychopathology—The majority of studies examining effects of pre-existing traits and psychopathology on intrusive memories used analogue distressing film paradigms. Participants were typically administered a battery of self-report measures prior to presentation of a distressing film in order to assess trait and psychopathological vulnerabilities. Film-related intrusive memories were typically assessed after the film while still in session (e.g., 5 min after) or via intrusive memory diary for a specific duration (e.g., 7-day period) post-film. Pre-existing factors included trait anxiety (Bomyea & Amir, 2012; Davies & Clark, 1998a; Laposa & Alden, 2008; Logan & O'Kearney, 2012; Marks & Zoellner, 2014; Regambal & Alden, 2009), depression (Bomyea & Amir, 2012; Davies & Clark, 1998a; Kubota et al., 2015; Laposa & Alden, 2008; Marks & Zoellner, 2014; Regambal & Alden, 2009; Williams & Moulds, 2007a), trait dissociation (Davies & Clark, 1998a; Hagenaars et al., 2008; Hagenaars & Krans, 2011; Holmes et al., 2004; Laposa & Alden, 2008; Mairean & Ceobanu, 2016; White & Wild, 2016), disgust propensity (Bomyea & Amir, 2012), tendency towards data-driven versus conceptual processing (Halligan, Clark, & Ehlers, 2002), tendency toward emotional suppression (Mairean & Ceobanu, 2016; Marks & Zoellner, 2014), rumination (Schaich et al., 2013; White & Wild, 2016; Williams & Moulds, 2007a), and communality (Kamboj et al., 2014) in the development of intrusive memories.

Pre-existing anxiety and depression appear related to one another, but their relationship to intrusive memory development is less clear. Pre-existing anxiety and depression predicted more frequent intrusive memories either directly or indirectly in five out of the eight studies examining this relationship; the other three studies found nonsignificant associations between anxiety, depression, and intrusive memories. Anxiety predicted intrusive memory frequency indirectly via peritraumatic cognitive processing, maladaptive coping strategies, or post-film state anxiety in three studies ($N = 68$, $N = 105$, $N = 148$; Laposa & Alden, 2008; Logan & O'Kearney, 2012; Regambal & Alden, 2009). In a recent well-designed study ($N = 90$), film-related rumination partially mediated the effects of pre-existing depression on intrusive memory frequency, though depression symptoms remained significant after controlling for film-related rumination (Kubota et al., 2015). Depressive symptoms predicted intrusive memory-related distress in a sample of undergraduates ($N = 57$), though the overall model that included ruminative responses, depression, and post-film sadness overall only accounted for 19% of variance of intrusive memory distress (Williams & Moulds, 2007a). Logan and O'Kearney (2012) found that sensory-perceptual interference during film viewing only led to decreased intrusive memories and intrusive memory-related distress for those

high in trait anxiety, but not those with low trait anxiety. Higher trait anxiety and pre-existing depression also predicted higher rumination in response to intrusive memories (Regambal & Alden, 2009), and post-film levels of anxiety (Laposa & Alden, 2008), assessed via self-report questionnaires, also predicted higher intrusive memory frequency. Inconsistent with these studies, Bomyea and Amir (2012), Davies and Clark (1998a) and Marks and Zoellner (2014) found nonsignificant associations between pre-existing anxiety, depression and frequency of intrusive memories, all using the same well-validated measures for assessing these constructs. Marks and Zoellner (2014) found anxiety sensitivity to predict frequency of intrusive memories. Bomyea and Amir (2012) had a small sample size ($N = 30$), whereas Davies and Clark (1998a) and Marks and Zoellner (2014) had relatively large sample sizes ($N = 90$ and $N = 148$, respectively). Overall, the relationship between pre-existing psychopathology and analogue intrusive memories appears mixed; in some cases, the relationship seems to occur via a third variable like rumination or event processing style, whereas in other cases the relationship appears weak. Despite inconsistent findings, a major advantage of these studies was the use of truly prospective designs, with trait factors assessed prior to an analogue distressing event.

In a well-designed prospective analogue study with a moderately sized sample ($N = 61$), Halligan and colleagues (2002) pre-selected non-clinical individuals high and low in data-driven processing based on self-reported assessment of general processing style. Individuals high in trait data-driven processing were also higher in trait anxiety and dissociation, in line with associations between pre-existing vulnerabilities and processing factors. Further, individuals higher in trait data-driven processing reported higher data-driven processing of the distressing film and more frequent and distressing intrusive memories compared to individuals higher in conceptual processing, showing moderate to large effects. One analogue study with a small sample ($N = 30$) found a large effect of disgust propensity as a vulnerability factor predictive of intrusive memories (Bomyea & Amir, 2012). However, this study lacked measurement of peri-event processing and post-film disgust, making it unclear whether disgust affected processing of the film and whether the film elicited disgust.

With respect to trait dissociation, it appears that pre-existing dissociative tendencies are not a good predictor of intrusive memories, given that five out of six studies did not find a significant relationship between trait dissociative tendencies and intrusive memories. Five studies ($N = 79$; $N = 99$; $N = 72$; $N = 148$; $N = 50$) did not find an effect of self-reported trait dissociation on intrusive memories (Hagenaars et al., 2008; Hagenaars & Krans, 2011; Holmes et al., 2004; Mairean & Ceobanu, 2016; White & Wild, 2016). Two of these studies were well designed in their assessment of trait dissociation prior to an induced dissociation manipulation, as they were testing trait dissociation as a direct predictor and also as an indirect predictor via state dissociation (Hagenaars et al., 2008; Holmes et al., 2004). Consistent with these findings but less rigorous methodologically, Hagenaars and Krans (2011) and Mairean and Ceobanu (2016) found trait dissociation was not significantly related to intrusive memories following film exposure once state dissociation was accounted for. White and Wild (2016) similarly found a lack of relationship between trait dissociation and intrusive memory frequency, and state dissociation was not measured as a part of their study. Laposa and Alden (2008) found a medium effect of preexisting trait dissociation on analogue intrusive memories. However, Laposa and Alden did not include a measure of state

dissociation, so it is possible that effects of trait dissociation occur indirectly by increasing likelihood of state dissociation. Notably, post-film state anxiety predicted intrusive memories above and beyond trait dissociation, further arguing against the seminal role of trait dissociation in the prediction of intrusive memories.

With regard to pre-existing rumination, one study experimentally induced rumination and found an effect on intrusive memories, while a second study found no significant effect of self-reported rumination on intrusive memories. Examining the effects of rumination on intrusive memories in a sample of undergraduates ($N = 66$), Schaich and colleagues (2013) employed a pre-film computerized training in order to investigate whether a concrete thinking style led to decreased intrusive memories. Participants were assigned to either an abstract (i.e., analyze the cause and meaning of situation) or concrete processing (i.e., imagine sequence of events as clearly as possible) condition and were presented with a series of positive and negative scenarios. The authors conceptualized the abstract condition as a ruminative condition. Participants trained in a concrete thinking style reported fewer intrusive memories compared to those trained in an abstract thinking style, but the effects were generally small with a large number of analyses conducted without experiment-wide controls. The study did not include a no-training control condition, necessary to determine whether the effects are mainly due to adaptive effects of concrete training or maladaptive effects of abstract training. White and Wild (2016) included a measure of perseverative thinking prior to film exposure, and did not find a significant relationship between this kind of rumination and intrusive memory frequency, but this finding is based on self-report only without any pre-exposure rumination manipulation.

Examining a combination of biological and personality traits, Kamboj and colleagues (2014) looked at the roles of gender, instrumentality (i.e., serving a purpose) and communality (i.e., cooperative member of a group) as they relate to film-related intrusive memories ($N = 79$). Instrumentality and communality were measured via self-report questionnaire prior to film viewing. Low communality predicted increased film-related intrusive memories in the subsequent week for men only, suggesting that communality may actually be a risk factor for intrusive memories specific to men.

In sum, the most conclusive findings from pre-existing traits and psychopathology suggest that higher pre-existing anxiety and depression are likely related to more frequent intrusive memories, and that trait dissociation appears unrelated to intrusive memories. Too few studies have examined rumination and communality to be conclusive at this point.

Pre-existing biological predictors—Nine studies examined pre-existing biological predictors of intrusive memories (Bisby et al., 2009; Bisby et al., 2010; Cheung & Bryant, 2015; Ferree et al. (2011); Hawkins & Cougle, 2013; Rombold et al., 2016a; Rombold et al., 2016b; Soni et al., 2013; Wegerer et al., 2014). Three of these studies (Ferree et al., 2011; Soni et al., 2013; Wegerer et al., 2014) examined menstrual cycle-related factors as they may relate to intrusive memories by measuring hormone levels prior to distressing film exposure in healthy females ($N = 40$, $N = 41$, $N = 37$). Wegerer and colleagues (2014) examined effects of estradiol levels on fear conditioning and intrusive memories using a differential fear conditioning paradigm that included distressing film clips. Lower levels of estradiol

predicted stronger intrusive memories, indexed by combining intrusive memory frequency, length, and distress; however, this finding was mediated by conditioned responding during fear extinction. Progesterone was not significantly associated with any intrusive memory-related outcome variables. Contrary to these findings, Ferree and colleagues (2011) instead found high progesterone levels to predict intrusive memory frequency, but not memory-related distress or vividness, and found no comparable effect of estradiol. Finally, Soni and colleagues (2013) found that an interaction of low estradiol and high progesterone predicted more frequent intrusive memories, rather than low estradiol alone or high progesterone alone. When examining phase of menstrual cycle, women in their luteal phase (Ferree et al., 2011) and more specifically early luteal phase (Soni et al., 2013) reported more frequent intrusive memories than those in other phases of their cycle.

Cheung and Bryant (2015) examined a specific polymorphism thought to be a risk factor for PTSD, FK506 binding protein 5 (FKBP5), as a predictor of intrusive memories. This polymorphism is a modulator of glucocorticoids. In an analogue study using negative and neutral images, participants considered to be high-risk FKBP5 allele carriers reported more film-related intrusive memories than did low-risk allele carriers, showing a large effect (N = 46).

Two studies by Rombold and colleagues (2016a; 2016b) experimentally manipulated stress and noradrenergic activity prior to viewing a distressing film in samples of healthy women. In one study, participants (N = 118) received either a noradrenergic inhibitor, a noradrenergic stimulant, or placebo prior to film viewing. Overall, participants who received the noradrenergic stimulant were slower in decreasing intrusive memory frequency and vividness; there were no differences in changes in intrusive memory distress over time across groups. In the second study, participants (N = 60) received either hydrocortisone (cortisol), or placebo prior to distressing film viewing. There were no differences in intrusive memory frequency, distress, or vividness between conditions, despite individuals in the hydrocortisone condition showing elevated cortisol levels throughout experimental procedures. Thus, while stress and noradrenergic activity may play a role in the trajectory of intrusive memory development and persistence, findings at this point are inconclusive.

Three studies have examined the effects of substance use on later intrusive memories prior to distressing film viewing (Bisby et al., 2009; Bisby et al., 2010; Hawkins & Cougle, 2013), and all three found some effect of substance on intrusive memories. Bisby and colleagues (2009) administered 0.4 or 0.8 g/kg of alcohol or a placebo to healthy participants (N = 48) prior to film viewing. Participants in the low-dose alcohol condition reported more intrusive memories in the week that followed compared to placebo, whereas participants in the high-dose condition reported fewer intrusive memories than placebo. These dose-dependent findings were replicated in Bisby and colleagues' (2010) work (N = 48). Hawkins and Cougle (2013) explored possible effects of nicotine administered prior to film exposure on intrusive memory development in a healthy non-smoking sample (N = 57). Participants ingested either nicotine or placebo and then viewed a distressing film clip. Immediately after the film, participants who had ingested nicotine reported more frequent intrusive memories compared to the placebo condition; however, this difference disappeared over the one-week

follow-up period, where intrusive memory frequency and distress were comparable across conditions.

In sum, menstrual cycle-related factors appear related to intrusive memories, though the specific findings regarding estradiol and progesterone levels as they relate to intrusive memories are mixed. Women in their luteal phase seem to experience more intrusive memories than women in their follicular phase. The relationship between noradrenergic activity and intrusive memories is unclear. High alcohol use appears to predict fewer intrusive memories compared to no use, whereas low dose appears to predict more intrusive memories compared to placebo.

Associative cues—Enhanced perceptual priming was investigated in several studies using neutral or distressing picture stories that were preceded by neutral stimuli. Across these studies ($N = 62$; $N = 92$; $N = 51$ respectively), enhanced priming of preceding neutral stimuli predicted more intrusive memories (Ehlers, Michael, Chen, Payne, & Shan, 2006; Michael & Ehlers, 2007; Sundermann, Hauschildt, & Ehlers, 2013). These studies reported small to medium effects of enhanced perceptual priming on increased frequency of intrusive memories, though in one case, the effect was moderated by a memory elaboration vs. control condition; participants who elaborated on the stimuli immediately after presentation showed less of an effect of perceptual priming than did those who did not elaborate on the experience (Michael & Ehlers, 2007). Notably, intrusive memory rates in two studies were low, with 20–27% reporting intrusive memories (Ehlers et al., 2006; Sundermann et al., 2013) and less than two intrusive memories on average in the other study (Michael & Ehlers, 2007).

Related to perceptual priming is the ability to form spatial memories using neutral stimuli that precede an event. Using a visuospatial contextual cueing task, Meyer and colleagues (2013) asked participants ($N = 82$) to locate a specific target stimulus among distractor stimuli prior to a distressing film. The ability to more quickly locate cues (i.e., form visuospatial memories) predicted fewer intrusive memories, with a moderate effect size, but was not significantly correlated with intrusive memory distress.

In sum, across both perceptual priming and contextual memory studies, there may be some preliminary evidence that these processes affect intrusive memories, despite modest sizes of effects and a limited number of studies to date.

Pre-existing negative appraisals—Four analogue studies have examined effects of tendency to make maladaptive appraisals of situations and internal experiences (e.g., “these kinds of memories mean that I am going crazy”) as a possible vulnerability factor for developing intrusive memories (Brown, Joscelyne, Dorfman, Marmar, & Bryant, 2012; Lang, Moulds, & Holmes, 2009; Wilksch & Nixon, 2010; Woud, Postma, Holmes, & Mackintosh, 2013). All four studies found that negative appraisals predicted more intrusive memories. Cognitive reappraisal training prior to analogue stressor exposure appears to affect the development of later intrusive memories (Lang et al., 2009; Woud et al., 2013). More specifically, participants ($N = 40$; $N = 54$) in a positive cognitive bias condition experienced less intrusive memory distress compared to those in a negative bias condition,

with large effects found in both studies. However, no assessment of actual intrusive memory appraisals was included with the intrusive memory diary, so it is unclear whether the function of the reappraisal training translated to altering the appraisals of later intrusive memories. In an analogue study ($N = 33$) (Brown et al., 2012), a specific type of self-appraisal, self-efficacy, or one's belief in their own abilities, was also found to predict intrusive memories. However, the authors did not report whether induction effects (i.e., high or low self-esteem) were still present 24 hours later. In a somewhat different approach, Wilksch and Nixon (2010) screened participants ($N = 49$) into high and low risk groups for interpreting intrusive memories negatively prior to viewing a distressing film. Individuals who were considered at high risk of developing negative beliefs about intrusive memories experienced more frequent intrusive memories both in session and during the following week, and also experienced more distressing intrusive memories in session than those in the low risk group. These findings held after controlling for depression, PTSD symptoms, and maladaptive cognitions.

In sum, across these four studies, appraisal inductions and the tendency to make negative interpretations consistently increased the occurrence of intrusive memories. In studies that involved experimental manipulation, a better assessment of appraisals during intrusive memory reporting in follow-up periods is warranted to clarify whether the effects of reappraisal training are carrying over to later experiences of intrusive memories.

Attentional control and working memory capacity—Four studies with non-clinical samples investigated the role of attentional control and/or working memory capacity (WMC) in the development of intrusive memories (Hagenaars & Putnam, 2011; James et al., 2016; Verwoerd et al., 2011; Wessel et al., 2008). Hagenaars and Putnam (2011) examined the association of attentional control and the development of intrusive memories ($N = 43$). Though lower attentional control did not directly affect frequency of intrusive memories, it did moderate the relationship between self-reported tonic immobility and intrusive memories, suggesting that higher cognitive control may be a protective factor against intrusive memories. However, assessment of attentional control was solely based on a self-report measure of attention, rather than an actual behavioral attention control task. Verwoerd and colleagues (2011) and Wessel and colleagues (2008) assessed attentional control and WMC via tasks rather than self-report ($N = 85$, $N = 104$). Verwoerd and colleagues (2011) used part of the California Verbal Learning Test to measure participants' ability to resist proactive interference, a specific executive control ability. Participants completed the test and then viewed a distressing film. Participants who demonstrated poorer ability to resist proactive interference reported more intrusive memories the following week after controlling for neuroticism. Consistent with this finding but using a random number generator task to assess cognitive control, Wessel and colleagues (2008) found cognitive control to predict frequency of intrusive memories. However, this finding did not hold for intrusive memory distress or vividness once depression and emotional arousal were controlled for.

James and colleagues (2016) took a different approach and sought to investigate whether a working memory task (Tetris) prior to distressing film exposure could interfere with intrusive memory development. Participants ($N = 56$) either played Tetris for 11 min or sat quietly and then watched a distressing film. This task appeared to not effectively interfere

with intrusive memory development, as there were no significant effects on intrusive memory frequency between experimental and control conditions.

In sum, findings appear mixed with regard to the relationship between WMC and attentional control and intrusive memories. Studies use a range of ways in which to define and assess attentional control and WMC, further complicating overall conclusions.

General mental imagery—Three analogue studies assessed self-reported use of mental imagery prior to distressing film viewing (Davies & Clark, 1998a; Krans, Naring, Speckens, & Becker, 2011; Morina, Leibold, & Ehring, 2013), with one study finding a positive association, one study finding a negative association, and one study finding a nonsignificant association between imagery and intrusive memories. In an undergraduate sample ($N = 67$), Morina and colleagues (2013) found a medium effect of higher vividness of mental imagery pre-film predicting more frequent, vivid, and distressing intrusive memories, independent of trait anxiety, depression, and emotional reactions to the film. In contrast, Krans and colleagues (2011) reported that undergraduates ($N = 59$) who used more mental imagery experienced fewer intrusive memories post-film. Similarly, Davies and Clark (1998a) did not find that mental imagery predicted intrusive memories in a community sample ($N = 90$). Importantly, there was substantial variability in the assessment of imagery across these three studies, ranging from an unpublished self-report questionnaire to a validated self-report questionnaire assessing multiple sensory modalities.

In short, the preliminary evidence of the role of mental imagery to date is weak given the scarcity of studies, divergence of findings, and variability in the assessment of mental imagery.

Other—A final study examined the relationship between autobiographical memory specificity, future event specificity, and intrusive memories. In a sample of non-clinical participants ($N = 101$), Belcher and Kangas (2015) administered the Autobiographical Memory Test (AMT) as well as a test of future event specificity (i.e., imagining a possible future event happening). Participants then viewed a distressing film and tracked intrusive memories for the following week. Overall, the more specific details participants were able to provide (both for past and future events), the fewer film-related intrusive memories they experienced.

Pre-event predictors summary—Evidence in analogue studies suggests that some pre-event vulnerabilities may predict intrusive memories following a distressing experience. Specifically, pre-existing levels of anxiety and depression seem to affect intrusive memories, likely indirectly, though the exact mechanism through which this occurs is less clear. Cognitive appraisals also consistently affect intrusive memories, with a tendency toward negative appraisals and manipulations inducing negative appraisal responses leading to more frequent intrusive memories. There is also preliminary evidence for increased perceptual priming predicting increased intrusive memories. Trait dissociation, in studies to date, does not appear to predict intrusive memories. Findings regarding working memory and mental imagery are inconclusive at this point due to lack of studies and study limitations. Importantly, we found no clinical studies that have examined the role of pre-existing

vulnerabilities on intrusive memories specifically, which limited this section to analogue studies only.

