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Protecting the Mind? How Inhibitory Control and Emotional Distress Relate to Intrusive Memories After Trauma Analogue Exposure

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Abstract

Intrusive memories are a chief complaint after trauma exposure and a hallmark symptom of posttraumatic stress disorder. Using a well-established trauma-film paradigm, the present study sought to investigate the role of inhibitory control ability and emotional distress as predictors of memory intrusion frequency. A nonclinical sample was recruited for participation in a trauma analogue exposure experiment wherein they completed a series of inhibitory control tasks, watched a series of film scenes, and reported their subsequent memory intrusions for a week. On the final day, they reported their level of emotional distress on the Impact of Event Scale. Contrary to the first hypothesis, inhibitory control did not predict the frequency of intrusive memories, however critical insights into the translational effects of inhibitory control tasks to naturalistic settings are offered. Contrary to the second hypothesis, emotional distress did not predict the frequency of intrusive memories. However, exploratory analyses revealed that an increase in the intrusion and hyperarousal subscale ratings of the Impact of Event Scale did result in an increase in memory intrusion frequency. Implications for future research are discussed.

Keywords: posttraumatic stress disorder, inhibitory control, traumatic memory, thought suppression, intrusive memories, adaptive forgetting, mental health

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Protecting the Mind? How Inhibitory Control and Emotional Distress Relate to Intrusive Memories After Trauma Analogue Exposure

Posttraumatic stress disorder (PTSD) is a pervasive global issue affecting millions of people each year (*Clinical Practice Guideline for the Treatment of Posttraumatic Stress Disorder (PTSD) in Adults*, 2017). Intrusive memories of a traumatic event have been named as the hallmark symptom of PTSD (Brewin, 2014; Iyadurai et al., 2019). Conventional therapeutic strategies commonly instruct suffering individuals to avoid suppressing intrusive memories, assuming that this will cause greater distress (Mamat & Anderson, 2023). However, this dubious assumption is not soundly supported, and emerging research has begun to show empirical evidence which directly opposes this conventional view (Mamat & Anderson, 2023). Inhibitory control has been implicated as a key mechanism in controlling unwanted thoughts and shown to modulate the development of intrusive memories (Streb et al., 2016). Similarly, emotional distress related to intrusive memories has been shown to be a vulnerability factor in the recurrence of unwanted thoughts (Regambal & Alden, 2009). Clinical research implores the need for further identification of potential risk and protective factors of PTSD as it is crucial for improving prediction, prevention and treatment strategies (Kessler et al., 2014). The present study aims to shed light on the ongoing debate regarding factors such as inhibitory control and emotional distress as they relate to the development and frequency of intrusive memories.

Posttraumatic Stress Disorder

According to global estimates, approximately 70% of people will be exposed to at least one traumatic event in their lifetime (Benjet et al., 2016). Although trauma can be defined in many different ways, it is generally understood to be the result of any experience that threatens a person's physical, emotional or psychological sense of safety to a degree that overwhelms their ability to cope (*Clinical Practice Guideline for the Treatment of Posttraumatic Stress Disorder (PTSD) in Adults*, 2017). According to the American Psychological Association, after surviving a traumatic event, individuals commonly experience a range of psychophysiological symptoms. The current Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) summarizes these into four diagnostic clusters: "intrusive and recurrent memories of the trauma, avoidance of trauma-related stimuli, numbing and/or negative changes in mood or cognitions pertaining to the

trauma, and changes in reactivity and arousal" (*Clinical Practice Guideline for the Treatment of Posttraumatic Stress Disorder (PTSD) in Adults*, 2017). Research has often characterized PTSD as a memory disorder and many cognitive models of PTSD propose that intrusive memories and trauma reexperiencing perpetuate all other features of the disorder (Brewin, 2014; Iyadurai et al., 2019).