Peri-traumatic Processing Factors

Thirty-four studies have used analogue designs to examine factors during a distressing event and their potential effects on intrusive memories; only one of these studies (Nicholson, Bryant & Felmingham, 2014) was done with a clinical sample. Peri-traumatic factors include processing style (i.e., the types of information encoded during the event; Bourne, Frasquilho, Roth, & Holmes, 2010; Brewin & Saunders, 2001; Holmes, Brewin, & Hennessy, 2004; Kindt, van den Hout, Arntz, & Drost, 2008; Krans, Langner, Reinecke, & Pearson, 2013; Krans, Naring, & Becker, 2009; Krans, Naring, Holmes, & Becker, 2010a; Krans, Naring, Holmes, & Becker, 2010b; Laposa & Alden, 2006; Laposa & Rector, 2012; Logan & O'Kearney, 2012; Morina et al., 2013; Pearson & Sawyer, 2011; Regambal et al., 2009; Segovia, Strange, & Takarangi, 2016; Stuart, Holmes, & Brewin, 2006; Sundermann et al., 2013; White & Wild, 2016), peritraumatic dissociation (Brewin & Saunders, 2001; Chou, La Marca, Steptoe, & Brewin, 2014a; Dorahy, Peck, & Huntjens, 2016; Hagenaars & Krans, 2011; Hagenaars et al., 2008; Holmes, et al., 2004; Holmes, Oakley, Stuart, & Brewin, 2006; Laposa & Rector, 2012; Mairean & Ceobanu, 2016), contextual information (Krans et al., 2013; Krans, Pearson, Maier, & Moulds, 2016; Pearson, 2012; Pearson, Ross, & Webster, 2012; Staugaard & Bernsten, 2014), and biological and emotional arousal during memory encoding (Cheung & Bryant, 2015; Chou, LaMarca, Steptoe, & Brewin, 2014b; Dunn, Billotti, Murphy, & Dalgleish, 2009; Hall & Bernsten, 2008; Holmes et al., 2004; Nicholson et al., 2014; Wegerer, Blechert, Kerschbaum, & Wilhelm, 2013).

Data-driven vs. conceptual processing—Two analogue studies (Halligan et al., 2002; Kindt et al., 2008) sought to manipulate data-driven and conceptual processing through stimulus viewing instructions. Kindt and colleagues (2008) conducted a two-study sequence, first manipulating data-driven vs. conceptual processing *after* a distressing film, and then manipulating processing *before* film viewing, and adding a neutral condition to the manipulation. In the first study ($N = 34$), participants in the data-driven condition wrote about "the separate images and physical details of the horrible scenes" (p. 548, Kindt et al., 2008); whereas participants in the conceptual condition were directed to write about "the rationale for the horrible scenes. What did the director aim to communicate with this film?" (p. 548, Kindt et al., 2008). They found a moderate increase in intrusive memories for participants in the data-driven processing condition compared to the conceptual condition. Contrary to these findings, Halligan and colleagues (2002) found no significant effect of processing condition on intrusive memory frequency in a sample of undergraduates ($N = 61$). They instead found that higher data-driven processing as assessed via self-report questionnaire, regardless of experimental condition, predicted higher intrusive memory distress, a medium effect. In this case, it appears that a pre-existing tendency to process information in a particular way overrode any attempt at manipulating processing style via instructions. Of note, the film used in Kindt and colleagues (2008) study was 29 min, whereas the film in Halligan and colleagues (2002) was 12 min, which may very well affect intrusive memory formation above and beyond processing style.

In addition to examining data-driven vs. conceptual processing via instructional manipulation, a third study ($N = 211$) looked at the possibility of memory disorganization at encoding being predictive of the development of intrusive memories (Segovia et al., 2016). The film was presented in either an organized or disorganized manner. Participants either received instructions to view the film while emphasizing data-driven processing ("Become absorbed in the images and sounds;" "See each scene as a series of unconnected snapshots"), conceptual processing ("Concentrate on the story"; "Try to figure out what is going on") or they received no instructions. However, no significant differences were found regarding memory disorganization or conceptual vs. data-driven processing.

Addressing the possibility that instructional manipulations of processing may be too weak to be effective, nine studies used either verbal or visuospatial concurrent tasks as a way of interrupting either verbal or sensory-perceptual processing during a film. Standard visuospatial tasks included a tapping task, where participants repetitively tapped an irregular pattern on a square keyboard (Bourne et al., 2010; Brewin & Saunders, 2001; Holmes et al., 2004; Krans et al., 2010b; Krans et al., 2013; Pearson & Sawyer, 2011) and a task where participants created cubes and pyramids out of plasticine (Logan & O'Kearney, 2012; Krans et al., 2010a; Stuart et al., 2006). Verbal tasks included counting backwards by a specified interval (Bourne et al., 2010; Krans et al., 2009; Logan & O'Kearney, 2012) or counting from one number to another repeatedly (articulatory suppression; Krans et al., 2010; Krans et al., 2013). There is good evidence from well-designed studies that concurrent visuospatial tasks reduce the frequency of intrusive memories, with consistently large effects (Bourne et al., 2010; Holmes et al., 2004; Krans et al., 2010b; Stuart et al., 2006). Logan and O'Kearney found this effect to be mediated by trait anxiety, wherein the visuospatial distractor task only led to decreased intrusive memories for those high in trait anxiety, compared to participants high in trait anxiety who simply watched the film. Importantly, on the post-film processing measure, participants in the visuospatial distraction task (building plasticine figures) were no different from controls on their level of data driven vs. conceptual processing, suggesting the distractor task did not truly inhibit data driven processing in the manipulation (Logan & O'Kearney, 2012).

Holmes and colleagues (2004) explored the idea of selective resource competition by comparing different levels of visuospatial demand in a sample of undergraduates ($N = 51$). As expected, the more demanding the tapping task, the fewer intrusive memories were reported in the week following, though effect sizes decreased from medium to small as task difficulty increased. With respect to concurrent verbal tasks, Bourne and colleagues (2010), in a community sample ($N = 40$) found an increase in later intrusive memories compared to both no-task control and visuospatial tasks, with large effects. However, five studies ($N = 39$, $N = 58$, $N = 86$, $N = 105$, $N = 24$ respectively) found no strong relationship between type of concurrent task and intrusive memories (Brewin & Saunders, 2001; Krans et al., 2013; Krans et al., 2010; Logan & O'Kearney, 2012; Pearson & Sawyer, 2011), and one study ($N = 76$) found decreased intrusive memories for a verbal enhancement condition compared to a verbal interference condition and a no task condition (Krans et al., 2009). The findings from the latter studies may be explained by differences in task difficulty of concurrent tasks, where general cognitive load may have affected amount of information encoded and thus intrusive memories, rather than effects of task modality on intrusive memories (Krans et al.,

2013; Krans et al., 2010). Indeed, Pearson and Sawyer (2011) manipulated cognitive load in the second of their two-study sequence, and found cognitive load, but not task modality, to predict intrusive memories, where high cognitive load predicted fewer intrusive memories, a medium effect. Further, low rates of intrusive memories were reported in two studies (Krans et al., 2013; Pearson & Sawyer, 2011). Finally, Brewin and Saunders (2001) assessed intrusive memories 2 weeks following film exposure, which is twice as long as other studies and may be addressing intrusive memory persistence rather than intrusive memory development. In sum, although the concurrent visuospatial tasks appear to alter intrusive memory development in several well-done studies, even here, the literature is somewhat mixed.

Four studies used variations of the Cognitive Processing Questionnaire (CPQ; Ehlers, 1998) to assess effects of processing style on intrusive memories from a distressing film or image series (Sundermann et al., 2013; Morina et al., 2013; Laposa & Rector, 2012; Regambal & Alden, 2009). This questionnaire assesses data-driven processing (e.g., “It was just like a stream of unconnected impressions following from each other”) and conceptual processing (e.g., “My mind was very clear and not muddled”) (Halligan et al., 2002). Processing style was assessed via CPQ immediately following an analogue event, with intrusive memory assessments ranging from 5 min to 2 weeks post-film. In these studies ($N = 51$, $N = 67$, $N = 91$, $N = 151$ respectively), data-driven processing was consistently associated with intrusive memory frequency, generally with medium effects (Sundermann et al., 2013; Morina et al., 2013, Laposa & Rector, 2012, Regambal & Alden, 2009), though in one case data-driven processing did not predict unique variance above and beyond other predictors (Laposa & Rector, 2012). These findings are in line with a subset of concurrent task manipulation studies (Bourne et al., 2010; Holmes et al., 2004; Stuart et al., 2006), arguing that, in analogue studies, higher data-driven processing during analogue trauma is associated with more frequent intrusive memories.

In a somewhat different manipulation of processing, two studies examined effects of strategically directing attention to particular aspects of what is happening during a distressing film (Laposa & Alden, 2006; White & Wild, 2016). Laposa and Alden directed participants ($N = 139$) to either pay attention to the medical components of the film, or simply to watch the film, which depicted emergency medical personnel attending to victims of a car accident. Participants with specific instructions to direct their attention to medical procedures reported fewer intrusive memories, a small effect. No differences were found related to intrusive memory distress, and findings could simply illustrate an effect of having instructions on where to focus attention during the film vs. not having any instructions. While Laposa and Alden (2006) were essentially comparing concrete processing of film content to a control condition, White and Wild (2016) compared an abstract processing condition to a concrete processing condition. In their study ($N = 51$), individuals in the abstract condition were told to consider questions such as “why these sorts of things happen” and “what it means for the people involved” (p. 409). The concrete condition was instructed to consider “the sequence of events as they are unfolding” and “what you can see, what you can hear” (p. 409). Participants in the concrete condition reported significantly fewer intrusive memories at one week follow-up compared to participants in the abstract condition, a medium effect.

In sum, there appears to be emerging evidence for higher data-driven processing occurring during memory encoding predicting more intrusive memories. Higher conceptual processing, though less frequently studied and reported, appears to predict fewer intrusive memories. Although a number of studies found no effect on particular data-driven versus conceptual processing manipulations, those with the strongest methods generally found data-driven processing to predict more frequent intrusive memories; when results were inconsistent with this finding, compelling alternative explanations were posited.

Context—Four analogue studies ($N = 58$, $N = 120$, $N = 40$, $N = 40$, respectively) examined the effects of context during a distressing event on later intrusive memories (Krans et al., 2013; Krans et al., 2016; Pearson, 2012; Pearson et al., 2012), three of which found the presence of context information to predict more intrusive memories. Context, as defined in these studies, was manipulated by presenting either distressing images (Pearson et al., 2012; Krans et al., 2013; Krans et al., 2016) or film clips (Pearson, 2012), with or without broader contextual information (e.g., "The scenes depict events that are related to war/crime and violence that have occurred throughout the world" [p. 575, Pearson et al., 2012]). Findings were consistent across three studies, where the presence of context information predicted more intrusive memories in the week following compared to encoding distressing images/film without context information (Krans et al., 2013; Pearson, 2012; Pearson et al., 2012). Of note, though medium effects were observed across studies, intrusive memory rates in the two studies that used images instead of a film were low (Krans et al., 2013; Pearson et al., 2012). Krans and colleagues (2016) used moderate and severe outcome information as their version of context (e.g., fatality for severe, survival for moderate). In this case, severe outcome information led to more intrusive memories following an intrusive memory provocation task, but did not predict increased intrusive memories via diary the following week. Overall, findings are inconsistent with the broader PTSD literature, where the inability to process contextual information during extinction-like processes may be associated with higher PTSD symptoms (e.g., Maren, Phan, & Liberzon, 2013). However, the definition of context used in these studies is quite different from context information in the broader literature, which may explain this discrepancy.

A fifth study looked less at context and more at cue specificity during encoding and the effects of these cues on later film memory retrieval (Staugaard & Bernsten, 2014). At encoding, participants viewed neutral and emotional picture scenes that were paired with either unique or repeated sound. Following encoding, participants completed a retrieval task, where they were presented with the same sound cues presented during encoding. Participants ($N = 32$) were either asked to recall the scene that was paired with the sound (i.e., voluntary retrieval condition), or were asked after sounds were presented whether any of the picture scenes came to mind (i.e., involuntary retrieval condition). Unique sounds predicted intrusive memories moreso than did repeated sounds, a large effect. Unexpectedly, no differences in intrusive memories between emotional and neutral pictures was found, and no measures of distress were taken, indicating that the intrusive memories assessed in this study likely do not parallel pathological intrusive memories.

In sum, while several studies examining context information suggest that the presence of context information leads to more intrusive memories, these findings should be taken with

caution given that context is defined quite differently in these analogue studies as compared to the clinical literature, and also due to the difference between contextual information related to a film that an individual observes as an "outsider" vs. contextual information that may be central to a traumatic event that someone personally experiences.

Dissociation during encoding—Eleven analogue studies have explored the relationship between dissociation during an event and intrusive memory development; five of these studies find some effect of state dissociation on intrusive memories, while the remaining six do not find significant relationships between dissociation during an event and later intrusive memories. Analogue studies use various methods, including inducing dissociative states (Brewin & Saunders, 2001; Dorahy et al., 2016; Hagenaars et al., 2008; Holmes et al., 2004; Holmes et al., 2006), retrospective reporting of state dissociation following an analogue event (Hagenaars & Krans, 2011; Holmes et al., 2004; Laposa & Rector, 2012; Mairean & Ceobanu, 2016), and via changes in heart rate during film viewing (Chou et al., 2014a; Holmes et al., 2004).

Studies that attempted to induce dissociation experimentally used a visuospatial task (Brewin & Saunders, 2001), a dot-staring task (Holmes et al., 2004), staring into a mirror (Dorahy et al., 2016), and hypnotically induced dissociation (Hagenaars et al., 2008; Holmes et al., 2006). Neither Brewin and Saunders (2001) nor Holmes and colleagues (2004) found an effect of experimentally manipulated state dissociation on intrusive memories. Brewin and Saunders ($N = 39$) did not include any form of manipulation check to determine whether dissociation was in fact induced. However, Holmes and colleagues (2004) found higher self-reported state dissociation assessed immediately post-film was moderately related to higher intrusive memory frequency, beyond effects of the study manipulation in a sample of undergraduates ($N = 51$). Dorahy and colleagues (2016), using distressing audio clips rather than film footage, did not find any effect of induced dissociative states on frequency of intrusive memories ($N = 60$). However, those in the dissociative conditions (dot-staring and mirror-staring) did report higher intrusive memory distress in the three days that followed, with no differences between the two dissociation conditions.

With regard to self-reported state dissociation post-film, Holmes and colleagues (2004) found that increases in state dissociation pre- to post-film viewing predicted increased intrusive memories after controlling for dual task activity and trait anxiety. Laposa and Rector (2012) also reported higher state dissociation recorded immediately post-film predicted higher intrusive memory frequency ($N = 91$), but this effect did not remain once self-referent and data-driven processing were controlled for. Mairean and Ceobanu (2016) found self-reported state dissociation to be related to intrusive image frequency; interestingly, state dissociation was not significantly predictive of intrusive thoughts. Hagenaars and Krans (2011) found that self-reported state dissociation did not significantly predict intrusive memory frequency.

Decreases in heart rate, thought to be indicative of dissociative states, were moderately associated with higher intrusive memories in two studies (Chou et al., 2014a; Holmes et al., 2004), though in one case, the relationship was only found in a subset of participants with restricted startle response (Chou et al., 2014). However, no analyses examining a direct

relationship between state dissociation and intrusive memories were conducted in these two studies; thus, it is unclear whether changes in heart rate are in fact indicative of dissociative states.

The two studies that used hypnotically induced dissociation involved an experimenter either providing verbal instructions meant to put participants (N = 16) in a hypnotic state (Holmes et al., 2006) or physically moving participants' heads, limbs, etc. (N = 79) until they reached a state of catalepsy (Hagenaars et al., 2008). In both studies, though manipulation checks showed that those in dissociative conditions did indeed report higher state dissociation while viewing the distressing film, induced dissociation did not appear related to later intrusive memories. Holmes and colleagues (2006) had a very small sample size. Hagenaars and colleagues (2008) found that non-movement conditions reported more frequent later intrusive memories compared to a free-to-move control condition, thus suggesting that state dissociation does not predict intrusive memories above and beyond movement/non-movement.

Overall, findings regarding peritraumatic dissociation and intrusive memories are inconclusive. It is unclear whether manipulated dissociative states are effective in inducing dissociation-like phenomena. Thus, we are left largely relying on retrospective reports of state dissociation following an event, and even these findings are mixed across studies.

Biological and emotional arousal during encoding—Seven studies examined the relationship between arousal during film exposure and later development of intrusive memories (Cheung & Bryant, 2015; Chou et al., 2014b; Dunn et al., 2009; Hall & Bernsten, 2008; Holmes et al., 2004; Nicholson et al., 2014; Wegerer et al., 2013). In a clinical sample (N = 58), Nicholson and colleagues (2014) examined cortisol and noradrenergic activity during encoding. Levels of cortisol and salivary alpha amylase (sAA), markers of stress and noradrenergic activity, were collected several times during exposure to negative, neutral, and positive images. Two days later, intrusive memory frequency was assessed. The interaction between sAA and cortisol predicted frequency of intrusive memories of negative images in the PTSD group but not in the trauma-exposed control or no trauma exposure groups. In the PTSD group, 34% of the variance in intrusive memories of negative images was explained by the cortisol × sAA interaction. In an undergraduate sample (N = 46), Cheung and Bryant (2015) examined the relationship between change in cortisol and salivary alpha amylase levels during film and later intrusive memories, and found no significant relationship between these stress markers and intrusive memory frequency.

Chou and colleagues (2014b) examined cortisol levels at pre-, peri-, and post-film (N = 58). Higher peri-film cortisol levels were moderately predictive of more frequent intrusive memories. However, this effect was isolated to participants who were considered "accelerators" with regard to their cardiac defense response. Accelerators were participants who showed not only a startle response to a probe but also a secondary heart rate increase following probe. Holmes and colleagues (2004) used heart rate as their index of arousal and found that greater reductions in heart rate over the course of the film predicted higher intrusive memories, a medium effect.

In an effort to systematically manipulate levels of emotional arousal during film viewing, Dunn and colleagues (2009) randomized participants ($N = 89$) to emotional suppression, acceptance, or no regulation instructions. However, no significant effect of condition on intrusive memory frequency emerged, even when trait emotion regulation tendencies were controlled for. The suppression condition had a higher proportion of "zero intrusive memory" days recorded on their diaries, indicating that emotional suppression may have impacted later intrusive memories. Hall and Bernsten (2008) used self-reported emotional reactions from participants ($N = 129$) to look specifically at emotional arousal during encoding of images, and found that higher emotions during encoding predicted more involuntary memories of images.

In a slightly different approach to studying arousal during encoding, Wegerer and colleagues (2013) used a novel conditioned-intrusion paradigm in order to examine whether fear conditionability was predictive of intrusive memories. Different sounds were paired with different distressing film segments, and participants ($N = 66$) essentially underwent fear conditioning and extinction, with sounds as conditioned stimuli and film clips as unconditioned stimuli. Fear "conditionability" was indexed using a combination of skin conductance response, stimulus valence, fear levels, and expectancy ratings. Participants with higher fear conditionability experienced more intrusive memories both 30 min post-task and 2 days post-task, suggesting that higher biological and emotional arousal during encoding may be a vulnerability factor at play.

In sum, a range of factors related to biological and emotional arousal have been examined in the intrusive memory literature, yet to date there are not a sufficient number of studies related to any one of these to draw substantive conclusions. It is, however, worth noting that Nicholson and colleagues' (2014) study with a clinical sample found that an interaction of cortisol and sAA predicted substantial variance in intrusive memories specifically in individuals with PTSD.

Summary—The vast majority of studies reviewed in this section are experimental studies with non-clinical samples that examine factors at play during an analogue trauma that may predict the occurrence of event-related intrusive memories. There is generally consistent evidence for higher data-driven processing during an event predicting more intrusive memories. Preliminary evidence suggests that more context information, or prefacing stimuli with what participants should expect, present during encoding leading to more frequent intrusive memories; however, these findings may not generalize to clinical samples. Less consistent evidence exists for higher peri-traumatic dissociation predicting intrusive memories, largely due to limitations in the ability to manipulate state dissociation well. Factors related to biological and emotional arousal during encoding remain elusive due to the range of factors examined as well as the small number of studies to date. Importantly, only one clinical study specifically examined a relationship between peri-traumatic factors and intrusive memories, so these conclusions are almost entirely limited to findings from analogue studies.

Post-traumatic Predictors

The prior pre-event and event-based sections of this review are largely limited by the absence of clinical studies that examine predictors of intrusive memories. There are considerably more prospective clinical studies that examine post-event predictors of intrusive memories, which allows for more careful consideration of whether analogue predictors map onto clinical predictors of intrusive memories. Forty-eight total studies looked at post-event predictors of intrusive memories; 13 of these studies were with clinical samples of some kind. Post-event factors include post-event appraisals and biases (Hagenaars & Arntz, 2012; Kleim, Ehring, & Ehlers, 2012; Newby, Lang, Werner-Seidler, Holmes, & Moulds, 2014; Verwoerd, Wessel, de Jong, & Nieuwenhuis, 2009; Woud, Postma, Dalgleish, & Mackintosh, 2012), rumination (Ball & Brewin, 2012; Ehring, Fuchs, & Klasener, 2009; Ehring, Szeimies, & Schaffrick, 2009; Kubota et al., 2015; Laposa & Rector, 2012; Santa Maria, Reichert, Hummel, & Ehring, 2012; Williams & Moulds, 2007a; Williams & Moulds, 2010; Zetsche et al., 2009), thought suppression and cognitive load (Aikins et al., 2009; Bomyea & Amir, 2011; Bomyea & Lang, 2016; Davies & Clark, 1998b; Geraerts, Hauer, & Wessel, 2010; Gillie, Vasey, & Thayer, 2015; Harvey & Bryant, 1998; Harvey & Bryant, 1999; Nixon et al., 2008; Nixon, Cain, Nehmy, & Seymour, 2009a; Nixon, Cain, Nehmy, & Seymour, 2009b; Nixon & Rackebrandt, 2016; Onden-Lim & Grisham, 2012; Rosenthal & Follette, 2007; Shipherd & Beck, 1999; Shipherd & Beck, 2005; Williams & Moulds, 2007), post-event processing/memory consolidation (Bryant, McGrath, & Felmingham, 2013; Das et al., 2016; Holmes, James, Coode-Bate, & Deeprose, 2009; Holmes, James, Kilford, & Deeprose, 2010; Kindt et al., 2008; Kleim, Wysokowsky, Schmid, Seifritz, & Rasch, 2016; Krans, Naring, Holmes, & Becker, 2009; Luo et al., 2013; Porcheret, Holmes, Goodwin, Foster, & Wulff, 2015; Tabrizi & Jansson, 2016), memory reconsolidation (James et al., 2015; Marks & Zoellner, 2014), vantage perspective (Luo et al., 2013; Williams & Moulds, 2008), and retrieval stress and distress (Cheung, Garber, & Bryant, 2015; Hopwood & Bryant, 2006; Schooler, Dougall, & Baum, 1999). Within this section, clinical studies, if available, will be reviewed first, followed by a review of analogue studies.