Intrusive Memories and Emotional Distress

The warning signal hypothesis suggests that intrusive memories can be understood as stimuli that, through temporal association with the traumatic event, acquire the status of a warning signal – so that if encountered again, would give a sense of impending danger (Ehlers et al., 2002). Instead of the worst parts of a trauma returning in the form of intrusive memories, researchers have noted a predominance of visual recollections from the peripheral events of the trauma being re-experienced and reported the most. Indeed, a common theme of qualitative interviews reveals that intrusive memory content often consisted of stimuli that were present immediately before the traumatic event or before the moment which had the largest emotional impact. This work leans on evolutionary psychology, theorizing that intrusive memories or "warning signals" are typically visual in nature, as visual cues can be identified from a distance and are often an early indicator of impending danger (Ehlers et al., 2002). Early qualitative research concerning the content and nature of intrusive memories provides the example of an assault survivor suffering intrusive images of "bricks along a path" – although reporting complete amnesia for the event. It was known from the perpetrator that the survivor had been dragged across a brick path moments prior to the assault (Christianson, 2014). Intrusive memories are a form of re-experiencing which is strongly characterized by a sense of "nowness" and current threat. These are different from a flashback where individuals lose all awareness of present surroundings, essentially reliving the experience. (Hackmann et al., 2004; Marks et al., 2018). Intrusive memories can elicit a sense of hyperarousal or impending danger.

Intrusive memories are involuntary and distressing thoughts, usually accompanied by vivid mental imagery which repeatedly protrude into consciousness following a traumatic experience (Herz et al., 2020). The fragmented nature of intrusive memories is characterized by enhanced perceptual memory and impaired episodic memory of an event (Brewin, 2014). For

most trauma-exposed individuals, it is common to experience memory intrusions in the immediate aftermath of an event which naturally decay over the course of weeks and months (Michael et al., 2005; Streb et al., 2016). However, for about one third of the exposed population, these intrusions will not naturally decay over time (Tortella-Feliu et al., 2019). Instead, they will persist as if a traumatic event just happened. Because the disorder is likely the result of complex interplay between pretrauma, peritrauma, and posttrauma factors, it is not fully understood why some develop PTSD and others do not (Tortella-Feliu et al., 2019). Concerning peritraumatic vulnerability factors contributing to the development of intrusive memories, Regambal and Alden (2009) proposed an integrative model using structural equation modeling, demonstrating a direct link between emotional reactivity, maladaptive coping strategies and intrusive memories. Identifying potential risk and protective factors is crucial to the field of treatments as it can improve prediction and develop better prevention and treatment strategies (Kessler et al., 2014).

Executive Function, Inhibitory Control and Thought Suppression

Relating to the aforementioned research, a pressing question in clinical neuroscience is why some individuals can cope with traumatic events while others remain haunted by recurrent, unwanted memories. Stemming from the Freudian notion of repression and evidence that certain attempts to avoid or suppress unwanted memories can worsen symptoms, handling unwanted or intrusive memories has been a topic of much controversy and psychological debate (Anderson & Green, 2001; Mary et al., 2020). Research has historically failed to find evidence of an unconscious, involuntary thought repression mechanism but instead identified thought *suppression* as an active and voluntary form of thought control, which recruits inhibitory control through executive function (Anderson & Green, 2001). Among working memory and cognitive flexibility, cognitive control is identified as a core component of executive function, which enables the control of one's attention, behavior, thoughts, and emotions – including the ability to override a strong internal predisposition or external cues in order to do what is more appropriate or needed. Executive function is trainable and something that can be exercised through goal directed action (Diamond et al., 2007). The role of the prefrontal cortex is critical to the executive function and cognitive control which are defined by their relationship to goal-directed

behavior in contrast to automatic processing. Current research has proposed a latent factor model of cognitive control which subsets this ability into three domains: inhibiting, updating, and mental shifting. Thus, in this way, inhibitory control may be considered as a component process of cognitive control (Friedman & Robbins, 2022).

The executive deficit hypothesis (Levy & Anderson, 2008) proposed a neurocognitive model which suggested that executive control, namely inhibitory control, plays a key role in down-regulating intrusive memories over time and concluded that individual differences in posttraumatic intrusive memory regulation is mediated by pre-existing differences in executive control ability. While the consequences of thought suppression are not fully understood or agreed upon, Levy and Anderson (2007) asserted that suppressing retrieval of an intrusive memory is accomplished through inhibitory control, making the memories harder to recall later and leading to forgetting. This difficulty in recall has been proposed as an active and motivated form of forgetting known as suppression induced forgetting (SIF), which occurs through stopping memory retrieval (i.e. thought suppression) thereby impairing memory retention (Anderson & Levy, 2009). The SIF phenomenon and direct training of and thought suppression recruited by inhibitory control has been extensively researched within a paradigm called the Think/No-Think task (Anderson & Green, 2001). The Think/No-Think task is an experimental paradigm used to study suppression and retrieval of memories wherein participants are instructed to either actively think about or inhibit retrieval of previously learned information. The results of a meta-analysis focused on 25 studies of memory suppression in the context of psychological disorders recently suggested that SIF is actually a hallmark of psychological well-being (Stramaccia et al., 2021).

A Domain-General View of Inhibitory Control

An ongoing question in cognitive control research is whether or not inhibitory control operates in a domain specific or domain general manner. Many cognitive theories feature inhibitory control as a process which controls a diverse host of mental operations (Anderson, 2005; Wessel & Anderson, 2023). Across a wide range of cognitive and psychological models of behavior, inhibitory control has been ostensibly implicated as a process which underlies everything from the ability to suppress unwanted mnemonic representations to

stopping inappropriate actions. This includes avoiding intrusive thoughts, resisting distraction, suppressing urges, resolving linguistic competition, and regulating externalizing behaviors. Enacting this range of goal-directed, complex behavior requires both cognitive and motor domains of inhibition (Wessel & Anderson, 2023)

Cognitive neuroscience has commonly investigated inhibitory control as separate domains within behavior and cognition studying its influence on the motor system memory, affect, and attention – separately – failing to make connections between the processes. Through this lens, neuropsychological research often assessed inhibitory control using paradigms that cue participants directly or indirectly to suppress and inhibit automatic motor or cognitive responses. Such is the case in the go/no-go task where participants are primed to press a button for all letters and stop when they see an 'X' (Raud et al., 2020) or in the think no-think paradigm in which participants are instructed to actively recall or suppress associate word pairs (Anderson & Green, 2001). A classical way of studying inhibitory control is by administering the Stroop task where participants must recite the color of a word that is incongruous with the ink color thereby necessitating the inhibition of automatic reading and instead, selectively attending to the color of the text alone.

Recent work questioning if inhibitory control is a unitary process sought answers by testing whether or not behaviors like action stopping and thought suppression recruit the same underlying mechanisms or if separate mechanisms are specialized for particular types of inhibition. Their findings suggest evidence for the former, suggesting that inhibitory control may act via the same fronto-subthalamic circuitry that inhibits both motor and nonmotor drive. Inhibition can also be conceptualized and roughly categorized as cued and incidental cognitive inhibition. Cued cognitive inhibition explicitly instructs individuals to inhibit mnemonic representations. Incidental cognitive inhibition incidentally activates the inhibitory process via salient stimuli. Although evidence is in a preliminary stage, studies investigating this question of domain general inhibitory control posit the possibility that mnemonic and motoric inhibition draw upon the same underlying mechanism, the fronto-subthalamic circuit (Wessel & Anderson, 2023).

An Adaptive Versus Maladaptive View of Thought Suppression via Inhibitory Control

Recent research has suggested that the ability to suppress unwanted thoughts may be a key determinant in a person's post-traumatic adaptability and vulnerability to memory intrusions (Mary et al., 2020). This claim goes against years of research which have repeatedly suggested that thought suppression is maladaptive. For example, an early study – on unwanted thoughts and the mind's ability to suppress them – required subjects to not think of a white bear which resulted in subjects struggling to think of anything but the white bear (Wegner, 1989). This "white bear" phenomenon pervaded seminal work on unwanted thoughts which extrapolated this idea that suppression can lead to obsession. Regardless of the valence, nature, or context of the thought intrusion, much research has investigated thought suppression with the presumption that it is inherently maladaptive. Indeed, a study on the topic of thought suppression and analogue post-traumatic thought intrusions asserted evidence of a "rebound effect" whereby thought suppression produced an immediate decrease but a delayed increase in thought intrusions (Davies & Clark, 1998). More than a decade later, studies were still showing that thought suppression intensifies intrusive thoughts (Magee et al., 2012). In fact, a well-established cognitive model of PTSD explicitly names thought suppression as a maladaptive cognitive strategy which must be mitigated (Ehlers & Clark, 2000). At the same time, these works seemed to disregard the nature of traumatic versus nontraumatic intrusions and failed to make the distinction between intrusive thoughts, intrusive memories, and the difference between explicit and implicit reminder cues.