Post-event appraisals and biases—One clinical study examined the role of cognitive biases on the presence of trauma-related intrusive memories (Kleim et al., 2012). In this study, the authors examined attentional bias, namely preferential processing of threat-related cues. Two hundred twenty-one assault survivors, ranging 3 to 12 months since assault, were asked to recall frequency and distress of trauma-related intrusive memories from the previous week, and then underwent a blurred picture identification task that included assault-related, general threat-related, or neutral pictures. Individuals with acute stress disorder (ASD) identified assault-related stimuli more quickly than those without ASD (Kleim et al., 2012). This processing advantage toward trauma-relevant stimuli was modestly associated with the frequency of intrusive memories retrospectively reported the week prior to procedures and with the re-experiencing subscale of a self-report PTSD measure.

Four analogue studies have examined the role of cognitive appraisals and biases in the occurrence of event-related intrusive memories; all four studies reported significant effects of negative appraisals or something similar on intrusive memories (Hagenaars & Arntz,

2012; Newby et al., 2014; Verwoerd et al., 2009; Woud et al., 2012). Typically, in order to alter appraisal style, participants undergo a computerized reappraisal training (Newby et al., 2014; Woud et al., 2012). In Would et al. (2012), the training consisted of a series of reappraisal-related vignettes, presented as a sentence completion task to a community sample ($N = 76$). Sentences ended with either a functional or dysfunctional reappraisal. Participants in the positive reappraisal condition, being trained after a distressing film, reported moderately fewer intrusive memories compared to those in a negative attribution condition, though no measures of intrusive memory distress were reported. Newby and colleagues (2014) compared a single session of positive reappraisal training with a single session of cognitive bias psychoeducation session and a no-training control condition in a community sample ($N = 60$). They found a large effect of psychoeducation on intrusive memory distress compared to no training; however, positive training did not significantly differ on intrusive memory distress from the psychoeducation or control conditions. Unfortunately, this study lacked a manipulation check, and neither study assessed appraisals of intrusive memories as part of the intrusive memory dairy. It is thus unclear whether effects were due to reappraisal alterations or another factor like positive or negative valence.

In a slightly different form of reappraisal training, Hagenaars and Arntz (2012) examined effects of imagery rescripting on film-related intrusive memories. Participants ($N = 76$) viewed a distressing film and were then assigned to a positive imagery, imagery rescripting, or imagery reexperiencing condition. Participants in the imagery rescripting condition reported fewer intrusive memories than participants in the positive and reexperiencing conditions, with medium to large effects. Low rates of intrusive memories and low distress during the rescripting intervention limit generalizability of these findings.

With respect to attention bias, an analogue study examined whether film-related reminders distracted participants ($N = 36$) during a target identification task following a distressing film viewing (Verwoerd et al., 2009). There was a large effect of distraction, such that those who were more distracted by the film reported more intrusive memories the following week. Limitations included a possible floor effect due to low error rates in the picture identification task, and attentional control was not manipulated.

In sum, the findings from the study with trauma survivors examining effects of attention bias (Kleim et al., 2012) on the occurrence of intrusive memories are generally in line with findings from analogue studies. Negative appraisals of intrusive memories were associated with more frequent intrusive memories, and focusing on trauma or analogue event-related information was associated with higher intrusive memory frequency. Further, with non-clinical samples, the effects of negative appraisals on intrusive memories were consistently modifiable via some type of intrusive memory reappraisal training.

Post-event rumination—Although no studies of trauma survivors have specifically examined effects of intrusive memory-related rumination on intrusive memories following an event, two studies with dysphoric individuals (Williams & Moulds, 2007a; Williams & Moulds, 2010), one study with individuals who had experienced negative life events (Santa Maria et al., 2012), and six analogue studies have examined this relationship (Ball & Brewin, 2012; Kubota et al., 2015; Ehring, Fuchs, & Klasener, 2009; Ehring, Szeimies, &

Schaffrick, 2009; Laposa & Rector, 2012; Zetsche et al., 2009). In the study with dysphoric participants, mildly depressed individuals ($N = 77$) were asked to recall a negative self-referent intrusive memory and were then assigned to either a rumination or distraction induction condition (Williams & Moulds, 2010). During the rumination induction, participants were presented with a series of ruminative sentences and were asked to dwell on each sentence's meaning and implication. Though intrusive memory frequency was not assessed, participants in the rumination condition reported more intrusive memory distress than those in the distraction condition, with the difference being a large effect. A second study compared low vs. high dysphoric participants ($N = 57$) and compared analytical, experiential, and distraction processing conditions following film viewing (Williams & Moulds, 2007a). Here, no significant associations were found between groups or conditions. However, an important difference is that intrusive memories from a personally important event may differ quite profoundly from intrusive memories from a distressing film that may be of no personal relevance whatsoever.

In an attempt to manipulate rumination related to a personally relevant memory, one study asked undergraduates ($N = 57$) to engage in either abstract-evaluative thinking or concrete-experiential thinking regarding a negative life event they had experienced following a symptom provocation task (Santa Maria et al., 2012). In the abstract-evaluative thinking, participants were asked to answer questions like "*Why did it happen? Why didn't I behave differently?*" In the concrete-experiential condition, participants answered questions like "*How did I feel during the event? What did I see, hear, think, and do during the event?*" At 36 hours post-manipulation, individuals in the concrete-experiential condition reported significantly fewer intrusive memories than the abstract-evaluative condition, a medium effect, and this relationship was not moderated by trait rumination.

In analogue studies with non-clinical samples, rumination was typically induced via some type of sentence presentation task (Ehring, Fuchs, & Klasener, 2009; Ehring, Szeimies, & Schaffrick, 2009; Zetsche et al., 2009) or self-report (Laposa & Rector, 2012). Rumination inductions were very similar to the inductions described above. Comparison conditions varied across studies; one study compared a rumination condition to a distraction condition and a memory integration condition, where participants were asked to think about the film in a chronological and self-referential manner (Zetsche et al., 2009). Other comparison conditions included rumination versus distraction (Ehring, Fuchs, & Klasener, 2009), film-related rumination, non-film-related rumination, and no-task control (Ball & Brewin, 2012), and concrete, abstract rumination, and distraction (Ehring, Szeimies, & Schaffrick, 2009). Ehring, Szeimies, and Schaffrick (2009) found in their sample of undergraduates ($N = 83$) that individuals in the distraction condition reported slightly more intrusive memories than the concrete thinking condition 3 days after the manipulation, but no significant differences between the concrete and rumination conditions were found. Furthermore, there were no significant differences between the distraction and rumination conditions, suggesting that rumination may not be maladaptive with regard to intrusive memories. Comparing two different types of rumination (film-related and unrelated) to a no rumination control condition, results from Ball and Brewin (2012) suggest that the type of rumination is not important. In a sample pre-selected to be moderate ruminators ($N = 57$), the rumination conditions combined reported more intrusive memories the following week compared to the

no-task control condition, a medium effect; no differences were found between the film-related and film-unrelated rumination. Furthermore, no differences in distress, vividness, or reliving emerged between conditions. In another study, Ehring, Fuchs, and Klasener (2009) found that analytical rumination led to more frequent and distressing intrusive memories immediately after manipulation compared to a distraction condition ($N = 51$), but that this effect reversed following a later symptom provocation task. Both of these studies suggest that effects of distraction on intrusive memories may be more problematic than potential effects of rumination.

Zetsche and colleagues (2009) compared rumination, memory integration, and distraction inductions after viewing a distressing film in order to examine effects of rumination on intrusive memories, and found no differences between rumination and memory integration on frequency of intrusive memories, either during the experiment or in a week follow-up period in an undergraduate sample ($N = 101$). When rumination was not directly manipulated in a study of 91 undergraduate students by Laposa and Rector (2012), where rumination in response to intrusive memories was recorded via self-report, rumination in response to intrusive memories from a distressing film was moderately associated with intrusive memory frequency one week following film viewing, even after controlling for depression. In a second study where rumination was not induced but was assessed following film exposure, film-related rumination mediated the effect of pre-existing depression on intrusive memory frequency and distress (Kubota et al., 2015). Notably, Laposa and Rector assessed intrusive memory-related rumination; all other studies (Kubota et al., 2015; Ehring, Fuchs, & Klasener, 2009; Ehring, Szeimies, & Schaffrick, 2009; Zetsche et al., 2009) assessed rumination about the analogue event, but did not assess whether participants were ruminating about their intrusive memories or how intrusive memory-related rumination related to intrusive memory frequency and distress.

In sum, the studies of dysphoric individuals (Williams & Moulds, 2007a; Williams & Moulds, 2010) suggest mixed findings as to whether those predisposed to a ruminative thinking style and who then undergo a rumination induction experience intrusive memories as more distressing. Analogue studies typically examined intrusive memory frequency rather than distress, with two studies showing a positive relationship between rumination and intrusive memories and two studies showing no differences. Overall, unlike the synthesis of negative appraisal findings, findings regarding rumination were more mixed, and methodological challenges were also present (e.g., varying ways of measuring/defining rumination, film vs. self-referent intrusive memories).

Suppression/cognitive load—Eight studies have examined effects of trauma-related thought suppression on trauma-exposed individuals ($N = 43$, $N = 42$, $N = 48$, $N = 56$, $N = 56$, $N = 61$, $N = 36$, $N = 55$, respectively) (Aikins et al., 2009; Bomyea & Lang, 2016; Harvey & Bryant, 1998; Nixon et al., 2008; Nixon & Rackebrandt, 2016; Rosenthal & Follette, 2007; Shipherd & Beck, 1999; Shipherd & Beck, 2005). In general, individuals those with Acute Stress Disorder (ASD; Harvey & Bryant, 1998; Nixon et al., 2008; Nixon & Rackebrandt, 2016) and PTSD (Aikins et al., 2009; Shipherd & Beck, 1999; Shipherd & Beck, 2005) experienced increased intrusive trauma-related thoughts following a 5 min suppression period, consistent with that of a “rebound effect,” compared to individuals

without ASD and PTSD, with medium to large effects of diagnosis on intrusive memory frequency. However, when extending the suppression period to 24 hours, Guthrie and Bryant (2000) found no evidence for this “rebound effect” following suppression of trauma-related thoughts in individuals with ASD ($N = 40$). Aikins and colleagues (2009) recruited veterans with and without PTSD and pre-deployed control participants and gave them thought suppression and thought-monitoring instructions during a series of 5 min periods. When told to suppress a neutral thought, trauma-related intrusive memories increased for individuals with PTSD, a large effect compared to trauma-exposed individuals without PTSD. In short, these trauma-related thought suppression studies suggest that severity of trauma-related symptoms may lead to increased, temporary intrusive thoughts immediately following a thought suppression period. However, these findings are very much expected given that essentially the studies are highlighting symptoms of PTSD (i.e., intrusive memories, and avoidance of trauma-related thoughts and feelings).

In a study of recently trauma-exposed individuals ($N = 56$), Nixon and Rackebrandt (2016) examined the effects of cognitive load experimentally via four conditions: cognitive load for individuals with and without ASD, and no cognitive load for individuals with and without ASD. Cognitive load tasks included memorizing numbers, a dot-probe task, and a word-stem completion tasks. Intrusive memories were monitored at baseline, following a 5 min suppression period, and following a 5 min “think anything” period. Though sample sizes in each condition were small, findings suggest that participants with ASD and cognitive load showed the strongest rebound effect of intrusive memories (i.e., reported the highest number of intrusive memories during the “think anything” period) compared to those with ASD but no cognitive load, a medium effect.

Contradicting this pattern of findings in clinical samples, Rosenthal and Follette (2007) found no differences in laboratory suppression vs. thought monitoring tasks in a sample of females who had experienced assault-related intrusive memories in the past month. None of these individuals met criteria for PTSD or ASD; it is thus possible that in managing occasional intrusive memories, these individuals had developed effective intrusive memory management strategies, such as cognitive reappraisal. As a follow-up manipulation, this study instructed participants to either suppress or monitor intrusive memories for the following day; though no differences were found either post-manipulation or post-day two, an interaction was found, where participants instructed to suppress showed an increase in intrusive memories, whereas those instructed to monitor showed a decrease in intrusive memories (Rosenthal & Follette, 2007).

Bomyea and Lang (2016) looked specifically at the relationship between avoidant-based thought regulation strategies (TRS), executive functioning, and intrusive memories. Participants ($N = 42$) completed an executive functioning assessment, and then underwent a series of three 5 min periods: thought monitoring, suppression, and then monitoring again. Participants then completed a thought suppression-reactivity questionnaire, which assessed their use of TRS. Participants who were lower in executive functioning were more likely to use TRS, and also experienced more intrusive memories. More specifically, executive functioning moderated the relationship between TRS and intrusive memory frequency, but there was no direct relationship between executive functioning and intrusive memories.

In analogue studies of suppression and cognitive load, participants typically are exposed to a brief distressing film, followed by suppression or thought monitoring (i.e., think about anything you want) periods after exposure to a distressing film (Davies & Clark, 1998b; Nixon et al., 2009a; Nixon et al., 2009b; Williams & Moulds, 2007). Of note, studies that only examined “white bear” thoughts or other comparable thoughts were not included in this review, due to thoughts about a white bear not being event-based thoughts. Other studies asked participants to select a negative autobiographical memory from their past rather than using a distressing film (Bomyea & Amir, 2011; Geraerts et al., 2010). To manipulate cognitive load, some studies presented participants with a 9-digit number string to be memorized before a brief thought monitoring period (Nixon et al., 2009a; Nixon et al., 2009b), whereas Bomyea and Amir (2011) used high and low inhibitory control tasks to manipulate proactive interference specifically. Typically, studies only assessed intrusive memories immediately following the experimental session, though some studies included daily intrusive memory diaries, allowing effects of thought suppression to be assessed longer term (Nixon et al., 2009a; 2009b).

Although Davies and Clark (1998) reported very large effects of suppression on immediate intrusive memories compared to a control condition ($N = 32$), two studies ($N = 97$; $N = 120$) found no significant suppression effect (Williams & Moulds, 2007; Nixon et al., 2009a). Geraerts and colleagues (2010) actually found that suppressing memories of an event, regardless of whether the event was negatively valenced or neutral, led to decreased intrusive memories, both during the suppression period and during post-suppression monitoring, as well as during an autobiographical memory test. Of note, these were small effects. In another study, Nixon and colleagues (2009b), using a demanding cognitive load task, found a medium effect of suppression plus cognitive load, with these individuals ($N = 80$) reporting more frequent intrusive memories during the following week compared to other conditions. However, in their other study (2009a), using a less demanding cognitive load task, Nixon and colleagues found no differences. As the authors suggest, perhaps these additional tasks fully drained cognitive resources, which may explain why effects are seen in one study but not the other. When looking at proactive interference, Bomyea and Amir (2011) found a medium effect of high inhibitory control in reducing intrusive memory frequency both during the suppression period and during the post-suppression monitoring period. Participants ($N = 50$) seemed more able to resist/inhibit unwanted intrusive memories after having completed a task demanding high inhibitory control.

Two studies examined the relationship between thought suppression and intrusive memories in the context of other potentially related variables. Gillie and colleagues (2015) sought to examine how heart rate variability (HRV) relates to suppression and intrusive memories, given that HRV is thought to indicate one’s ability to self-regulate. Participants ($N = 142$) recorded frequency of personally relevant thoughts during three monitoring periods, and were randomized to either suppress or continue monitoring for the middle period. Fittingly, participants with higher HRV who were instructed to suppress reported greater declines in intrusive memories from monitoring to suppression and from monitoring to second monitoring period, which was not true for control participants. Onden-Lim and Grisham (2012) explored thought suppression through the lens of body dysmorphic disorder, and looked at how body image concerns affected intrusive images of a distorted portrait.

Participants (N = 92) listened to an imagined scene that involved becoming aware of a wart on their face in a crowded room, and were then presented with a self-portrait photo that was edited to have a wart on the nose. While there was no significant relationship between body image concerns and intrusive memory frequency in suppression or monitoring phases, participants with more body image concerns did report increased intrusive memory vividness.

Overall, when reviewing effects of suppression and cognitive load on intrusive memories, clinical findings suggest that individuals with higher psychopathology report more trauma-related intrusive memories following suppression instructions, though longer-term effects of suppression on intrusive memories are much less clear due to lack of studies examining longer-term effects. Analogue studies are inconsistent in their findings of suppression effects during 5 min experimental periods, which is unfortunate given that intrusive memories occurring in the days following the manipulation are likely those that best parallel pathological intrusive memories post-trauma. Additional work in this area is needed, examining longer persistence of intrusive memories that more closely represent those seen in psychopathology.

Post-event processing—Ten studies have examined the possibility of post-event processing predicting intrusive memories (Bryant et al., 2013; Das et al., 2016; Holmes et al., 2009; Holmes et al., 2010; Kindt et al., 2008; Kleim et al., 2016; Krans et al., 2009; Luo et al., 2013; Porcheret et al., 2015; Tabrizi & Jansson, 2016). In two studies, participants (N = 40; N = 60) played a visuospatial computer game (i.e., Tetris), completed a series of trivia questions (Holmes et al., 2009), or sat quietly (Holmes et al., 2010) for 30 min (Holmes et al., 2009; Holmes et al., 2010) or 4 hours (Holmes et al., 2010) following distressing film viewing. In line with their hypotheses, both studies found that individuals in visuospatial task conditions reported decreased intrusive memories compared to individuals in the quiz condition, reporting medium to large effect sizes. Though the earlier study did not have a control comparison group, the latter study included a control and still found decreased intrusive memories in the visuospatial task condition. Luo and colleagues (2013) had participants (N = 92) either provide a verbal description of the film using “why” questions (i.e., why the accident occurred), using “what” questions (i.e., what happened in the film), or not provide a description. Participants in the “why” condition reported more frequent intrusive memories than both the “what” condition and the non-verbal condition, a medium effect. In a similar fashion, Kindt and colleagues (2008) had participants (N = 42) write about the film immediately after, either in a data-driven style (e.g., “write about the images and physical details”) or in a conceptual style (e.g., “write about the rationale of the horrible scenes”) (p. 549). Participants in the data-driven writing condition reported more intrusive memories 15 min after the written task, a small effect. Further, the proximity of intrusive memory assessment to the actual task limits our applicability of this finding to longer-term intrusive memory development.

Rather than engaging specific cognitive resources to manipulate post-event processing, Krans and colleagues (2009) used a recognition test following a distressing film (N = 57). The recognition test was meant to serve as a form of memory integration in order to promote conceptual processing. Half of participants were administered a verbal recognition memory

test of a specific part of the distressing film, with events presented in chronological order. Participants who received the test reported fewer intrusive memories than those who did not receive a recognition test, albeit with a small effect. However, this study did not include a comparator task that incorporated some kind of re-exposure to film material, without targeting memory integration; it is possible that any kind of re-exposure to film material would lead to decreased intrusive memories compared to no re-exposure. Tabrizi and Jansson (2016) used four different tasks (executive load counting task, phonological loop, visuospatial, no task) after exposure to a stressful auditory stimulus to examine effects of task type on auditory intrusive memories ($N = 41$). Participants in the executive load, where participants counted backwards by 3's from varying starting numbers, and phonological loop conditions, where participants counted aloud from 1 to 10 repeatedly, reported fewer auditory intrusive memories than the other two conditions (large effects), suggesting that tasks that engage phonological loop influenced subsequent auditory intrusive memories. No significant differences were found between conditions with respect to visual intrusive memories.