Contrary to this view, recent clinical work on traumatic memory intrusions has been challenging this century-old argument. In examining the relationship between trauma exposure, inhibitory control, and PTSD, a recent study which assessed both objective and subjective measures of cognitive inhibition, suggests that inhibitory control could be a possible resilience factor in preventing the development of posttraumatic symptoms (Hammar et al., 2023). Similarly, another study has recently demonstrated that training thought suppression can improve mental health and reduce memory for suppressed fears (Mamat & Anderson, 2023). Indeed, Mamat and Anderson (2023) acknowledged that conventional therapies often urge distressed clients to avoid suppressing their thoughts, warning that

intrusions may rebound in frequency and intensity. They hypothesized that training thought suppression would actually have the opposite effect and after 3 days of thought suppression training, 120 adults from 16 countries reported less distress with lasting depression symptom relief. Notably, participants high in trait anxiety and posttraumatic stress gained the most durable benefits. The present study aims to build on this work.

The Trauma-Film Paradigm

In contrast to the dominant way of studying fear and anxiety disorders through Pavlovian threat conditioning paradigms, the trauma film paradigm pioneered by Lazarus and colleagues in the 1960s (Lazarus, 1964), provided a framework for studying numerous aspects of intrusive memories and PTSD symptomology in a manner that provides greater ecological validity to the study of psychological trauma (James et al., 2016). Using motion picture films, they proposed that psychological stress and threat remembering analogous to real life could be produced by exposing participants to violent and disturbing scenes. As this paradigm has been developed over the years, the basic methodology in current trauma film studies typically follows this protocol: pre-film measures, film and manipulations, post-film measures, memory intrusion diary, and follow-up measures. The diary methodology – requiring participants to report the frequency and nature of film flashbacks – has become crucial to the paradigm (Holmes & Bourne, 2008). Peritraumatic processing and individual differences in event distress has been identified as a possible vulnerability to memory intrusions (Marks et al., 2018). That's why an additional self-report measure that is commonly administered in this film paradigm is the revised impact of event scale (IES-R)(Weiss & Marmar, 1997), which indexes intrusive memories and PTSD symptoms on three subscales: intrusions, avoidance, and hyperarousal (James et al., 2016).

While it is common for participants to experience trauma analogue memory intrusions, some individuals report none. With inconclusive findings, a meta-analysis urged future studies to investigate psychological factors related to the lack of memory flashbacks (Clark et al., 2015). Strikingly, in search of possible explanations for flashback variability, this meta-analysis did not consider the role of individual differences in cognitive control. In the most recent review of the trauma film paradigm as an experimental psychopathology model of trauma, researchers critically assert that cognitive ability has been investigated within this paradigm but point to a

somewhat inconsistent pattern of findings showing that in some cases interference and working memory tasks positively correlated with the frequency of memory intrusions and in other cases, negatively correlated (James et al., 2016). Thus, as an important direction for future research, this review implores the continued identification of individual differences and vulnerability factors contributing to memory intrusions. Despite recent findings in clinical and nonclinical studies, the role of inhibitory control in memory intrusion development is still not fully understood.

Present Study

Using a well-established experimental paradigm, the present study aims to explore and extend current theory by investigating the interaction of individual differences in cognitive ability and memory intrusion development. The scope of the present study was carved out of a broader research project investigating the memory and emotional effects of a trauma analogue. Given the general memory impairment associated with PTSD and considering the distinct and distressing nature of intrusive memories and suggested role of inhibitory control, it is important to know how and to what extent these variables can predict intrusive memories. Such theoretical findings have clinical implications which will inform the continued efforts to effectively and efficiently treat posttraumatic symptoms. This study answers the call to further understand basic mechanisms underlying symptom development so laboratory findings can translate to the clinic and reduce the debilitating effects of traumatic events (James et al., 2016). Coined as the “elusive bridge to translation”, Dunsmoor and colleagues (2022) suggest a possible overreliance on neurobiological models of PTSD and encourage future studies to integrate emerging trends in the cognitive neuroscience space to more fully capture the human experience of emotion regulation and behavior into laboratory research of trauma (Dunsmoor et al., 2022). Since the focus on inhibitory control is relatively new to the field and an emerging aspect of trauma research that has only begun to challenge century old wisdom, the present behavioral study aims to shed light on optimal approaches to further understanding the prospective link between inhibitory control and memory intrusions. Guided by the question of whether or not inhibitory control measures and event induced emotional distress can predict memory intrusion frequency after trauma analogue exposure, the present study hypothesized that inhibitory control measures would

predict the frequency of reported memory intrusions (H1) and that emotional distress acts as a vulnerability factor for intrusions and positively correlates with intrusion frequency (H2).

Methods

Participants

Due to the potentially emotionally distressing nature of the investigation, participants were carefully recruited digitally and in-person to take part in a "movie study" through a thorough pre-screening process. Interested participants received an informational email which included a detailed explanation of the experiment and link to a secure psychological screening. The survey was built according to previous research that implemented the trauma film paradigm to ensure that unsuitable and vulnerable individuals were excluded (Herz et al., 2020). Exclusion criteria included mood altering medication, drug abuse, uncorrected visual or hearing impairment, neurological or mental disorders, depression symptoms assessed with the PHQ-9 (score > 4) (Spitzer et al., 1999) anxiety symptoms assessed with the STAI trait scale (> 44 points) (Spielberger et al., 1983), and trauma exposure needing psychiatric care. Individuals who were under 18 or had previously seen the experimental film were also excluded.

The pre-screening process was supervised by a clinical psychologist and each survey was manually reviewed for mental health and trauma history. After review, all submissions received a response via email notifying individuals of their eligibility or ineligibility to participate. In total, 90 pre-screenings were submitted, 40 individuals met inclusion criteria, and 32 individuals completed the study. In line with similar studies, the target number of participants was set to N = 30. The final sample (N = 32) was between 20-53 years of age (M = 28.6 / SD = 6.9) with 23 individuals identifying as female (72%). Convenience sampling through word-of-mouth and social media platforms provided a fairly heterogeneous group varying in culture, profession, and social background. Participants were compensated with a cinema voucher after their first lab visit and a bookstore voucher after their second visit, totaling a value of approximately 300 Swedish kronor.

Laboratory and materials

The trauma analogue experiment was conducted at Lund University's Humanities Lab. The lab computer ran on Windows 10 Pro version 1909 and the experimental movies were

watched on a 22-inch 59 Hz Dell P2210 flat panel monitor with resolution 1680 x 1050. A set of Behringer HPS3000 headphones were used to provide audio to the participants. The volume of the audio was standardized at 70% for all participants but adjusted upon request. The films, Digit Stroop Task and Go/NoGo stimuli were designed and presented using the E-Prime 3.0 software (Psychology Software Tools Inc., Pittsburgh, PA, USA). Go/no-go task responses were collected on a Dell keyboard and Digit Stroop Task responses were recorded on a Chronos multifunctional response and stimulus device (Psychology Software Tools Inc., Pittsburgh, PA, USA).

Tasks and Measures

The administered Stroop Color and Word Test (Stroop, 1935) and the Go/NoGo task (Menon, 2011) was provided by the department of psychology at Lund University. The Digit Stroop Task, an adaptation of the Emotional Stroop Task (Cisler et al., 2011), was designed at Lund University and its template was used to build the present study's experiment. Measurement of intrusive memories followed a preexisting diary format (Herz et al., 2020) and the Revised Impact of Event Scale (Weiss, 2007) was used.