Two studies examined effects of sleep deprivation on the formation of film-related intrusive memories (Kleim et al., 2016; Porcheret et al., 2015). Both studies ($N = 65$, $N = 42$ respectively) manipulated amount of sleep (total sleep deprivation vs. sleep as usual) following exposure to a traumatic film. Porcheret and colleagues reported that the sleep-deprived condition reported moderately fewer intrusive memories, suggesting that sleep deprivation may disrupt consolidation of emotional memories. No significant effect of sleep condition was found for intrusive memory-related distress. Moreover, the difference in intrusive memory frequency was isolated to the first two days following film exposure and disappeared in the remaining four days of intrusive memory diary recording. In other words, sleep deprivation may be a protective factor for intrusive memory development, but perhaps not for intrusive memory persistence. Kleim and colleagues (2016) found sleep to be a protective factor for intrusive memory development, where participants who slept as usual following film exposure reported fewer and less distressing intrusive memories over the course of the following week. Taken together, sleep deprivation may have an initial protective effect on intrusive memory development, but longer-term normal sleep appears to be protective in the persistence of intrusive memories.

Looking at more biological processes involved in memory consolidation, Bryant and colleagues (2013) administered a high stress (cold pressor) or low stress (warm water) task after participants ($N = 78$) viewed neutral and distressing images. Salivary alpha amylase and cortisol levels were measured. Participants in the high stress condition reported more intrusive memories two days following these procedures compared to participants in the low stress condition. In men specifically, an interaction of higher cortisol and higher salivary alpha amylase predicted more intrusive memories two days following.

In an effort to examine disruption of memory consolidation, Das and colleagues (2016) administered either nitrous oxide, an NMDA receptor inhibitor, or placebo air immediately following a film viewing. Memory consolidation requires long-term potentiation, and NMDA receptor inhibitors interrupt this long-term potentiation process; nitrous oxide should therefore disrupt consolidation of distressing memories, leading to lower film-related

intrusive memories compared to placebo gas. In their study ($N = 50$), while there were no significant differences between conditions at 7-day follow-up, participants in the nitrous oxide condition showed a more rapid decrease in intrusive memories over the course of the first two days of the intrusive memory assessment, consistent with the time frame required for initial memory consolidation.

In sum, findings from analogue studies suggest that a variety of aspects of post-event processing may be related to intrusive memory frequency, including increased conceptual processing of stimuli predicting fewer intrusive memories. However, the limitations of comparison conditions limit the strength of the conclusions regarding post-event processing. Studies examining consolidation processes suggest that disrupting consolidation may well affect intrusive memory development. While specific mechanisms through which this occurs need further elucidation, this avenue appears promising as a possible intervention point for reducing the development of intrusive memories.

Memory reconsolidation—Two studies have examined the relationship between memory reconsolidation, where, post-retrieval, the recalled memory becomes labile, and intrusive reexperiencing (James et al., 2015; Marks & Zoellner, 2014). Similar to studies investigating the possibility that engaging in a visuospatial distractor task during memory consolidation would compete for specific cognitive resources and thus block development of intrusive memories, James and colleagues (2015) had participants play Tetris following memory retrieval in order to block reconsolidation. In their first study ($N = 52$), participants in the Tetris condition during reconsolidation reported fewer intrusive memories compared to participants in a no-task control condition, a large effect. A follow-up study ($N = 72$) added a Tetris only condition and a memory reactivation only condition, and still the Tetris plus memory reactivation condition was the only one to significantly differ on intrusive memories from the no-task control condition, again a large effect.

Examining the relationship between memory reconsolidation and intrusive memories from a somewhat different angle, Marks and Zoellner (2014) used a distressing film segment in a fear conditioning-like paradigm, where participants watched a film segment once on day one (acquisition), and then repeatedly (extinction) two days later. Participants ($N = 148$) were either assigned to a pre-extinction retrieval cue (reconsolidation), a delayed-extinction retrieval cue (no reconsolidation) or a pre-extinction non-retrieval cue (no reconsolidation). Contrary to hypotheses, participants in the pre-extinction retrieval cue condition reported more intrusive memories 24 hours after extinction compared to participants in the control conditions, a medium effect. However, the retrieval cue was a distressing image of a mutilated woman from the film, so it is possible that cue valence and distress at time of retrieval affected the development of intrusive memories.

In sum, memory reconsolidation appears to be a promising window where we have the opportunity to affect intrusive memory development, yet given only two studies to date have examined this area, findings are much too preliminary to make more definitive conclusions.

Vantage perspective—Two studies examined the role that first-person field perspective vs. third-person observer perspective may play in the development of intrusive memories

(Luo et al., 2013; Williams & Moulds, 2008), one finding a relationship between perspective and intrusive memories, and one study not finding such a relationship. Luo and colleagues had participants ($N = 93$) either take a first-person perspective in describing the film immediately after film viewing, asking them to describe bodily sensations and psychological states, or a third-person perspective, where they were asked to describe what the person in the film did. Perspective did not appear to predict differences in intrusive memories in this study. Williams and Moulds (2008) took a somewhat different approach, surveying participants ($N = 134$) about their perspective (field vs. observer) when they recall a negative autobiographical event. Participants were then asked to switch perspectives and write about their memory in great detail using this new perspective. Intrusive memory vividness (medium effect) and distress (large effect) decreased for individuals who switched from first-person to third-person perspective. However, these ratings were taken immediately after the perspective switch, and do not provide insight into any longer-term effects of switching perspectives on intrusive memories.

The lack of studies examining vantage perspective as well as the lack of significant findings in one of the two studies make these findings too preliminary to draw extensive conclusions. That said, the idea of intervening at the point of memory retrieval, rather than memory encoding or prior to memory encoding is a particularly important one from the perspective of treatment as previously mentioned.

Retrieval Stress and Distress—Three studies have examined the role of retrieval stress and distress; two of the three studies report on clinical samples, and Cheung and colleagues (2015) examined effects of stress hormones and distressing memory retrieval on later intrusive memories ($N = 63$). Participants viewed a distressing film, and two days later returned for memory retrieval tasks, where they were either assigned to a retrieval + socially evaluated cold pressor task (SECPT), SECPT alone without retrieval, or retrieval while sticking hand in warm water (i.e., no stress). Cortisol and salivary alpha amylase (sAA) levels were measured throughout day one and day two, and an intrusive memory assessment was completed two days following the SECPT procedures. Findings suggest that cortisol, but not sAA, increases following the SECPT and memory retrieval predicted 29% of variance on intrusive memory assessment, suggesting that what is happening biologically as a memory is retrieved, particularly if stress is high during retrieval, may play an important role in the persistence of intrusive memories.

In a clinical sample of trauma-exposed individuals with and without ASD, Hopwood and Bryant (2006) examined the potential role of physiological distress during involuntary memory retrieval using a hyperventilation task. Participants ($N = 60$) were randomized to either hyperventilate or do a control task while monitoring intrusive memories. Participants with ASD reported more intrusive memories during the hyperventilation task compared to baseline period, whereas participants with ASD in the control condition reported comparable intrusive memories across both periods. Participants without ASD reported fewer intrusive memories during the hyperventilation task compared to baseline task, whereas participants with ASD in the control condition reported comparable intrusive memories across periods. Overall, findings suggest that high arousal predicts intrusive memories, but only in those participants with generalized fear and hyperarousal symptoms.

Clinically, Schooler, Dougall, and Baum (1999) found evidence in line with Cheung and colleagues' (2015) biological findings, that distress during retrieval predicted later intrusive memories. This unique longitudinal study tracked intrusive memories in survivors of an airline crash ($N = 118$) over the course of a year. Participants completed intrusive memory assessments and self-report questionnaires at 4–8 weeks post-crash, then again at 6, 9, and 12 months post-crash. Findings suggest an important predictor of intrusive memories at 12 months; distress associated with intrusive memories was highest for individuals experiencing uncued intrusive memories, and the presence of uncued intrusive memories and intrusive memory-related distress in the weeks following the crash predicted more frequent intrusive memories at 6, 9, and 12 months. Notably, intrusive memory frequency did not predict either intrusive memory frequency or distress at the later time points.

While specific findings are more nuanced within each study, all three of these studies provide evidence for the importance of retrieval-related processes in predicting the persistence of intrusive memories post-trauma, which is promising given our increased likelihood of intervening via memory retrieval, as well as the emphasis on retrieval processes in the broader memory theory.

Summary—In comparison to pre-event or factors during an event, post-event factors reviewed above have been studied in more depth, and include more clinical samples as part of this body of literature. However, results of clinical studies and analogue studies are both more discrepant (i.e., findings themselves are very mixed) and difficult to compare, primarily due to differences in study methodologies including timing of assessments, different ways of measuring the same construct, and differences in comparison conditions. The role of post-event negative appraisals appears to be most consistent, with more negative appraisals leading to increased intrusive memories across both clinical and analogue studies. Findings are inconclusive regarding the role of thought suppression, with little data available on longer-term effects of suppression on intrusive memories. Similar problems exist for post-event rumination, with mixed findings and differences in follow-up period for intrusive memory assessment. Findings from several analogue studies suggest preliminary evidence that higher conceptual processing predicts decreased intrusive memories, in line with the event-based findings discussed previously. Importantly, a range of studies examining different aspects of memory retrieval processes suggest that there is indeed likely opportunity for intervention and altering intrusive memory processes once a memory has already been consolidated and is reactivated via some type of memory retrieval.

Discussion

Summary of Findings

This review highlights several main findings across pre-event factors, factors at play during an event, and post-event factors, with post-event factors having the most clinical studies examining what predicts the development of intrusive memories, but no one area of predictors (pre-, peri-, post-event) coming out as a clear leader in strength of prediction. This may in large part be due to the fact that most studies are examining the *presence* of intrusive memories, rather than the *persistence* of intrusive memories. When referring to intrusive

memories in a psychopathological sense, they are by default persistent. In analogue studies, pre-existing levels of anxiety and depression seem to affect the presence of intrusive memories indirectly (Regambal & Alden, 2009; Laposa & Alden, 2008), and negative appraisals also consistently appear to lead to more frequent intrusive memories. Trait dissociation does not appear to predict intrusive memories according to studies reviewed here. The findings regarding pre-event predictors are limited, given that no clinical studies to date have examined the role of pre-existing vulnerabilities on intrusive memories, specifically. Though findings regarding factors at play during an event are similarly limited by the lack of studies with clinical samples, evidence consistently suggests that higher data-driven processing during an event predicts more intrusive memories, whereas there is less consistent evidence that higher peri-traumatic dissociation predicts more frequent intrusive memories. With respect to post-event studies, more clinical studies exist but results of clinical studies and analogue studies are inconclusive (e.g., mixed findings from suppression and rumination literature, with mixed methodologies make overall conclusions challenging). Most consistently, more negative appraisals lead to increased intrusive memories across both clinical and analogue studies, and preliminary evidence suggests that higher conceptual processing predicts increased intrusive memories. Despite having more clinical studies to draw on, comparisons between analogue and clinical studies may be discrepant in part due to the role of memory retrieval. Participants in clinical studies are not only distinct from those in analogue studies due to their trauma exposure/post-trauma symptoms, but also in the amount of time they have had to repeatedly retrieve their trauma memory, whether voluntarily or involuntarily. Given the important role of memory retrieval in altering the strength of different memory traces, it is clear that examining memory encoding and immediate retrieval is not sufficient for understanding prediction of intrusive memories persistence.

Pre-existing factors—Though clinical studies of pre-event factors are non-existent, an important and consistent finding across several different areas of pre-existing vulnerabilities is that there likely exist certain factors that make some individuals more at risk than others for developing intrusive memories. This is most evident with regard to pre-existing anxiety and depression, with higher levels of anxiety and depression prior to event exposure predicting more intrusive memories, typically with small to moderate size of effects, though this may reflect promotion of data-driven processing during the event (Halligan et al., 2002; Laposa & Alden, 2008; Regambal & Alden, 2009). Negative appraisal tendencies prior to exposure also consistently predicted intrusive memories in analogue studies, with large effects (Brown et al., 2012; Lang et al., 2009; Woud et al., 2013). Pre-existing trait dissociation does not appear to be a good predictor of intrusive memories; state dissociation appears to predict intrusive memories above and beyond any pre-existing dissociative tendencies. Although the vast majority of these studies are analogue studies, they are generally well designed, and eliminate retrospective reporting biases by assessing a particular trait prior to distressing event exposure. Notably, pre-existing anxiety, depression, and negative appraisal tendencies may reflect similar or overlapping constructs rather than unique pathways increasing intrusive memories. This also makes sense considering the importance of intrusive memory distress, and how individuals coming into a traumatic experience with anxiety, depression, and/or negative appraisal tendencies are probably more

likely than someone without to find an intrusive memory highly distressing. Importantly, no clinical studies have examined these pre-event predictors of intrusive memories, and even within analogue studies, further replication is warranted. That said, knowing that pre-trauma intervention is most challenging, and that unlike memory retrieval, memory encoding cannot be altered after the fact, pre-event predictors of intrusive memories are perhaps less relevant than event-based and post-event predictors.

Peri-event factors—The substantial body of literature regarding predictors of intrusive memories during the event point to the importance of processing factors, specifically data-driven processing, as a predictor of intrusive memories. It appears that processing primarily sensory-perceptual aspects of an event rather than chronological and meaning-based aspects is predictive of later intrusive memories (e.g., Bourne et al., 2010). Though several studies did not find data-driven processing to predict intrusive memories (Krans et al., 2009; Krans et al., 2013; Pearson & Sawyer, 2011), these studies were limited by low rates of intrusive memories and lack of appropriate comparison conditions (Krans et al., 2009). Pre-existing tendencies to engage in data-driven processing also fits well with these findings (Halligan et al., 2002), arguing for a vulnerability link between pre-existing factors altering during event processing. Overall, these findings are in line with existing theories of intrusive memories and PTSD (Ehlers & Clark, 2000; Brewin et al., 1996; Brewin, 2014). In these theories, the strong emphasis is on memory encoding processes rather than retrieval processes, wherein a traumatic memory is primarily encoded in a sensory-perceptual manner, with weak semantic retrieval. Brewin (2014) purports that during encoding, sensory representations of the event are strengthened, while contextualized representations and connections between sensory and contextualized representations are weakened. Interestingly, most paradigms used to examine peri-traumatic processing seem to promote data-driven processing. Furthermore, studies do not follow-up encoding manipulations with any retrieval data, in order to see how later retrieval of a strongly encoded memory may alter intrusive memories of the event.

Findings regarding state dissociation as a predictor of intrusive memories were mixed, in part due to difficulties experimentally manipulating dissociation. All five analogue studies examining the role of context information during encoding suggest that the presence of context information predicts more intrusive memories, consistent with findings of data-driven processing. Context is defined here as information about the type of stimuli being presented. Examples seem to serve as additional information about the picture stimuli being presented, rather than time, place, what happened immediately before the trauma, etc. that we typically conceptualize as trauma-related context information. Examples from studies of context include “After a sudden rainstorm several collisions occurred at one spot on the motorway” (Pearson, 2012); “This woman was asleep when a fire started in her kitchen. She is unconscious and being carried out of her house by firemen” (Krans et al., 2013). Context in these studies seems to be used more as “scene setting” rather than additional information that helps make meaning of a traumatic event. Further, with traumatic events, we think of contextual information as information that helps someone better understand the sequence of events in order to shift perspective (e.g., the three times an assault survivor tried to reach for their phone to call 911 for an individual thinking they could have done more to stop the

assault), rather than simple lead-in or outcome information as is often considered “context” in analogue studies.

Importantly, factors at play during a traumatic event are by far the hardest to control, making the real-world translation and application of some of these findings to clinical samples less realistic than pre-event and post-event findings.

Post-event factors—With respect to post-event predictors of intrusive memories, a large number of studies reviewed in this area indicate ways in which intrusive memories can be reduced following exposure to an analogue distressing event. With regard to negative appraisals, analogue research suggests that reappraisal training (Lang et al., 2009; Newby et al., 2014; Woud et al., 2012) can moderately decrease intrusive memories. Findings from studies examining suppression and rumination are less clear, as intrusive memories were typically only assessed for a brief period of time during experimental procedures, limiting the longer-term understanding of relationships. With respect to post-event data-driven and conceptual processing, results suggest increased conceptual processing following analogue trauma predict decreased intrusive memories, with effect sizes ranging from small to large. Overall, an important strength of the post-event studies is the number of prospective studies using pathological samples compared to pre-event and peri-event studies. Clinically, post-event factors have the highest likelihood of translating into treatment implications, given that as clinicians we are seeing individuals who have already completed the encoding process. Thus, it is what we can do to alter the memory via post-event processes where our best odds of reducing intrusive memories and related distress are. We can see from studies reviewed here that appraisals may be an important part of some kind of negative feedback loop, where negative appraisals are adding to distress which may in turn lead to increased likelihood of more persistent and distressing intrusive memories. However, even in post-event factors, the role of memory retrieval is rarely directly manipulated, and when it is manipulated (e.g., in reconsolidation studies), the manipulation only focuses on retrieval very soon after encoding. The role of longer-term memory retrieval processes continues to be largely ignored.

Limitations of Intrusive Memory Studies To Date

Failure to capture intrusive memory distress—As defined earlier, intrusive memories are vivid, distressing, snap-shot-like memories of an event that come to mind involuntarily and are typically sensory-perceptual in nature (e.g., Ehlers et al., 2006; Ehlers & Steil, 1995). Critically, in pathological samples, distress about the intrusive memories is a key conceptual component. It is not just that the intrusive memory occurs but it causes extreme distress. Unfortunately, the vast majority of analogue studies reviewed here use intrusive memory frequency as their primary dependent variable in analyses. In many respects this decision makes sense, given that analogue distressing events, by their very nature, do not elicit levels of distress and emotion that begin to approach those of extremely distressing or traumatic events. In most studies, the majority of participants reported the presence of at least one event-related intrusive memory during the assessment period. Distress levels, however, tended to be low or were not assessed. Importantly, if the goal is to examine predictors of intrusive memories in order to better understand them in the context

of the clinical phenomenon of intrusive re-experiencing, this may be emphasizing the wrong aspects of intrusive memories. It is well established that intrusive memories are common experiences following distressing events. Clinically, frequency of intrusive memories does not appear to be an important predictor of the development of psychopathology (e.g., Kleim, Ehlers, & Glucksman, 2007). In one prospective study examining the development of PTSD after a traumatic event, intrusive memory frequency only predicted 9% of the variance in PTSD severity six months after initial assessment (Michael, Ehlers, Halligan, & Clark, 2005). Rather, it appears to be the distress experienced during these intrusive memories, among other factors, that serves as a better predictor of PTSD development (e.g., Clohessy & Ehlers, 1999; Ehlers & Steil, 1995; Michael et al., 2005). A shift in emphasis to study both frequency and importantly related distress needs to occur in order to better reflect what has been established clinically.

Failure to disentangle normal intrusive memories from pathological intrusive memories—There is also substantial variability across studies with regard to time frame of intrusive memory assessment. In some studies, particularly in studies of post-event rumination and suppression, intrusive memories are only assessed for 5 min periods following experimental procedures (e.g., Ehring, Szeimies, & Schaffrick, 2009; Williams & Moulds, 2010; Shipherd & Beck, 2005), while other studies assessed intrusive memories over a week-long period (e.g., Holmes et al., 2004), a month-long period (e.g., Michael & Ehlers, 2007), or up to three months (e.g., Sundermann et al., 2013). Given that the vast majority of these studies use analogue distressing events to induce intrusive memories, we would expect most participants to be intrusive memory-free after a short period of time, given that trauma-related intrusive memories naturally decrease over time in the majority of people (e.g., Galatzer-Levy et al., 2013) and in combination with the comparatively mild nature of these analogue events. This brings to light a question of precisely what phenomenon is being studied; indeed, if what is being assessed early versus later are just quantitatively different or if they are qualitatively different. Intrusive memories that are present 5 min following an analogue distressing event are considered normal, everyday experiences. Intrusive memories that persist for a week following an analogue distressing event may be moving closer toward the more persistent intrusive memories that we see clinically, whereas intrusive memories that persist and are distressing for a month or three months following a distressing film or picture story may represent persistent intrusive memories with better clinical translation. In short, without a systematic study of the trajectory of intrusive memories following exposure to a distressing film or other analogue traumatic event, we cannot be sure what timeframes are capturing analogue intrusive memories most relevant to persistent intrusive memories that can develop following real-world extremely distressing or traumatic events. Experience sampling of intrusive memories as they occur, particularly following actual traumatic experiences and following analogue manipulations, is an important avenue for future research.

Lack of external validity of experimental paradigms—The distressing film paradigm (see Holmes & Bourne, 2008, for review) is a widely used and well-validated paradigm for eliciting intrusive memories in non-clinical samples. However, there are several key aspects, namely the content of the distressing film and the chronological

sequence (or lack thereof) of different scenes that are included, that may limit its ecological validity as an analogue traumatic event.