Stimuli

The trauma analogue exposure consisted of four, nine-minute clips from two movies totaling 36 minutes of run time. Three separate scenes from the film *Irréversible* (Noé, 2002) and one scene from the film *Paterson* (Jarmusch, 2016) were selected for the experiment. The two trauma analogue scenes selected from *Irréversible* portrayed a violent rape and murder, respectively. The third scene from *Irréversible* portrayed a benign commute scene. The *Paterson* scene was a mundane portrayal of a bus driver's day. The movie stimuli waswere alternated so that participants were always shown a nontraumatic then trauma analogue scene. The order of film scenes wereas counterbalanced across participants.

The Stroop Color and Word Test contained a series of three papers which the participants were required to read aloud. The first presentation was an 8x6 block of congruently colored dots, the second was an 8x6 block listing the names of colors in black ink, and the final presentation was the Stroop test condition containing an 8x6 block of incongruently colored words where participants had to name the color of the ink, not the name of the word. For example, "red" was

listed in blue ink and the correct response was "blue."

The Go/NoGo was designed with letter stimuli presented on a white screen where participants were required to press 'space' (go trials) for quickly appearing letters except the letter 'X' (no go trials). The task was designed so that the 'go' to 'no go' trial proportion was an 80/20 ratio totalling two blocks of 100 trials each. This ratio served to initiate prepotent motor response.

The Digit Stroop Task was designed for the purposes of an umbrella project focused on the reactivation of traumatic memory. Resembling a combination of an emotional Stroop and interference task, the task was designed with incongruent, congruent, and neutral Stroop trials wherein different images would appear between. Totaling 320 pseudo randomized trials, one practice block of 20 trials was followed by 16 experimental blocks of 20 trials each. The Digit Stroop Task utilized a blocked design wherein negative and neutral stimuli were separated by blocks, not trials. Images were presented for three seconds, and Stroop trials gave a 500-millisecond response window. Each Stroop trial consisted of black text numbers or symbols in all conditions. For example, a neutral trial contained 1-4 hash symbols where participants would be presented with something such as "####" and on the response box, they would need to press the fourth button. An incongruent trial design would present the participant with "444" and it was their job to press the corresponding button on the response box (numbered 1-4) that represented the correct number of characters, *not* the number itself. So, in this example, the correct response would be button number 3. A congruent trial design presented the participant with something like "333" and the correct response would be three.

As for the images presented between each trial, negatively and neutrally valenced screenshots from each film of the exposure were used as stimulus presentation. Negatively and neutrally valenced control images from the Nencki Affective Picture System (NAPS) were also presented (Marchewka et al., 2014). These images have been well-validated and were chosen from a database according to valence and arousal ratings matching the desired negative and neutral emotional valence for the present study.

Accounting for screenshots from all four films and control images, a total of 120 unique distractor images were shown in the Digit Stroop Task: 45 screenshots were taken from each *Irréversible* film clip 15 of which were neutral in valence and 15 were negative in valence, 15

screenshots were taken from the mundane *Paterson* film, and 30 images from the NAPS research picture database which included 15 neutrally valenced images and 15 negatively valenced images. Absent of emotional valence, five black screen images were included in each block as baseline measurement of cognitive control. These black screen baseline trials were extracted as the sole focus of the Digit Stroop Task for the purposes of the present study. All screenshots and images were sized to 1920 ×1080 pixels for optimal resolution.

Procedure

Participants were provided with an information sheet and an informed consent form prior to and upon their arrival to the lab. They were given the opportunity to ask any questions and reassured that we could pause for questions at any time during the experiment. After obtaining informed consent, they were oriented to the space. Participants were then instructed to complete the Go/NoGo and Stroop Color and Word Test in a counterbalanced fashion. Upon completion of the inhibitory control tasks, they were offered the opportunity for one final break before the film presentation began. Before starting, one final trigger warning was read aloud to participants disclosing the violent and disturbing nature of the trauma analogue films and reiterating their right to withdrawal at any time. Upon giving verbal acknowledgement of the warning, the exposure began. The sequence always alternated between non-traumatic scenes and trauma analogue scenes, with the trauma analogue scenes being counterbalanced. When the film-watching concluded, participants were debriefed and reminded about the week of intrusion diary surveys they would begin receiving the following day as well as their second lab appointment within the next 24-48 hours.

Ethical considerations

The present study was conducted in accordance with the Swedish Act concerning the Ethical Review of Research involving Humans (2003:460) and was approved by the Swedish Ethical Review Authority (reference number 2022-05425-01). Complementing these principles, the ethical framework for this study was also informed by APA ethical guidelines as it pertains to the study of human subjects, the Belmont Report (1978) and the Declaration of Helsinki (2013). The primary ethical considerations of this study concern participant disclosure of sensitive

information regarding trauma and mental health status, symptoms and history. Considerations also include the potential for adverse reaction as a result of the trauma film analogue exposure. This risk was mitigated by an extensively detailed pre-screening process supervised by a board-certified clinical psychologist and an informed consent process which emphasized participant's right to withdrawal at any time. Furthermore, a 3-week follow-up was done with each participant, and all were offered the opportunity for professional psychological after-care. All personal data collected throughout the study was code pseudonymized and securely stored in accordance with General Data Protection Regulations (GDPR). Any data that could possibly lead to participant identification was password secured.

Data Analysis

To investigate inhibitory control and event distress as factors contributing to the development of memory intrusions following trauma analogue exposure, each participant completed the go/no-go task (Go/NoGo), Stroop Color and Word Test (Stroop Color and Word Test), Digit Stroop Test (Digit Stroop Task), ta 6-day intrusion diary, and Impact of Event Scale (IES-R). Inhibitory control summary scores were formulated respective to each task and relevant literature. The Go/NoGo score was derived from a hit rate – false alarm rate accuracy formula (Menon, 2011). The Stroop Color and Word Test score was calculated using a formula which accounted for reaction time in both congruent and incongruent conditions (incongruent – [(congruent+congruent)/2]) (Scarpina & Tagini, 2017). The Digit Stroop Task score was computed with a congruency effect formula wherein median reaction time for baseline trials was subtracted from median reaction time for incongruent trials (incongruent RT – baseline RT) (Zhang et al., 2023). To avoid type I errors, mitigate bias, and make more sensitive comparisons, all summary scores and IES-R scores were standardized using a Z-score normalization before modeling them as predictor variables in the analysis (Berger & Kiefer, 2021). Memory intrusions were measured on a scale from 0-4+ and participants reported them for six consecutive days. A 21-item version of the IES-R was administered on the seventh day, evaluating emotional distress caused by memory intrusions from the trauma analogue film exposure. Answers were given on a Likert scale (0 = not at all, 4 = extremely). See Figure 2 of the appendix for an example.

To investigate whether inhibitory control scores predicted the frequency of memory

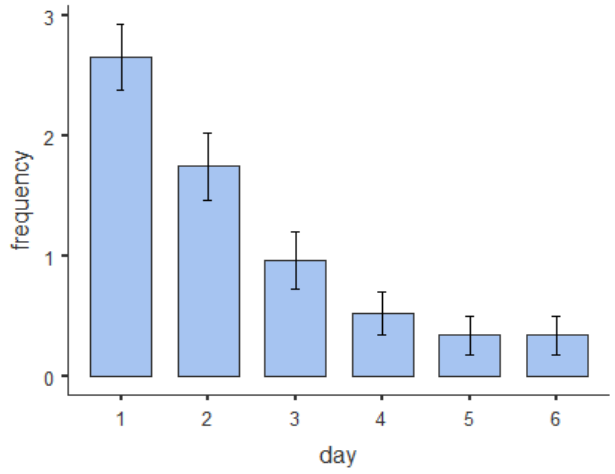
intrusions (H1) and test if event distress correlates with intrusion frequency (H2) data was analyzed using linear mixed effect models (LMEM). This method was selected over ANOVAs due to the low sample size, expected individual differences, and concern with reducing all data to averages. Therefore, LMEMs were applied using the GAMLj module within the Jamovi software (The jamovi project, 2022; R Core Team, 2021; Gallucci, 2019). Restricted maximum likelihood estimation was used to avoid bias. Assumptions of linearity, constant variance, independence, and normal distribution of residuals were checked. The assumptions of linearity, constant variance of residuals, independence of residuals, and normal distribution of residuals were violated but not in a concerning way especially since LMEMs are known for their robustness against assumption violations (Schielzeth et al., 2020). The dataset was inspected for missing values and outliers. One participant failed to complete the Digit Stroop Task, so a group median score was imputed to preserve the rest of this participant's data. Across all days and participants, ten missing values were found in the memory intrusion reports and set to zero. Three participants did not complete the IES-R, so their data was saved by imputing a group median score.