Film content: Almost all analogue studies that use a distressing film segment as a way to parallel real-world trauma acknowledge the fundamental limitations of this paradigm. That is, a film cannot be equivocal to the severity of an actual traumatic event given that it is viewed remotely, viewed from an observer perspective, and viewed in a controlled environment (e.g., James et al., 2016; Pearson, 2009; Meyer et al., 2013; Regambal & Alden, 2012). These are very important limitations to consider. Film paradigms lack the level of distress associated with traumatic experiences; there is no threat to the viewer's life, and, in most cases, lack personal relevance to the viewer. Distress, personal relevance, and threat to life or physical integrity are three core features of traumatic experiences. Additionally, through the consenting process, participants in analogue studies become aware that they will be exposed to potentially distressing or graphic material and choose to participate in these studies. Some individuals, potentially those who are different in some meaningful way (such as personality characteristics), choose not to participate in these studies. Conversely, traumatic experiences are usually unexpected and usually not chosen. Clearly, ethical considerations influence analogue study designs, yet it is essential to keep in mind that this paradigm lacks many key features of a traumatic event, which likely leads to substantive differences in the characteristics of subsequent event-related intrusive memories.

Many of the films include multiple, short segments of motor vehicle accidents (MVAs), surgical procedures, or interpersonal violence (e.g., 15 min total with 7 separate, 2 min segments). Some film segments only include the aftermath of traumatic events (e.g., Brewin & Saunders, 2001), falling short of mirroring the emotional trajectory of actual trauma. Such segments lack pre-event context, anticipatory emotions prior to the event, the experience of the actual threat, and then the aftermath. Studies that use short clips from several different types of events (e.g., Lang et al., 2009; Meyer et al., 2013) may increase the likelihood of eliciting intrusive memories across a range of participants. Different types of traumatic events may be more likely to induce intrusive memories for participants, depending on their own histories and emotional reactions to different types of trauma. However, despite increasing the likelihood of intrusive memories using film segments of this design, such segments may fail to capture the theoretically critical elements of a traumatic event, specifically an event with a beginning where threat is first recognized, a middle where the feared threat comes to fruition or not, and an end/aftermath where the threat has been minimized and safety/lack of ongoing threat perceived.

Chronological characteristics of film: With an event like a sexual assault, the beginning, middle, and end of the event all have strong emotional components that may be distinct. For example, an individual may experience a sense of safety that shifts to threat, and to fear leading up to the assault, intense fear, disgust, and helplessness during the assault, and relief and shame in the aftermath. However, many of the analogue studies reviewed here used a rapid-fire series of distressing film clips, likely truncating the varied emotional experiences of a real trauma. This would be a particularly salient issue in studies that only use aftermath footage (e.g., Brewin & Saunders, 2001; Bourne, Frasquilho, Roth, & Holmes, 2010).

Several studies using clinical samples suggest that intrusive memories may reflect the most distressing moments of a trauma (e.g., Holmes, Grey, & Young, 2005) or the moments right before the most distressing moment (e.g., Ehlers et al., 2002). In a montage of scenes from aftermath of MVAs, it may be less likely that there is one moment of peak distress or a moment of extreme arousal during which data-driven processing is likely to occur (e.g., Dolcos, 2013). Further, there is no anticipation or build-up to the actual event.

Conceptual processing occurs as individuals make meaning of the event using chronological information, contextual cues, etc. Clips, particularly montages, that are intense, graphic, and emotional in nature and that do not include a beginning, middle, and end are more amenable to be processed in a fragmented, sensory-driven way. These types of film segments promote data-driven processing, due to lack of context leading up to the analogue trauma and the brevity of each individual clip in the montage. Of note, a handful of studies used film segments that included footage leading up to the trauma, the actual trauma, and the aftermath, better paralleling actual traumatic events (e.g., Laposa & Rector, 2012; Regambal & Alden, 2009; Kindt et al., 2008). Thus, some discrepant findings, particularly those related to processing style, may be explained by differences in film stimuli that promote one type of processing more than the other.

Lack of assessment of intrusive memory trajectories—In the vast majority of the studies examined in this review, assessment of intrusive memories focused solely on each memory at a single time point rather than changes in frequency, distress, or quality of the intrusive memories over time. This type of assessment often presumes that original encoding is the most important feature determining future intrusive memories and neglects memory retrieval effects. Once a distressing memory is retrieved in the form of an involuntary intrusive memory, the future likelihood of again retrieving the memory as an intrusive memory increases (Zoellner, Farach, Pruitt, & Feeny, 2014). In fact, the likelihood of a memory being recalled is thought to be fully contingent on its retrieval strength (Bjork & Bjork, 2006; Bjork & Bjork, 2003; Anderson, Bjork, & Bjork, 2000; Bjork & Bjork, 1996; Anderson, Bjork, & Bjork, 1994); the way in which intrusive memories are assessed in the reviewed studies fails to capture patterns of retrieval strength. According to Bjork and colleagues, each time the memory is retrieved, how that particular memory is represented in memory is thought to be actually altered, further highlighting the necessity of examining memory retrieval patterns in order to fully understand the effects of specific factors on intrusive memories. For example, if a particular part of town cues an intrusive image of a perpetrator's face, the retrieval strength of that snapshot face image and the strength of the association between the context and the face both increase, thus increasing the probability that that particular memory trace will be re-experienced again. If studies captured specific information regarding the content of intrusive memories and any cues that prompted the intrusive memories, we would be better equipped to differentiate between an individual who is reporting the similar intrusive memories "on a loop," resulting in enhanced or spreading retrieval strength, and an individual who is reporting a periodic, more random intrusive memories that dissipates over time. The former is more likely to represent a pattern that is more qualitatively similar to longer-term psychopathological intrusive memories. Notably, patterns of natural recovery show the presence of PTSD-like symptoms, such as

reexperiencing, in the immediate aftermath of trauma but show the strong dissipation of those reactions in the first three months following an event, with pathological PTSD samples separating themselves better separating themselves over time (e.g., Riggs, Rothbaum, & Foa, 1995; Galatzer-Levy et al., 2013; Koren, Arnon, & Klein, 2001), further arguing for the importance of trajectory rather than solely presence of re-experiencing. The one study reviewed here that assessed trauma-related intrusive memories longitudinally (Schooler et al., 1999) indeed found that the magnitude of distress related to intrusive memories early on post-trauma are predictive of later intrusive memories.

Lack of clinical studies of intrusive memories—A large discrepancy exists between the number of studies examining predictors of intrusive memories in clinical samples and the number of studies examining these predictors in non-clinical, typically undergraduate samples. Of the 106 studies reviewed, 92 were analogue studies that utilized non-clinical samples. We did exclude studies that examined intrusive thoughts that were not specifically anchored to a concrete autobiographical memory (i.e., obsessive thoughts characteristic of OCD and eating disorders), further decreasing the number of clinical studies included in our review. Of the studies that were specific to intrusive memories, though many studies with clinical samples examined predictors reviewed here such as negative appraisals, peritraumatic dissociation, and rumination, these studies typically use overall PTSD or depression symptom severity scores as their dependent variables (e.g., Bryant & Guthrie, 2007; Ehring, Frank, & Ehlers, 2008; Murray et al., 2002). In other words, the emphasis in these studies is on how certain predictors influence clusters of symptoms, rather than intrusive memories specifically. Re-experiencing symptom cluster scores typically include only one item assessing intrusive memories. Further, many studies with trauma-exposed samples were cross-sectional, rather than prospective or longitudinal. Thus, we excluded most clinical studies that were identified with our original search criteria, either on the basis of intrusive memories not being explicitly assessed or lack of a prospective design. A key piece of furthering the understanding of intrusive memories is to investigate whether findings from analogue studies map onto the clinical literature. This proves to be challenging when so few clinical studies directly examine what predicts intrusive memories. Particularly in light of the limitations of current analogue methodology and intrusive memory assessment noted above, studies that include clinical samples and careful assessment of intrusive memories will be critical to advancing our understanding of intrusive memories.

A Retrieval-based Feedback Loop Model of Pathological Intrusive Memories

Integrating the above research on intrusive memories with the broader literature on memory encoding and retrieval, we can begin to further our understanding of intrusive memories of events and what factors maintain them. The vast majority of studies examining predictors of intrusive memories have emphasized factors that exist before, during, and immediately after a distressing event that affect encoding of the initial memory. Yet, post-event factors have some of the strongest evidence in increasing the likelihood of future intrusive memories. Factors that may affect retrieval in the weeks and months after a distressing event have been largely neglected in the empirical intrusive memory literature. As reviewed in the introduction, two prominent models of intrusive memories (Ehlers & Clark, 2000; Ehlers et al., 2004; Brewin et al., 1996; Brewin, 2014) have primarily emphasized the encoding of the

traumatic memory and factors occurring during or immediately after the trauma, with the role of memory retrieval incorporated but not necessarily viewed as a central process. This shift in emphasis may better reflect the dynamic, reconstructive processes in memory at play with intrusive memories.

Undoubtedly, pre-event factors are implicated in the development and persistence of intrusive memories. Indeed, pre-existing psychopathology and the way in which individuals tend to appraise events appear to be fairly consistent findings of this review that appear to predict intrusive memories. Higher pre-existing psychopathology likely makes an individual more vulnerable to developing intrusive memories, as do tendencies to appraise situations negatively.

Two key factors highlighted in existing models and this review include negative cognitive appraisals after the event, as well as data-driven rather than conceptual processing during the event, with these factors most consistently predicting intrusive memories. However, as previously discussed, the paradigms used to study data-driven and conceptual processing are often designed to facilitate data-driven processing, in turn decreasing conceptual processing. Conceptual processing involves processing the meaning of an event and encoding the event in an organized way, in a way that would make the memory more likely to be able to be voluntarily retrieved (Roediger, 1990; Arntz, Groot, & Kindt, 2005). Thus, one determinant of who is more or less likely to develop intrusive memories may be the degree of conceptual processing that occurs during encoding and potentially more critically *during retrieval*. This idea is in line with treatment outcome findings in exposure-based therapy for PTSD, where intentionally revisiting the trauma memory in detail promotes conceptual processing associated with decreased PTSD symptoms (e.g., Kindt, Buck, Arntz, & Soeter, 2007). Specifically, it may be more important to consider how conceptual processing and negative cognitive appraisals can contribute to *intrusive memory persistence and distress* in a memory retrieval framework rather than a framework predominantly emphasizing memory encoding. It may be that one of their key roles is maintaining or increasing retrieval strength via heightened distress, maintaining or even increasing the likelihood of future intrusive memories.

Further understanding memory retrieval processes in a framework for intrusive memories may help shift the field to a more dynamic systems perspective on intrusive memories that more specifically helps understand various trajectories of resilience and psychopathology following distressing, destabilizing life events. Specifically, retrieval-induced forgetting suggests that as certain items associated with a memory trace are repeatedly retrieved, other items associated with the same trace are less likely to be retrieved (e.g., Anderson, Bjork, & Bjork, 1994; Anderson, Bjork, & Bjork, 2000; Barnier, Hung, & Conway, 2004; MacLeod & Macrae, 2001). The content of initial intrusive memories is thought to be formed by the initial learning experience, pairing internal and external stimuli with the distressing event, incorporating traditional conditioning mechanisms. With intrusive memories, the parts of the memory that are typically re-experienced are often the moments where the event becomes more traumatic or the moments that signal the onset of imminent danger (Ehlers et al., 2002; Bernsten, 2002; Hackmann et al., 2004; Holmes, Grey, & Young, 2005). This material often has evolutionary value for protecting from future threat or has high personal relevance in

some form. As an individual continues to experience intrusive memories of a particular danger cue such as the sound of a gunshot and people fleeing, the retrieval strength for those memory traces, and the associated distress or fear persists or even increases. Applying Anderson and colleagues' retrieval-induced forgetting model (Anderson et al., 1994), each time an individual has a memory intrusion of that scene, he or she is more likely to have another intrusive memory because retrieval strength for that gunshot moment of the memory trace has now either sustained or increased its retrieval strength. In particular, associating extreme distress or current threat to those memory traces increases or maintains their further retrieval strength. Initial intrusive memories are retrieved either from out of the blue (i.e., uncued) or come from cues that match the memory from the environment, including cues that are salient because of the detection of threat, cues that have generalized from the original stimuli, or cues that are ambiguous. However, as some aspects of retrieval strength associated with the memory trace are increasing, others are decreasing. Retrieval strength associated with a different aspect of the memory trace, such as shielding a friend or calling for help, may have subsequently decreased. Thus, the individual is frequently sustaining or increasing the retrieval strength of the most horrifying bits of the memory trace, which in turn increases the likelihood of future involuntary or cued retrieval, meanwhile decreasing the retrieval strength of more semantically meaningful, contextual information that may be less emotionally charged. Accordingly, this type of retrieval-induced forgetting model would posit that more conceptual, meaning-related pieces of the memory may become less available over time either for spontaneous or cued retrieval specifically due to the presence of intrusive memories. The cycle of involuntary retrieval, fear, distress, and memory retrieval strengthening is thought to occur within seconds, reflecting a more automatic process occurring immediately following the involuntary memory retrieval. However, slowing down the process and making the process more strategic (e.g., intentionally recalling that moment when the individual shielded a friend or called for help) may be an important window for altering the meaning and related distress surrounding the memory. Yet, notably, at present, there is clear lack of empirical studies examining how memory retrieval may predict intrusive memory persistence, arguing for the need for future study in this regard.

More specifically, maladaptive appraisals and conceptual processing of intrusive memories could also be viewed through a memory retrieval lens, as part of the "feedback loop" that likely leads to increased likelihood of future intrusive memories. Appraisals of an event can not only change emotions about an event but can also change how an event is remembered (e.g., Levine, 1997; Gross, 2002; Levine, Prohaska, Burgess, Rice, & Laulhere, 2001) and how often we think of it (e.g., Schartau, Dalgleish, & Dunn, 2009; Mellings & Alden, 2000). Intrusive memory-related distress may be reduced by fostering alternative appraisals of the event and promoting broader conceptual processing of the meaning of the event. Although there may be individual variability in pre-existing appraisal and processing styles priming an individual to process an intrusive memory in a particular way, these processes are thought to either increase or decrease distress about the intrusive memory and over time help to alter the future retrieval strength of the memory trace. Notably, according to this type of retrieval-based model, the target is not to block the experience of intrusive memories but to alter the distress surrounding them, with the distress first decreasing followed by the frequency of intrusive memories decreasing. That is, when there is no distress, intrusive memories will

only occur under typical cuing scenarios, where there is a strong match between cues and the memory trace, or periodically random "out of the blue" scenarios but will not loop in such a manner to increase the future likelihood of intrusive memories. When intrusive memories are viewed as distressing, this serves to further strengthen this retrieval pathway; when a memory is retrieved and new information is added to it (i.e., distressing appraisal) via protein synthesis in neurons (e.g., Nader, Schafe, & LeDoux, 2000), this added distress and new protein synthesis then increases retrieval strength of initial memory. In this type of dynamic retrieval model, this in turn leads to more future intrusive memory distress and more urges to avoid the memories themselves and potential cues for these intrusive memories. This avoidance does not allow for alternative processing of the intrusive memories. Accordingly, in an intrusive retrieval feedback loop, retrieval of less distressing, more conceptually meaningful information about the event becomes less likely.

This type of dynamic retrieval model can be seen in Figure 2. The model posits that a dynamic re-experiencing process alters subsequent retrieval of a memory trace, helping explain the divergent trajectories of intrusive memories over time following a distressing life event, accounting for both natural remittance and pathological persistence. This divergent trajectory is a key phenomenon that must be accounted for in any plausible theory of intrusive memories, including accounting for the vast majority of individuals who have temporary, non-pathological intrusive memories. Unique predictions of this model would suggest that, while encoding processes are thought to be implicated in the initial presence of intrusive memories, retrieval processes are more implicated in their pathological persistence over time. For those with pathological persistence of intrusive memories, ease of retrieval for other salient traces of the memory, besides the intrusive trace, should decrease over time. This model also posits that reducing distress related to intrusive memories, through various means, is critical for reducing intrusive memories. Finally, this model does not rely on the critical role of a perceptual long-term memory storage system. According to this model, cognitive appraisals and conceptual processing, both fairly robust predictors of intrusive memories evidenced through analogue experimental studies reviewed above, facilitate the development and persistence of distressing intrusive memories through strengthening retrieval of future distress associated with these intrusive memories, including the perception of current threat and ease of recall of the worst moments of the memory. The model, however, does not specify the *when* and *how* of distress reduction. That is, it is posited that distress reduction is a precursor to frequency of intrusive memory reduction; but it does not specify for how long or under what circumstances the distress reduction must be present before intrusive memories decrease nor does it specify the means by which this distress reduction occurs. Accordingly, it leaves open multiple temporal configurations and multiple methods for reducing distress. Finally, the model, like the literature reviewed above, does not address the presence of positive intrusive memories (e.g., seeing a dear friend); however, these types of intrusive memories tend not to be persistent or pathological, key constructs thought to be addressed in this model. In summary, this retrieval-based model argues that the reduction of intrusive memories lies in the promotion of retrieval of information that helps make sense of what happened, altering what is actually retrieved in the future, such that it decreases distress, and eventually the frequency of the brief, vivid intrusive memories.

Limitations of Review

This review has several limitations that should be noted. First, we excluded "grey literature" from the review; we only included peer-reviewed empirical studies, and thus excluded unpublished dissertations, qualitative studies, and book chapters, as well as empirical studies that were not published in English. Second, this review focused specifically on event-based intrusive memories, rather than on broader re-experiencing. This often excluded studies examining predictors of obsessive thoughts in OCD, where content did not reflect memory for an episodic event per se. Although there is certainly a need to better understand what predicts re-experiencing, there are sufficient nuances and complexities, particularly involving the role of autobiographical memory, that may be distinct or similar to other forms of distressing, repetitive phenomena. A related third limitation is that we did not request data from authors who published studies with clinical samples where a dependent variable was a cluster of re-experiencing symptoms rather than intrusive memories specifically. For most PTSD measures, this would result in a single-item data point for re-experiencing of the trauma memory, which would be retrospectively reported across weeks or months and would be undifferentiated from ruminating or more voluntary retrieval processes about the event. Fourth, we did not conduct a meta-analysis of predictors of intrusive memories. Not only were there a wide variety of predictors often with a small number of studies within each predictor, but also the key dependent variables varied widely across studies, including outcomes such as intrusive memory frequency or distress and temporal differences from immediately after a manipulation to days, weeks, and months after an event. Finally, we did not use a standardized metric of study quality. Study designs ranged from non-clinical experimental manipulations to prospective clinical studies, with most metrics heavily weighing this design difference and not balancing additive quality factors such a psychometrically-validated clinical assessment in a clinical sample. Study tables provide the reader with these key factors, including study design, sample size, and assessment methods to facilitate comparison regarding the quality of reported studies.

Research and Clinical Implications

When considering implications and applications related to intrusive memories, the most difficult point of intervention is during an actual event, though intervention here may be possible when some types of events are relatively predictable (e.g., house fire for a fire fighter). Yet, these types of more predictable events may be less likely to produce long-term intrusive memories due to their predictability and controllability (e.g., Rachman, 2001). Peri-traumatic, data-driven processing emerged as a consistent but modest predictor of short-term intrusive memories. One implication for future research is figuring out a way to shift this type of processing from occurring in the first place and how to intervene post-event to decrease the likelihood of intrusive memories developing for those that processed the event in a more data-driven manner.

An important consideration is the difference between intrusive memory production and intrusive memory persistence. The analogue studies reviewed above incorporated paradigms designed to produce intrusive memories, rather than to make intrusive memories persist. This is an important distinction. Clinically, what we are most interested in is the *persistence*, rather than the production per se of intrusive memories. As discussed above, distress is likely

a factor related to persistence. If we are really trying to understand intrusive memories as the distressing and impairing clinical phenomena that they are, a drastic shift in our methods needs to occur. First and foremost, paradigm innovation needs to happen, in order to induce longer-lasting intrusive memories; distressing films are unlikely to elicit intrusive memories that last long enough to be considered persistent, especially with the proliferation of graphic, violent media, TV shows, and films. A different level of immersion in an experience may be needed. Perhaps something like a haunted house, where individuals are fully "in" it and are able to engage multiple senses at once, would help induce longer-lasting intrusive memories, particularly given that intrusive memories are often cued by sensory experiences (e.g., smells, body sensations). Even within the distressing film paradigm, more time-sensitive assessments of intrusive memories are needed to better explore trajectory of intrusive memories and intrusive memory persistence, as analyses in most analogue studies currently group together all intrusive memories reported over a week-long period. This blurs the distinction between participants who are experiencing high numbers of intrusive memories that dissipate over the week and individuals who experience consistent, distressing intrusive memories that do not decrease in frequency. Identifying the subsample of individuals who experience persistent intrusive memories over time, should help increase understanding of what differentiates pathological from non-pathological intrusive memories. In other words, normative intrusive memory development and intrusive memory persistence may represent two distinct constructs that need to be separated.

Another research implication of this review stems from the absence of intrusive memory retrieval manipulations in current paradigms. As previously discussed, memory retrieval is a key way in which memories are strengthened, weakened, and updated. It is essential that new paradigms be developed that manipulate the retrieval and distress of intrusive memories, rather than manipulating the initial encoding. Patients present with problems of memory retrieval, where images of their trauma are being involuntarily retrieved, causing functional impairment, both due to their unpredictability and associated distress. This has particular relevance to clinical implications. Outside of laboratory settings, clinicians often see patients well after an event has been encoded, being unable to alter how someone initially encoded or immediately processed a distressing event. This means that almost by default, these are strongly encoded events, making it all the more important to focus on changing the retrieval strength of various memory traces. Retrieval processes are where we have opportunities for intervention, and also where we have the least amount of research data. We need to develop paradigms that target how to decrease memory strength of those traces that are currently being re-experienced by individuals in distressing ways, knowing that post-trauma these traces are most strongly encoded and that initial encoding strength cannot be changed. These paradigms will also elucidate how to properly increase retrieval strength of the parts of the memory that are more adaptive.

For pre-existing prevention of data-driven processing, perhaps individuals in professions where trauma exposure is highly likely or guaranteed (i.e., EMTs, combat soldiers, firefighters) could be trained to focus on particular aspects of analogue traumatic events. These aspects could be those associated with conceptual processing and reducing maladaptive appraisals. For example, individuals could play a virtual reality video game that presents them with a series of potential events in line with what they may experience in their

line of learning to identify adaptive information mentioned above and lose points for identifying maladaptive information. Notably, however, a simple repeated presentation of variations of the same events are unlikely to mirror events that are likely to cause future intrusive memories, as for these individuals it is the more personally relevant event, one that is different in some way, that is not routine, that evokes themes closely related to personal integrity or their families' integrity, that will likely cause long term intrusive memories. Accordingly, training that covers a variety of potentially difficult, personally-relevant scenarios and targets altering processing of intrusive memories from these scenarios in an adaptive way will be more important than solely training a general processing strategy across standard scenarios. Further, research directly promoting enhanced differential retrieval could be used to augment these training scenarios.

In sum, intrusive memories are common following extremely distressing events, and while for most these memories dissipate naturally over time, for those individuals where intrusive memories persist, they are disruptive and impairing. As such, our understanding of current patterns in the literature and our efforts to advance and improve experimental designs will be incredibly important, as we seek to comprehensively understand what drives intrusive memories. Despite a substantial body of literature that examines potential predictors of event-related intrusive memories, we need paradigm shifts and more studies with clinical samples in order to really advance our understanding of the psychopathological phenomenon of intrusive memories. Although we can hypothesize as to how findings from experimental analogue studies might apply to clinical samples, we do not yet have the empirical evidence to test such hypotheses. If we can shift the emphasis to intrusive memory distress and persistence in analogue studies and extend experimental designs to clinical samples, all while addressing inconsistencies in assessment of intrusive memories, we will be much better equipped to answer the key question of what factors predict intrusive memories following distressing events. Given that intrusive memories are transdiagnostic, highly distressing, and often the target of treatment across a range of presenting psychiatric problems, our comprehensive understanding of what predicts intrusive memories is crucial and will ultimately lead to improvements in both prevention and treatment efforts.

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Public significance statement

Intrusive memories commonly occur after events such as stumbling over words during a speech, the final argument with former spouse, or sexual assault. Their persistence occurs across mental disorders such as social anxiety, depression, and PTSD. Pointing toward ways to better target interventions and direct future research, negative appraisals and lower meaning-oriented processing were consistently associated with intrusive memories; yet, examining repeated retrieval of these memories remains critical in this field.

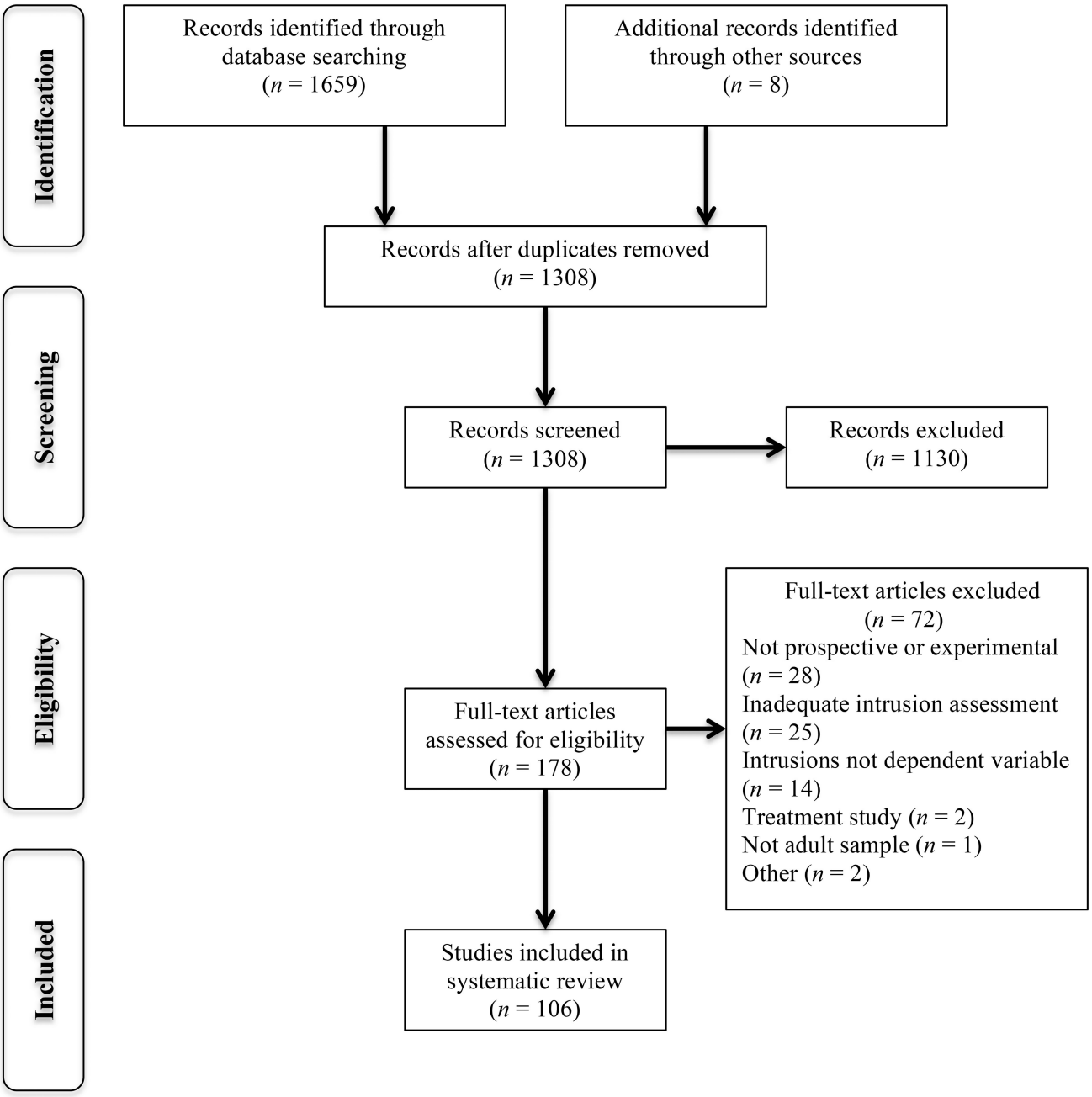

Figure 1.
Study Flow Diagram

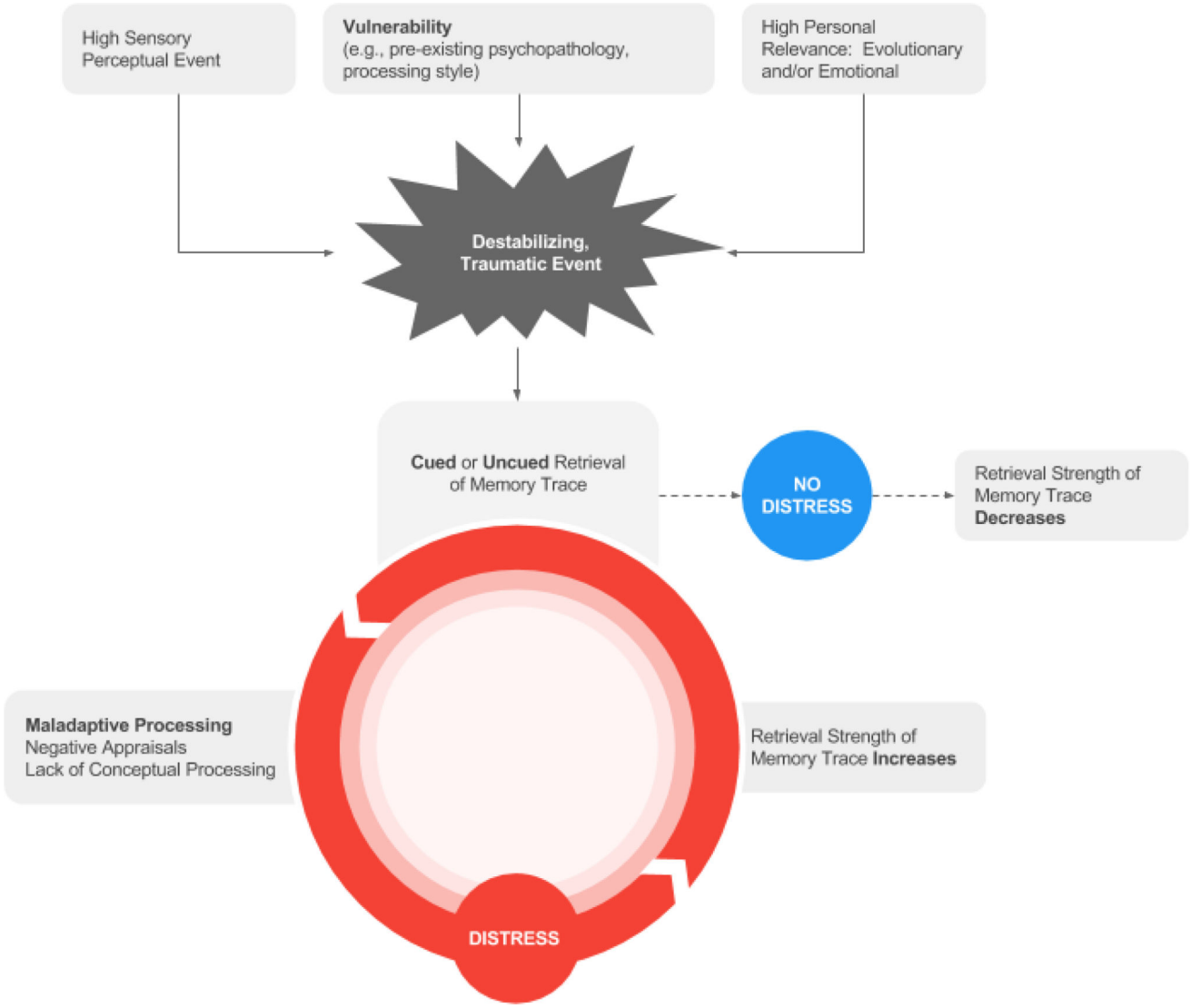

Figure 2.
Retrieval-Based Feedback Loop Model of Intrusions

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Table 1

Reasons for Exclusion for Full-Text Articles Examined ($N = 72$)

Study (first author and year)	Not a chapter, diss, review, etc.	Participants over 18	Adequate assessment of event-based memory intrusions	Prospective or experimental	Association between predictor IVs and intrusions as DV	Not a treatment study	Other reason
*Webleau et al. (2016)	✓	✓	✓	✗			
Bouvard et al. (2016)	✓	✓	✗				
Moeller et al. (2016)	✓	✓	✗				
Moore et al. (2016)	✓	✓	✗				
Van den Broeck et al. (2016)	✓	✓	✗				
Hellerstedt et al. (2016)	✓	✓	✓	✓	✗		
*Muller et al. (2016)	✓	✓	✓	✗			
*Contractor et al. (2016)	✓	✓	✓	✗			
*Clark et al. (2016)	✓	✓	✓	✗			
Lawrence-Wood et al. (2016)	✓	✓	✓	✓	✗		
Takarangi et al. (2016)	✓	✓	✓	✓	✗		
Norrholm et al. (2015)	✓	✓	✗				
*Olatunji et al. (2015)	✓	✓	✓	✗			
*Kleim et al. (2015)	✓	✓	✓	✗			
Dibbets et al. (2015)	✓	✓	✓	✓	✗		
*Clark et al. (2014)	✓	✓	✓	✗			
Valitabar et al. (2014)	✓	✓	✓	✓	✓	✗	
Kupper et al. (2014)	✓	✓	✓	✓	✗		
*Smets et al. (2014)	✓	✓	✓	✗			
Garcia-Soriano et al. (2014)	✓	✓	✗				
*Walsh et al. (2014)	✓	✓	✓	✗			
*Bernsten et al. (2014)	✓	✓	✓	✗			
Miller et al. (2013	✓	✓	✗				
*Priebe et al. (2013)	✓	✓	✓	✗			

Study (first author and year)	Not a chapter, diss, review, etc.	Participants over 18	Adequate assessment of event-based memory intrusions	Prospective or experimental	Association between predictor IVs and intrusions as DV	Not a treatment study	Other reason
Cheung et al. (2013)	✓	✓	✗				
Kleim et al. (2013)	✓	✓	✓	✓	✗		
Monds et al. (2013)	✓	✓	✓	✓	✗		
Goldsmith et al. (2013)	✓	✓	✗				
*Erbes et al. (2012)	✓	✓	✓	✗			
Smets et al. (2012)	✓	✗					
Smets et al. (2012)	✓	✓	✓	✓	✗		
*Reynolds et al. (2012)	✓	✓	✓	✗			
Levi-Gigi et al. (2012)	✓	✓	✗				
Lang et al. (2012)	✓	✓	✗				
*Moulds et al. (2012)	✓	✓	✓	✗			
Engelhard et al. (2011)	✓	✓	✗				
Nixon et al. (2011)	✓	✓	✓	✓	✗		
Bryant et al. (2011)	✓	✓	✗				
Kvavilashvili et al. (2011)	✓	✓	✓	✓	✗		
*Newby et al. (2010)	✓	✓	✓	✗			
*Weidmann et al. (2010)	✓	✓	✓	✗			
*Malmo et al. (2010)	✓	✓	✓	✗			
Jelinek et al. (2010)	✓	✓	✓	✗			
Weidmann et al. (2009)	✓	✓	✓	✓	✓	✓	Looks at what films best elicit intrusions
Lemogne et al. (2009)	✓	✓	✗				
*Rubin et al. (2008)	✓	✓	✓	✗			
Hauer et al. (2008)	✓	✓	✗				
*Moulds et al. (2008)	✓	✓	✓	✗			
Wimalaweera et al. (2008)	✓	✓	✗				
*Williams et al. (2008)	✓	✓	✓	✗			
*Yoshizumi et al. (2007)	✓	✓	✓	✗			

Study (first author and year)	Not a chapter, diss, review, etc.	Participants over 18	Adequate assessment of event-based memory intrusions	Prospective or experimental	Association between predictor IVs and intrusions as DV	Not a treatment study	Other reason
Nixon et al. (2007)	✓	✓	✗				
*Williams et al. (2007)	✓	✓	✓	✗			
*Verwoerd et al. (2007)	✓	✓	✓	✗			
Rosenthal et al. (2006)	✓	✓	✗				
Dalgleish et al. (2006)	✓	✓	✗				
*Starr et al. (2006)	✓	✓	✓	✗			
Michael et al. (2005)	✓	✓	✓	✓	✗		
Brewin et al. (2005)	✓	✓	✗				
*Holmes et al. (2005)	✓	✓	✓	✗			
Elsesser et al. (2004)	✓	✓	✗				
*Halligan et al. (2003)	✓	✓	✓	✓	✓	✓	The prospective study looked at predictors of PTSD rather than intrusions; intrusion variables were assessed, but only at baseline
*Bernsten et al. (2003)	✓	✓	✓	✗			
Engelhard et al. (2002	✓	✓	✗				
*Ehlers et al. (2002)	✓	✓	✓	✗			
Carlier et al. (2000)	✓	✓	✗				
Brewin et al. (1999)	✓	✓	✓	✓	✗		
*Reynolds et al. (1998)	✓	✓	✓	✗			
Brewin et al. (1998)	✓	✓	✓	✓	✗		
Mayou et al. (1997)	✓	✓	✓	✓	✗		
Balder et al. (1997)	✓	✓	✗				
Freeston et al. (1995)	✓	✓	✗				

*Denotes study excluded due to cross-sectional design

Table 2

Summary of Findings of Studies Examining Pre-Event Predictors Included in Systematic Review

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 day	Other	Monitor	Diary	Other		
Traits/Psychopathology																
Bomyea & Amir (2012)	Undergrad (excluded trauma history and PTSD sxs)	30		✓	DS-R STAI-T BDI-II	✓			✓			✓			Higher disgust propensity → more intrusive memories; held when anxiety and depression controlled for	f^2 = .35
Davies & Clark (1998a)*	Community (excluded previous treatment, suicidality)	90		✓	BDI STAI-T EPQ TSS PICS FBQ	✓			✓	✓		✓	✓		Depression: nonsig. Anxiety: nonsig. Neuroticism: nonsig. Suppression → more in-session intrusive memories Beliefs → more diary intrusive memories Proneness → more days w/intrusive memories	
Hagenaars & Krans (2011)*	Undergrad (excluded psychopathology)	99		✓	DES-C	✓				✓			✓		Trait dissociation did not significantly predict intrusive memory frequency when state dissociation and state horror included; horror mediated relationship but state dissociation did not	
Hagenaars et al. (2008)*	University (excluded psychopathology)	89		✓	DES-C	✓				✓			✓		Nonsig. association with intrusive memory freq when entered in regression	
Halligan et al. (2002)*	Undergrad	61		✓	CPQ	✓	✓			✓				✓ VMQ	Higher data-driven processing → more intrusive memories	

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 day	Other	Monitor	Diary	Other		
															and higher intrusive memory distress	
Holmes et al. (2004) *	Undergrad	72	✓	✓	TDQ	✓				✓			✓		Nonsig. association	
Kamboj et al. (2014) *	University/Community (excluded blood phobia, prior treatment)	79		✓	BEM Sex-Role Inventory Gender	✓	✓	✓		✓			✓		Higher communality → more intrusive memories in men only	
Kubota et al. (2015)	University (excluded psychopathology)	90	✓	✓	Low mood induction pre-film vs. low mood induction post-film vs. control DASS PTQ	✓	✓		✓	✓		✓			Depressive symptoms→ more frequent and distressing intrusive memories; remained significant after controlling for trait and trauma-related rumination	
															Nonsig. associations between induction conditions and intrusive memory freq or distress	
Laposa & Alden (2008)	Undergrad (excluded treatment history, MVA experience)	68		✓	STAI-T WPT BDI-II DES	✓				✓			✓		Higher post-film anxiety mediated all three trait predictors of intrusive memories	
Logan & O'Kearney (2012) *	University/Community	105	✓	✓	STAI-T	✓	✓			✓			✓		Higher trait anxiety → more intrusive memories	*r* = .22 (post film)
															Nonsig. association between trait anxiety and intrusive memory distress	*r* = .28 (day 7)
																r = .26 (total)
Mairean & Ceobanu (2016) *	Undergrad (excluded MVA experience)	148		✓	DES-II WBSI ERQ	✓				✓			✓		Thought suppression → more intrusive memories; mediated by state anxiety	
															Nonsig. relationship between trait dissociation and emotion suppression	

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 day	Other	Monitor	Diary	Other		
															on intrusive memories	
Marks & Zoellner (2014)*	Undergrad	148		✓	BDI-II STAI-T PDS ASI-II ERQ	✓	✓				✓ 24 hr post-extinction			✓ Phone Assessment	Anxiety sensitivity → more intrusive memories post-extinction Nonsig. associations between all other psychopathology IVs and intrusive memory frequency and distress	
Regambal et al. (2009)*	Undergrad (excluded current treatment, MVA in last 6 mos)	148		✓	BDI-II STAI-T	✓				✓			✓		Higher depression/ trait anxiety → more intrusive memories indirectly via peritraumatic processing and maladaptive coping	
Schaich et al. (2013)	Undergrad (excluded psychopathology, trauma history, suicidality)	68	✓	✓	Abstract or concrete processing style RRS	✓	✓	✓	✓	✓				✓ Intrusive memory Questionnaire	Trait rumination → more intrusive memories in session in abstract processing condition only; held for frequency, distress, and vividness in week post-film	
White & Wild (2016)*	Undergrad (excluded PTSD & MDD)	50	✓	✓	TDQ-Short PTQ	✓				✓			✓		Nonsig. associations between IVs and DVs	
Williams & Moulds (2007a)*	Undergrad	57		✓	BDI RRS	✓	✓		✓			✓			Higher depression → more distressing intrusive memories Nonsig. associations between trait rumination and intrusive memory freq, distress	B = .44 (BDI/ intrusive memory distress)
Biological Factors																
Bisby et al. (2009)	Undergrad/Post-grad (excluded treatment history, trauma history)	48	✓	✓	Alcohol dose (low, high, pbo)	✓				✓			✓		Low dose → more intrusive memories than high dose and pbo	

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 day	Other	Monitor	Diary	Other		
															High dose → fewer intrusive memories than pbo	
Bisby et al. (2010)	University (excluded treatment history, trauma history, problematic drinking)	48	✓	✓	Alcohol dose (low, high, placebo), egocentric vs. allocentric	✓				✓			✓		Low dose → more intrusive memories than high dose and pbo	
															High dose → fewer intrusive memories than pbo	
Cheung & Bryant (2015) *	Undergrad (excluded PTSD & MDD)	46		✓	Image valence (neutral, neg.); FKBP5 allele (low, high risk)	✓					✓ 48 hrs			✓ Adapted IES items	High risk allele group → more intrusive memories in both neutral and negative picture conditions	$\eta^2 = 0.11$
Ferree et al. (2011)	Undergrad	40		✓	Menstrual cycle phase; Progesterone, estradiol levels	✓					✓ 48 hrs			✓ Retrospective Interview	Luteal → more intrusive memories than follicular	
															Lower progesterone → fewer intrusive memories	
															Nonsig. relationship for estradiol and intrusive memories	
Hawkins & Cougle (2013)	Undergrad (excluded smokers, MVA experience, blood phobia, current PTSD/MDD	54	✓	✓	PTQ Nicotine vs. pbo	✓	✓		✓	✓		✓	✓		Nicotine → more intrusive memories than pbo	Post: $\eta^2 = .09$
															Low trait rumination + nicotine → more intrusive memories than low trait rumination + pbo via diary	
															Nonsig. associations between condition and intrusive memory distress via diary	
Rombold et al. (2016a)	University (excluded psychopathology, history of rape or sexual abuse)	118	✓	✓	Yohimbine vs. clonidine vs. pbo	✓	✓	✓			✓ 4 days		✓		Delayed decrease in frequency and vividness for yohimbine	Freq: $\eta^2 = 0.05$

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 day	Other	Monitor	Diary	Other		
																Vivid: η^2 = 0.04
															Nonsig. effects on distress	
Rombold et al. (2016b)	University (excluded psychopathology, history of rape or sexual abuse)	60	✓	✓	HCT vs. pbo Menstrual phase	✓	✓	✓		✓			✓		Nonsig. associations between any IVs and intrusive memory DVs	
Soni et al. (2013)	University (excluded treatment history, blood phobia)	41		✓	Menstrual cycle phase	✓	✓	✓			✓ 3 days		✓		Low estradiol + high progesterone → more image-based intrusive memories	
															Nonsig. effect of estradiol and progesterone alone on intrusive memories	
															Nonsig. effects on distress, vividness	
Wegerer et al. (2014)	University (excluded psychopathology, history of severe interpersonal violence)	37		✓	Estradiol and progesterone levels	✓	✓	✓			✓ Post-exp + 2 days after			✓ IMQ	Lower estradiol → stronger intrusive memories partially explained by differences in fear conditionability	
															Nonsig. association between progesterone and intrusive memories	
Associative Cues																
Ehlers et al. (2006)	University (excluded trauma history, severe depression, blood phobia)	62		✓	Perceptual priming (speed of blurred picture identification)	✓					✓ 3 mos			✓ IMQ	Enhanced encoding of cues → more intrusive memories	
Michael & Ehlers (2007)	University (excluded trauma history, severe depression, blood phobia)	92	✓	✓	Perceptual priming (ID rates, priming index); memory elaboration vs. control	✓					✓ 1 mo			✓ MTQ	Enhanced encoding of cues pre-picture stories → more intrusive memories in control condition but not in elaboration condition	η^2 = 0.046

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 day	Other	Monitor	Diary	Other		
Meyer et al. (2013)	Undergrad (excluded “psych complaints”, substance abuse, trauma history)	82		✓	Performance on Spatial Contextual Cueing Task	✓	✓			✓			✓		Better learning performance → fewer intrusive memories; nonsig. effect on intrusive memory distress	$r = -.28$ (total) $r = -.33$ (image-based intrusive memories only)
Sundermann et al. (2013)*	Community (excluded blood phobia, depression, trauma history, freq exposure to graphic material)	51		✓	Perceptual priming (ID rates)	✓	✓				✓ wks mos			✓ Phone Interview	Enhanced priming → more intrusive memories at 2 wks but not at 3 mo follow-up	$\eta^2 = 0.08$ (2 wk)
Negative Appraisals																
Brown et al. (2012)	Undergrad	33	✓	✓	Self-efficacy (high vs. low)	✓			✓		✓ 24 hr	✓		✓ Phone Assessment	Low self-efficacy → more intrusive memories	$d = 0.62$ (post-film) $d = 0.80$ (24 hr)
Lang et al. (2009)	University	40	✓	✓	+ or - cognitive bias modification	✓	✓			✓			✓		+ CBM → fewer thought intrusive memories; nonsig. differences in image-based intrusive memories and distress	
Wilksch & Nixon (2010)	University	49		✓	Risk of interpreting intrusive memories negatively (High risk, low risk groups ID’ed via Posttraumatic Cognitions Inventory)	✓	✓		✓	✓		✓	✓		High risk group → more intrusive memories after controlling for depression, PTSD, and maladaptive cognitions both in session and via diary	$g = 0.87$ (in session) $g = 0.52$ (diary)
															High risk group → higher intrusive memory distress during session only	$g = 1.27$ (1 wk) $g = 0.63$ (distress in session)
Woud et al. (2013)	Community (excluded psychopathology, trauma history)	54	✓	✓	+ or - cognitive bias modification	✓	✓			✓			✓		+ CBM → lower intrusive memory distress; nonsig. differences in frequency	$d = 0.79$ (intrusion-related distress)

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 day	Other	Monitor	Diary	Other		
Attentional Control/Working Memory Capacity																
Hagenaars & Putman (2011)	University (excluded psychopathology, MVA experience)	43		✓	ACS TIS	✓				✓			✓		Increased tonic immobility → more intrusive memories for low but not high attentional control group	*r* = .48
James et al. (2016)	University/Community (excluded psychopathology)	56	✓	✓	Tetris or no task pre-film	✓				✓			✓	✓ IPT	Nonsig. differences in intrusive memory frequency	
Verwoerd et al. (2011)	Undergrad	85		✓	Subtest of CVLT	✓				✓			✓		Weak ability to resist proactive interference → more intrusive memories after controlling for neuroticism	*r* = .24
Wessel et al. (2008)	Undergrad	104		✓	Cognitive control (random number generator task; RNG)	✓	✓	✓			✓ 48 hr		✓		Better cognitive control via RNG → more intrusive memories	
															Nonsig. effects on intrusive memory distress and vividness when depression and emotionality controlled for	
General Mental Imagery																
Davies & Clark (1998a)*	Community (excluded previous treatment, suicidality)	90		✓	MIRQ	✓			✓	✓		✓	✓		Nonsig. association	
Krans et al. (2011)	University (excluded psychopathology, MVA experience)	59	✓	✓	Film vs. imagery SUIS VVQ	✓				✓			✓		Higher use of imagery → fewer intrusive memories	*r* = −.26 (SUIS)
															Visual processing style → more intrusive memories in imagery condition only	*r* = .41 (VVQ)
															Nonsig. associations between intrusive	

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 day	Other	Monitor	Diary	Other		
															memories and film vs. verbal report	
Morina et al. (2013) *	Undergrad (excluded psychopathology, trauma history)	67		✓	QMI	✓			✓		✓ 5 days		✓	✓ Intrusive memory Questionnaire	Higher mental imagery → more uncued intrusive memories in session and via diary	
															Nonsig. Association between mental imagery and cued intrusive memories during session	
Other																
Belcher & Kangas (2015)	Undergrad/Community (excluded psychopathology)	101	✓	✓	AMT scores (past + future event specificity)	✓				✓			✓		More event specificity → fewer intrusive memories	

Study Quality: “Ran” = randomized, “Pros” = prospective; DS-R: Disgust Scale-Revised; STAI-T: State-Trait Anxiety Inventory-Trait; BDI-II: Beck Depression Inventory-II; EPQ: Eyesenck Personality Questionnaire; TSS: Thought Suppression Scale; PICS: Proneness to Intrusive Cognitions Scale; FBQ: Fire Beliefs Questionnaire; DES-C: Dissociative Experiences Scale-C; CPQ: Cognitive Processing Questionnaire; TDQ: Trait Dissociation Questionnaire; DASS: Depression Anxiety Stress Scale-D; PTQ: Perseverative Thinking Questionnaire; WPT: Wonderlich Personnel Test; WBSI: White Bear Suppression Inventory; ERQ: Emotion Regulation Questionnaire; PDS: Posttraumatic Diagnostic Scale; ASI-II: Anxiety Sensitivity Index-II; RRS: Ruminative Response Scale; HCT: hydrocortisone; PTCI: Posttraumatic Cognitions Inventory; ACS: Attentional Control Scale; TIS: Tonic Immobility Scale; CVLT: California Verbal Learning Test; MIRQ: Mental Imagery Ratings Questionnaire; SUIS: Spontaneous Use of Imagery Scale; VVQ: Verbal Visualizer Questionnaire; QMI: Questionnaire upon Mental Imagery; AMT: Autobiographical Memory Test; IPT: Intrusion Provocation Task; IMQ: Intrusive Memory Questionnaire; MTQ: Memories & Thoughts Questionnaire; VMQ: Videotape Memory Questionnaire

* Study included multiple times in table due to presence of multiple predictors of intrusions

Table 3

Summary of Findings of Studies Examining Peri-Event Predictors Included in Systematic Review

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 day	Other	Monitor	Diary	Other		
Peritraumatic Processing																
Bourne et al. (2010)	Community	40	✓	✓	Visuospatial vs. verbal task vs. control	✓				✓			✓		Visuospatial → fewer intrusive memories than both verbal and control conditions	*d* = 0.80 (visuo vs. control *d* = 1.30 (visuo vs. verbal) *d* = 1.57 (verbal vs. control, study 2)
Brewin & Saunders (2001)	Undergrad	39	✓	✓	Visuospatial vs. no task	✓					✓ 2 wks		✓		Nonsig. associations	
Halligan et al. (2002)	Undergrad	61	✓	✓	Data-driven vs. conceptual viewing instructions	✓	✓			✓				✓ Questionnaire	Nonsig. effect of processing condition on intrusive memory freq or distress	
Holmes et al. (2004) * (3 studies)	University	72/80/60	✓	✓	Study 1: Visuospatial vs. dot-staring vs. no task	✓				✓			✓		Visuospatial → fewer intrusive memories than no task and dissociation condition Nonsig. Association between dissociation and control	*d* = 0.63 (visuo vs. control *d* = 1.03 (visuo vs. dot-staring)
					Study 2: Single key tap vs. overpracticed visuospatial vs. underpracticed visuospatial										Underpracticed → fewer intrusive memories than control Overpracticed → fewer intrusive memories than control	*d* = 0.40 (under vs. control) *d* = 0.35 (over vs. control)
					Study 3: Verbal interference vs. verbal enhancement vs. control										Verbal interference → more intrusive memories than control Nonsig. associations for enhancement and control	*d* = 1.18 (interference vs. control)

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 day	Other	Monitor	Diary	Other		
Kindt et al. (2008) *	Undergrad (excluded indivs w/abuse histories)	73	✓	✓	Data-driven vs. conceptual viewing instructions	✓				✓			✓		Nonsig. association	
Krans et al. (2010b)	University (excluded psychopathology)	54	✓	✓	Visuospatial vs. configurational task vs. no task	✓				✓			✓		Visuospatial → fewer intrusive memories than configurational and control Nonsig. association between configurational and control	*d* = 0.78 (visuo vs. control *d* = 0.63 (visuo vs. config)
Krans et al. (2010a)	University/ Community (excluded psychopathology)	86	✓	✓	Visuospatial vs. verbal vs. no task	✓				✓			✓	✓ IPT	Visuospatial and verbal → fewer intrusive memories than no task	*d* = 0.71 (visuo vs. control *d* = 0.66 (verbal vs. control
Krans et al. (2013) *	Undergrad (excluded psychopathology)	60	✓	✓	Visuospatial vs. verbal vs. no task	✓				✓	✓ 3 days		✓		Nonsig. associations	
Laposa & Alden (2006)	Nurses w/ 1 yr experience in acute care	136	✓	✓	Medical focus vs. normal film viewing instructions	✓	✓			✓			✓		Medical focus → fewer intrusive memories Nonsig. association for intrusive memory distress	*d* = 0.41
Laposa & Rector (2012) *	University (excluded psychopathology and history of any mental health treatment)	91		✓	CPQ	✓				✓			✓		Less self-referent processing → more intrusive memories when controlling for state dissociation and data-driven processing; not significant when post-anxiety added Data-driven processing not a unique predictor	
Logan & O'Kearney (2012) *	University/ Community	105	✓	✓	Conceptual vs. sensory vs. no interference	✓	✓	✓	✓	✓	✓ Day of film viewing		✓		High trait anxiety + sensory interference → fewer intrusive memories compared to low trait anxiety + sensory interference day of film viewing; nonsig. effects on 7 day diary	*d* = 0.82 (day of film intrusive memory frequency) *d* = 0.66 (day of film intrusive

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 day	Other	Monitor	Diary	Other		
															memory distress)	
															Nonsig. effects of conceptual interference on intrusive memory DVs	
Morina et al. (2013) *	Undergrad (excluded trauma hx, psychosis, MDD, current treatment)	67		✓	CPQ	✓	✓	✓	✓		✓ 5 days		✓	✓ Questionnaire	Higher data-driven processing associated with more intrusive memories, higher intrusive memory distress and vividness at all timepoints	Range: r = .30 – r = .42
Pearson & Sawyer (2011)	University/Community	24/36	✓	✓	Study 1: Visuospatial vs. nonspatial vs. no task	✓				✓			✓		Visuospatial and nonspatial → fewer intrusive memories than no task	
					Study 2: High and low cognitive load for both visuospatial and verbal										High cognitive load → fewer intrusive memories regardless of task modality	
Regambal et al. (2009) *	Undergrad (excluded current treatment, MVA in last 6 mos)	148		✓	STAI-S CPQ	✓				✓			✓		Greater increases in negative emotions → more intrusive memories	
															Data-driven processing → more intrusive memories indirectly via maladaptive coping	
Segovia et al. (2016)	Community	211	✓	✓	Organized vs. disorganized film clip; conceptual vs. data-driven vs. normal viewing instructions	✓	✓			✓			✓		Nonsig. effects of either manipulation on intrusive memory frequency and distress	
Stuart et al. (2006) *	University (excluded any mental health treatment)	20	✓	✓	Visuospatial vs. no task	✓				✓			✓		Visuospatial → fewer intrusive memories	η^2= 0.34
Sundermann et al. (2013) *	Community (excluded trauma history, depression, blood phobia)	51		✓	DDP	✓	✓				✓ wks; mos			✓ Phone interview	Higher data-driven processing → more intrusive memories at 2 wks but not 3 mos follow-up	

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 day	Other	Monitor	Diary	Other		
White & Wild (2016) *	University (excluded PTSD & MDD)	50	✓	✓	Abstract vs. concrete training	✓				✓			✓		Concrete training → fewer intrusive memories	*d* = 0.59
Context																
Krans et al. (2013)	Undergrad (excluded psychopathology)	60	✓	✓	Context vs. no context information	✓				✓	✓ 3 day		✓		Context info → more intrusive memories only when no dual task being performed after 3 days Nonsig. differences for 7 day diary	
Krans et al. (2016)	Undergrad/grad students (excluded psychopathology)	120	✓	✓	Moderate vs. severe outcome vs. no information	✓	✓	✓		✓	✓ 7th day post		✓	✓ IPT	Severe outcome → more intrusive memories on provocation task than moderate and control conditions Nonsig. effect on intrusive memory frequency, vividness, distress via diary	
Pearson (2012)	University (excluded psychopathology)	40	✓	✓	Contextual information vs. no information	✓		✓		✓			✓		Contextual information → more intrusive memories Nonsig. effects on vividness, emotionality	
Pearson et al. (2012)	University	40	✓	✓	Contextual information vs. no information	✓		✓		✓			✓		Contextual information → more intrusive memories Nonsig. effects on vividness, emotionality	η^2= 0.12
Staugaard & Bernsten (2014)	University	32	✓	✓	Sound cue type (unique vs. repeated)	✓			✓					✓ Retrieva l phase	Unique sounds → more intrusive memories	
Dissociation																
Brewin & Saunders (2001) *	Undergrad	39	✓	✓	Dissociation induction (visuospatial vs. distraction)	✓					✓ 2 wks		✓		Nonsig. association	
Chou et al. (2014a)	Community (excluded psychopathology & MVA experience)	64		✓	Startle group (low, medium, high); HR change	✓		✓		✓			✓		Greater decrease in HR → increased intrusive	

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 day	Other	Monitor	Diary	Other		
															memory vividness in low startle group only Nonsig. effects on frequency	
Dorahy et al. (2016)	Undergrad	60	✓	✓	Mirror staring vs. dot staring vs. neutral image M-PDEQ	✓	✓				✓ 3 days		✓		Dot condition → more intrusive memories than neutral on day 1 post-session Nonsig. effects on intrusive memory frequency on days 2, 3, and 3-day total Dot condition → more intrusive memory distress on day 1 Both dissociation conditions → more distress on 3-day total M-PDEQ →more intrusive memories on day 1 and 3-day total M-PDEQ→ higher intrusive memory frequency on day 1, day 2, and 3-day total	
Hagenaars & Krans (2011) *	University (excluded psychopathology)	99		✓	DSS	✓				✓			✓		Nonsig. effect of DSS on intrusive memory frequency	
Hagenaars et al. (2008) *	University (excluded MDD & blood phobia)	79	✓	✓	Dissociative non-movement vs. deliberate non-movement vs. control	✓				✓			✓		Both non-mvement conditions → more intrusive memories Nonsig. differences between movement types	
Holmes et al. (2004) *	University	54/80/60	✓	✓	3-study sequence; DSS and HR assessed in each study	✓				✓			✓		Increases in state dissociation → more intrusive memories after controlling for dual task and trait anxiety in studies 1 & 2; nonsig. effect in study 3 Greater reductions in HR over film → more	

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 day	Other	Monitor	Diary	Other		
															intrusive memories in studies 1 & 2; nonsig. effect in study 3	
Holmes et al. (2006)	University (excluded any mental health treatment)	16	✓	✓	Suggested dissociation vs. control	✓				✓			✓		Nonsig. association	
Laposa & Rector (2012) *	University (excluded psychopathology, treatment history history)	91		✓	PDEQ	✓				✓			✓		PDEQ did not significantly predict intrusive memories when self-referent processing and data-driven processing controlled for	
Mairean & Ceobanu (2016) *	University (excluded MVA experience)	148		✓	DSS	✓				✓			✓		State dissociation → more intrusive images but not thoughts State dissociation did not mediate relationship b/w thought and emotion suppression and intrusive memories	
Biological & Emotional Arousal																
Cheung et al. (2015) *	Undergrad	63	✓	✓	sAA and cortisol levels	✓		✓			✓ 2 days			✓ specific items from IES	Nonsig. associations between sAA, cortisol and intrusive memory freq using post-film saliva samples	
Chou et al. (2014b)	University/Community (excluded psychopathology, treatment, MVA experience	58		✓	Cortisol levels; HR groups (accelerators & decelerators)	✓		✓		✓			✓		Higher peri-film cortisol → more intrusive memories only for accelerators but not decelerators Lower post-film cortisol → more vivid intrusive memories	*r* = .53 (peri-film cort in accelerators)
Dunn et al. (2009)	Community (excluded current psychopathology, past PTSD)	89	✓	✓	Emotion suppression vs. acceptance vs. no regulation instructions	✓				✓			✓		Nonsig. associations between conditions and intrusive memories including when trait emotion regulation strategies controlled for Post hoc: greater proportion of zero intrusive memory days	

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 day	Other	Monitor	Diary	Other		
															for suppress vs. other conditions	
Hall & Bernsten (2008)	University	129		✓	STAI-S Intensity, valence, mood impact, dislike, bodily reaction, self-relevance of pictures	✓		✓			✓ 5 days		✓		Higher emotion during encoding → more memories of pictures (both voluntary and involuntary)	
Holmes et al. (2004) *	University	54/80/60	✓	✓	HR in 3-study sequence	✓				✓			✓		Greater reductions in HR over film → more intrusive memories in studies 1 & 2; nonsig. effect in study 3	
Nicholson et al. (2014)	Trauma-exposed (mixed trauma)	58		✓	Norepinephrine Cortisol NE*cort interaction PTSD vs. trauma-exposed vs. non-trauma exposed	✓					✓ 2 days			✓ Retrospective diary	NE*cort → intrusive memories only in PTSD group Nonsig. associations for all other IVs and DVs	
Wegerer et al. (2013)	University (excluded mental and neuro disorders)	66		✓	Fear conditionability (via SCR and subjective ratings)	✓			✓		✓ 2 days		✓	✓ IMQ	Higher fear conditionability → more intrusive memories 30 min post-task and in 2 days follow-up	

Study Quality: “Ran” = randomized, “Pros” = prospective; DDP: Data-Driven Processing subscale of CPQ; LSRPS: Lack of Self Referent Processing Scale; CPQ: Cognitive Processing Questionnaire; STAI-S: State-Trait Anxiety Inventory- State; HR: heart rate; M-PDEQ: Modified Peritraumatic Dissociative Experiences Scale; DSS: Dissociative State Subscale; sAA: salivary alpha amylase; SCR: Skin conductance response; TMQ: Trauma Memory Questionnaire; IPT: Intrusion Provocation Task; IMT: Intrusive Memory Questionnaire

*Study included multiple times in table due to presence of multiple predictors of intrusions

Table 4

Summary of Findings of Studies Examining Post-Event Predictors Included in Systematic Review

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 Day	Other	Monitor	Diary	Other		
Appraisals and Biases																
Hagenaars & Arntz (2012)	University (excluded psychopathology, MVA experience)	76	✓	✓	Imagery rescripting vs. reexperiencing vs. positive	✓				✓			✓		Imagery rescripting → lower intrusive memories than reexperiencing and positive conditions	$\eta^2 = 0.11$ (overall) $d = 0.57$ (rescripting vs. positive) $d = 0.87$ (rescripting vs. reexperiencing)
Kleim et al. (2012)	MVA or assault survivors	221	✓	✓	Processing advantage for trauma-related stimuli: ID rate of trauma-relevant pictures minus neutral ID rate	✓				✓				✓ Intrusive memory Interview	Higher processing advantage for trauma-related stimuli → more intrusive memories	$r = 0.14$
Newby et al. (2014)	Community (mildly depressed; excluded bipolar depression)	60	✓	✓	Positive appraisal vs. education vs. control	✓	✓			✓			✓	✓ IMI	Education → greater reductions in intrusive memory distress (IMI) compared to control; nonsig. difference between education and positive appraisal Nonsig. association w/ frequency via diary	$d = 0.89$ (education vs. control)
Verwoerd et al. (2009)	Undergrad	36		✓	RSVP difference score	✓				✓			✓		Bias toward trauma-relevant information → more intrusive memories	
Woud et al. (2012)	University	76	✓	✓	+ vs. – reappraisal training	✓				✓			✓		+ reappraisal training → lower intrusive memories Nonsig. association between condition and intrusive memory distress	$d = 0.49$
Rumination																
Ball & Brewin (2012)	University (moderate-to-high ruminators) (Excluded treatment history, trauma history, MVA experience)	60	✓	✓	Film related rumination vs. non-film related vs. no task	✓	✓	✓		✓			✓		Rumination conditions → more intrusive memories, greater # of	$d = 0.59$ (intrusive memory freq)

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 Day	Other	Monitor	Diary	Other		
															days w/ intrusive memories	
															Nonsig. association with intrusion-related distress, reliving, or vividness	d = 0.79 (days with intrusive memories)
Ehring et al. (2009)	University (excluded psychosis, depression, suicidality, trauma history)	83	✓	✓	Abstract rumination vs. concrete thinking vs. distraction	✓	✓	✓	✓		✓ 3 days			✓ Intrusive memory Questionnaire	Distraction → more intrusive memories after reminders	η^2 = 0.10 (distraction vs. abstract + concrete after reminders)
															Nonsig. effect on intrusive memory freq after manipulation or 3-day follow-up	
															Nonsig. differences b/w abstract and concrete	
															Nonsig. effects on vividness and distress	
Ehring et al. (2009)	University (excluded psychosis, depression, suicidality, trauma history)	51	✓	✓	Rumination vs. distraction	✓	✓	✓	✓					✓ Intrusive memory Questionnaire	Rumination → more intrusive memories pre- to post-manipulation	η^2 = 0.21 (pre-post * condition interaction; frequency)
															Distraction → greater reductions in intrusive memory distress pre- to post-manipulation, and post-manipulation to post-provocation task	η^2 = 0.25 (pre-post * condition interaction; distress)
																η^2 = 0.25 (post-manipulation – post-provocation; distress)
Kubota et al. (2015)	University (excluded psychopathology)	90		✓	PTQ-S	✓	✓		✓	✓		✓			State rumination did not significantly mediate relationship between depression and intrusive memory freq when trait rumination controlled for	κ^2 = .15 (indirect effect of state rumination on intrusive memory distress)
															Did mediate relationship between depression and intrusive memory distress	

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 Day	Other	Monitor	Diary	Other		
Laposa & Rector (2012) *	University (excluded psychopathology, treatment history history)	91		✓	ARQ RIQ	✓				✓			✓		Higher rumination in response to intrusive memories → more intrusive memories even after controlling for depression Nonsig. association between anxious rumination and intrusive memories	*r* = .38
Santa Maria et al. (2012)	University (excluded depression, suicidality, psychosis, sexual assault history)	57	✓	✓	Abstract vs. concrete rumination; RRS; PTQ	✓	✓	✓	✓		✓ 1 and 3 days post			✓ 3 items from IES	Abstract → smaller decrease in intrusive memories pre- to post-manipulation and pre- to end of session even after controlling for trait rumination Nonsig. effects on vividness and distress	*d* = 0.57 (pre-to post) *d* = 0.60 (pre to 3 days post)
Williams & Moulds (2007a) *	Undergrad	57	✓	✓	Low vs. high dysphoria groups; Analytical vs. experiential vs. distraction	✓	✓		✓			✓			Nonsig. associations between IVs and DVs	
Williams & Moulds (2010)	Undergrads w/ dysphoria	77	✓	✓	Analytical rumination vs. distraction		✓	✓	✓					✓ IMI	Analytical → higher intrusive memory distress, intrusion-related sadness, intrusive memory negativity even after controlling for trait rumination	
Zetsche et al. (2009) *	Community (excluded depression, blood phobia, trauma history)	101	✓	✓	Rumination vs. memory integration vs. control	✓			✓	✓			✓	✓ IMQ	Nonsig. associations between IVs and DV during session and via diary	
Suppression/Cognitive Load																
Aikins et al. (2009)	Combat veterans	43		✓	PTSD vs. trauma exposed vs. non-trauma exposed	✓		✓	✓			✓			PTSD → more post-suppression intrusive memories compared to other groups	
Bomyea & Amir (2011)	Undergrad	50		✓	Working memory task: high vs. low inhibitory control (HIC; LIC) Monitor vs. suppression vs. post-suppression monitor period	✓			✓			✓			HIC → fewer intrusive memories during suppression and post-suppression monitoring	*d* = 0.51 (HIC vs. LIC suppression) *d* = 0.51 (HIC vs. LIC, post-

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 Day	Other	Monitor	Diary	Other		
																suppression monitoring)
Bomyea & Lang (2016)	Sexual assault survivors with PTSD	42		✓	OSPAN task score Thought suppression task-reactivity questionnaire Monitor vs. suppression vs. post-suppression monitor period	✓			✓			✓			Thought regulation strategies → more intrusive memories, moderated by executive functioning performance; those with poorer executive functioning used more thought reg. strategies Nonsig. direct relationship between executive functioning and intrusive memories	
Davies & Clark (1998b)	Undergrad (excluded treatment history, history of fire involvement)	32	✓	✓	Traumatic vs. neutral thought content Suppression vs. monitoring instructions	✓			✓			✓			Suppression → fewer intrusive memories during first period for both neutral and trauma film Suppression → more intrusive memories during post-suppression monitor for traumatic but not neutral film-related intrusive memories	
Geraerts et al. (2010)	Undergrad	87	✓	✓	Negative vs. neutral autobiographical event Suppression vs. monitoring instructions	✓			✓			✓			Suppression → fewer intrusive memories during first period and during AMT regardless of event valence	*d* = 0.44 (first period suppression vs. control) *d* = 0.42 (AMT suppression vs. control)
Gillie et al. (2015)	Undergrad	142	✓	✓	Suppression vs. monitor instructions HRV	✓			✓			✓			Suppression → fewer intrusive memories during first period compared to monitor Suppression → greater decline in intrusive memories from first to second period but not from first to third Higher HRV → greater declines in	

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 Day	Other	Monitor	Diary	Other		
															intrusive memories from first to second and first to third period in suppression but not control condition	
Guthrie & Bryant (2000)	Trauma-exposed (mixed trauma)	40	✓	✓	Suppression vs. non-suppression instructions; ASD vs. no ASD	✓					✓ (3 separate 24 hr monitor periods)	✓			ASD → more intrusive memories regardless of suppression condition Suppression condition → more intrusive memories during third monitor period	
Harvey & Bryant (1998)	MVA survivors	48	✓	✓	Suppression vs. non-suppression; ASD vs. no ASD	✓			✓			✓			ASD → more intrusive memories regardless of suppression condition for all three monitor periods Suppression condition → more intrusive memories during third monitor period than non-suppression	
Harvey & Bryant (1999)	University	96	✓	✓	Distressing vs. neutral film Suppression vs. control High vs. low anxiety (via STAI)	✓			✓			✓			Distressing film viewers → more intrusive memories after period 1 than neutral film viewers High anxiety → more intrusive memories after period 1 than low anxiety in nonsuppression condition only Suppression → more intrusive memories after period 2 than nonsuppression in low anxiety group only	
Nixon et al. (2008)	Trauma-exposed (mixed trauma)	56		✓	White bear vs. trauma-related intrusive memories; ASD vs. no ASD	✓			✓			✓			ASD → more trauma-related and white bear intrusive memories during suppression period than group w/o ASD	*d* = 0.67 (ASD vs. no ASD trauma-related intrusive memories)

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 Day	Other	Monitor	Diary	Other		
																d = 0.58 (ASD vs. no ASD white bear)
Nixon et al. (2009a)	University	80		✓	Suppression + cognitive load vs. cognitive load only vs. suppression only vs. control	✓	✓		✓	✓		✓	✓		Suppression + cognitive load → more intrusive memories compared to other conditions via 7 day diary Nonsig. effect of condition on intrusive memory distress Nonsig. effect of condition on intrusive memory freq during in-session monitor period	
Nixon et al. (2009b)	University	120		✓	Suppression + cognitive load vs. hypervent. + suppression vs. block rehearsal + suppression vs. suppression vs. no task control	✓		✓	✓	✓		✓	✓		All experimental conditions → significantly shorter intrusive memory duration than no task control (in session) Nonsig. associations between IVs and intrusive memory variables via diary	
Nixon et al. (2016)	Trauma-exposed (mixed trauma)	56		✓	Cognitive load vs. no cognitive load ASD vs. no ASD	✓			✓			✓			ASD → more intrusive memories than non-ASD overall ASD + cognitive load → more intrusive memories following suppression compared to ASD w/o cognitive load	*d* = 0.90 (ASD vs. non-ASD overall) *d* = 0.63 (ASD w/ and w/o cognitive load)
Onden-Lim & Grisham (2012)	Undergrad (excluded BDD diagnosis)	92	✓	✓	Suppression vs. monitor instructions; BICI	✓	✓	✓	✓			✓			Nonsig. association between body image concern and intrusive memory frequency Nonsig. differences between conditions in intrusive memory vividness or perspective	

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 Day	Other	Monitor	Diary	Other		
															Supression → shorter intrusive memory duration than monitor Higher body image concern → increased intrusive memory vividness	
Rosenthal & Follette (2007)	Assault survivors	61	✓	✓	Suppression vs. monitoring instructions Lab vs. natural environment	✓	✓		✓		✓ 24 hr, 48 hr	✓			Nonsig. associations between conditions and intrusive memory freq during in-session monitoring Nonsig. differences in intrusive memory freq between conditions in natural environment 24 & 48 hr post Monitor → more intrusive memory distress during 24 hr post Nonsig. differences in distress 48 hr post	*d* = 0.70 (monitor vs. suppress 24 hr post)
Shipherd & Beck (2005)	MVA survivors	55	✓	✓	MVA vs. neutral task Suppression vs. monitor instructions PTSD vs. no PTSD	✓			✓					✓ Written thought listing	MVA task → more target thoughts than neutral task regardless of PTSD diagnosis PTSD → more target thoughts than no PTSD in MVA task during post-suppression monitoring (rebound effect) Nonsig. differences in target thoughts between diagnostic groups during neutral task	
Shipherd & Beck (1999)	Sexual assault survivors	36		✓	Suppression vs. expression instructions PTSD vs. no PTSD	✓		✓	✓					✓ Written thought listing	PTSD → more intrusive memories during post-suppression monitor period than no PTSD group (rebound effect)	

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 Day	Other	Monitor	Diary	Other		
															PTSD → lower thought controllability during suppression than no PTSD	
Williams & Moulds (2007)	University	97	✓	✓	Suppression vs. expression of film-related thoughts (2 phases of each) Mildly depressed vs. non-depressed	✓	✓	✓	✓			✓			Nonsig. effect of depression group on intrusive memories Suppression 1 → more intrusive memories than suppression 2 Nonsig. rebound effect between expression 1 and expression 2 phases Nonsig. effect of depression group on intrusive memory duration or distress	
Post-Event Processing/Consolidation																
Bryant et al. (2013)	University	78	✓	✓	Cold pressor task vs. warm water control sAA and cortisol levels Negative vs. neutral images	✓					✓ 2 days post			✓ 3 items from IES	High stress → more intrusive memories of negative images than low stress Interaction of cort + sAA → more intrusive memories in men only	
Das et al. (2016)	Community (excluded psychopathology, drug use, trauma history)	50	✓	✓	Nitrous oxide vs. placebo	✓				✓			✓		Nitrous oxide → more rapid intrusive memory decrease (day 1 to 2 and 1 to 3)	
Holmes et al. (2009)	Community	40	✓	✓	Visuospatial vs. no post-film task	✓			✓	✓		✓	✓		Visuospatial → fewer intrusive memories 10 min post-film Visuospatial → fewer intrusive memories via 7 day diary	
Holmes et al. (2010)	University/Community (excluded treatment history)	60	✓	✓	Visuospatial vs. verbal vs. no post-film task	✓				✓		✓	✓		Visuospatial → fewer intrusive memories than no task 10 min post Nonsig. effect of condition on intrusive	*d* = 0.70 (visuospatial vs. no task via diary)

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 Day	Other	Monitor	Diary	Other		
															memory freq between verbal and no task	
															Visuospatial → fewer intrusive memories than no task and verbal conditions via diary	*d* = 1.21 (visuospatial vs. verbal via diary)
															Verbal → more intrusive memories than no task via diary	*d* = 0.62 (verbal vs. no task via diary)
Holmes et al. (2010)	University/Community (excluded treatment history)	75	✓	✓	Visuospatial vs. verbal vs. no post-film task	✓				✓	✓ 4 hr post-film	✓	✓		Visuospatial and verbal → fewer intrusive memories 4 hr post-film compared to no task	*d* = 0.70 (visuospatial vs. verbal via diary)
															Visuospatial → fewer intrusive memories compared to verbal and no task via diary	
															Nonsig. difference on intrusive memories between verbal and no task via diary	*d* = 0.62 (visuospatial vs. no task via diary)
Kindt et al. (2008) *	Undergrad (excluded history of physical or xexual abuse)	42	✓	✓	Data-driven vs. conceptual post-film instructions	✓			✓					✓ VAS	Data-driven → more intrusive memories compared to conceptual	$\eta^2 = 0.08$
Kleim et al. (2016)	Community (excluded psychopathology and exposure to interpersonal trauma)	65	✓	✓	Sleep deprivation vs. normal sleep	✓	✓			✓			✓		Normal sleep → fewer and less distressing intrusive memories	
Krans et al. (2009)	Undergrad	52	✓	✓	Recognition memory test vs. no memory test	✓	✓			✓			✓		Recognition test → fewer intrusive memories	$\eta^2 = 0.11$
															Nonsig. effect on intrusive memory distress	
Luo et al. (2013) *	Undergrad	92	✓	✓	"What" vs. "why" processing	✓					✓ 2 day diary		✓		"Why" → fewer intrusive memories than "what" condition	
Porcheret et al. (2015)	University	42	✓	✓	Sleep deprivation vs. normal sleep	✓	✓				✓ 6 day diary		✓		Sleep deprivation → fewer intrusive memories during first two-day period	

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 Day	Other	Monitor	Diary	Other		
															Nonsig. effect of sleep on intrusive memory distress	
Tabrizi & Jansson (2016)	Undergrad	41	✓	✓	Visuospatial vs. phonological loop vs. executive processing vs. no task control Auditory vs. visual intrusive memories	✓				✓			✓		Executive processing → fewer auditory intrusive memories compared to no task and visuospatial	*d* = 1.13 (executive processing vs. no task)
															Nonsig. difference in auditory hallucinations between phonological loop and other conditions	*d* = 1.03 (executive processing vs. visuospatial)
															Nonsig. effect of condition on visual intrusive memory freq	
Memory Reconsolidation																
James et al. (2015)	University/Community	52	✓	✓	Reactivation + visuospatial vs. no reactivation no task	✓				✓			✓	✓ IPT	Visuospatial + reactivation → fewer intrusive memories both via diary and IPT	*d* = 1.14 (intrusive memory freq)
															Visuospatial + reactivation → more rapid intrusive memory decrease	
James et al. (2015)	University/Community	72	✓	✓	Reactivation + visuospatial vs. reactivation only vs. visuospatial only vs. no reactivation no task control	✓				✓			✓		Visuospatial + reactivation → fewer intrusive memories than visuospatial only, reactivation only, and no task control	*d* = 0.84 (visuospatial + reactivation vs. visuospatial only)
															Reactivation + visuospatial → more rapid intrusive memory decrease compared to other three conditions	*d* = 1.11 (visuospatial + reactivation vs. reactivation only)
																d = 1.00 (visuospatial + reactivation vs. no task control)
Marks & Zoellner (2014) *	Undergrad	148	✓	✓	Pre-extinction vs. post-extinction vs. no retrieval cue	✓	✓				✓ 24 hr post-extinction			✓ Phone Assessment	Pre-extinction → more intrusive memories than no retrieval cue when controlling for	*d* = 0.62

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 Day	Other	Monitor	Diary	Other		
															peak distress during acquisition	
															Nonsig. effect of condition on intrusive memory distress	
Vantage Perspective																
Luo et al. (2013) *	Undergrad (excluded serious MVA experience)	93	✓	✓	First-person vs. third-person vantage perspective	✓		✓			✓ 2 days		✓		Nonsig. effect of vantage perspective on intrusive memory frequency, level of intrusive memory realism, or severity of intrusive memories	
Williams & Moulds (2008)	Undergrad	134	✓	✓	Field vs. observer perspective		✓	✓		✓				✓ IMI	Switch from field to observer → decreased intrusive memory vividness and distress	
Retrieval Stress / Distress																
Cheung et al. (2015) *	Undergrad	63	✓	✓	Reactivation + stressor vs. reactivation + control vs. no reactivation + stressor	✓					✓ 5 days			✓ 3 items from IES	Reactivation + stressor → more intrusive memories than control conditions	
															Cortisol increase following stressor → more intrusive memories in reactivation + stressor condition only	
Hopwood & Bryant (2006)	Trauma-exposed (mixed trauma)	60	✓	✓	Hyperventilate vs. normal breathing instructions ASD vs. no ASD	✓			✓			✓			ASD → more intrusive memories during hyperventilation compared to baseline	$\eta^2 = 0.13$ (overall group × condition × time)
															Non-ASD → fewer intrusive memories during hyperventilation compared to baseline	
Schooler et al. (1999)	Plane crash survivors	118		✓	Frequency and distress of intrusive memories 2 wks post-trauma	✓	✓				✓ 6, 9, and 12 mo post-trauma			✓ ITQ	Presence of uncued intrusive memories at 2 wks → more intrusive memories at 6, 9, 12 mos	
															More intrusion-related distress → more	

Study	Sample	*N*	Study Design		Independent Variable(s)	Intrusion Variables Reported (DVs)			Intrusion Assessment Timing			Intrusion Measurement			Main Findings	Effect Size (if reported)
			Ran	Pros		Freq	Distress	Other	During	7 Day	Other	Monitor	Diary	Other		
															intrusive memories at 6, 9, and 12 mos	

Study Quality: “Ran” = randomized, “Pros” = prospective; PTQ-S: Perseverative Thinking Questionnaire-State Version; ARQ: Anxious Rumination Questionnaire; RIQ: Response to Intrusions Questionnaire; RRS: Ruminative Response Subscale of Response Style Questionnaire; OSPAN: Operation span; HRV: Heart rate variability; ASD: Acute Stress Disorder; BICI: Body Image Concern Inventory; sAA: Salivary alpha amylase; IMI: Intrusive Memory Interview; IES: Impact of Event Scale; IMQ: Intrusive Memory Questionnaire; VAS: Visual Analogue Scales; IPT: Intrusion Provocation Task; ITQ: Intrusive Thoughts Questionnaire

*Study included multiple times in table due to presence of multiple predictors of intrusions