Results

Across all inhibitory control tasks, the sample performed around expected levels according to previous literature and the daily data trend of reported memory intrusions was in line with previous research (James et al., 2016). The Go/NoGo was answered correctly in 82% of the no-go trials and in 97% of the go trials. For the Stroop Color and Word Test, median reaction time was 17 seconds in the congruent word condition (*Min* = 12, *Max* = 24, *SD* = 2.36), 27 seconds in the congruent colored-dot condition (*Min* = 22, *Max* = 41, *SD* = 3.67), and 36 seconds in the incongruent Stroop condition (*Min* = 29, *Max* = 59, *SD* = 7.02). The Digit Stroop Task was answered correctly in 94% of the incongruent trials and 97% of the neutral trials. Significance criterion was set to $p < .05$ for all analyses. The completion rate of memory intrusion surveys was 95% with the highest frequency of intrusions being reported on day one after exposure and incrementally decreasing each day (Figure 1). Completion rate of the IES-R was 91% (*Min* = 0, *Max* = 51, *SD* = 13.9).

Figure 1

Reported memory intrusion frequency by day



Memory intrusion frequency and inhibitory control

Go/no–go task

To investigate whether or not inhibitory control scores predicted the frequency of memory intrusions (H1), each task was modeled separately. The Go/NoGo model was specified with "frequency" as the dependent variable, "Go/NoGo score" as the fixed effect, and a random intercept (effect) for each participant. Contrary to the hypothesis, the Go/NoGo model indicated no main effect of the task on intrusion frequency $p = .232$, $R^2 = .109$. Further results can be found in table Table 1. Suggesting the importance of random effects, a small amount of variability was detected at the subject level, revealed by the random components analysis (see Table 2).

Table 1

Fixed Effects Parameter Estimates for Memory Intrusion Frequency Predicted by the Go/NoGo

Fixed Effects Parameter Estimates

				95% Confidence Interval				
Names	**Effect**	**Estimate**	**SE**	**Lower**	**Upper**	**df**	**t**	**p**
(Intercept)	(Intercept)	0.996	0.143	0.716	1.275	29.0	6.979	< .001

Fixed Effects Parameter Estimates

				95% Confidence Interval				
Names	**Effect**	**Estimate**	**SE**	**Lower**	**Upper**	**df**	**t**	**p**
Go/NoGo	0 - -1	0.511	0.326	-0.129	1.150	29.0	1.565	0.128

Table 2

Go/NoGo Variance Explained by Individual Subject Differences

Random Components

Groups	Name	SD	Variance	ICC
ID	(Intercept)	0.444	0.197	0.0883
Residual		1.427	2.036	

Note. Number of Obs: 192, groups: id 32

The Stroop color and word test

The Stroop Color and Word Test model was specified with "frequency" as the dependent variable, "Stroop Color and Word Test score" as the fixed effect, and a random intercept (effect) for each participant. Contrary to the hypothesis, the Stroop Color and Word Test model showed no main effect on intrusion frequency $p = .541$, $R^2 = .124$. Further results can be found in Table 3. The random components analysis revealed some variability between subjects (see Table 4).

Table 3

Fixed Effects Parameter Estimates for Memory Intrusion Frequency Predicted by Stroop Color and Word Test

Fixed Effects Parameter Estimates

				95% Confidence Interval				
Names	**Effect**	**Estimate**	**SE**	**Lower**	**Upper**	**df**	**t**	**p**
(Intercept)	(Intercept)	0.8653	0.252	0.371	1.36	27.0	3.4276	0.002
Stroop	0 - -1	0.5764	0.408	-0.223	1.38	27.0	1.4128	0.169

Table 4

Stroop Color and Word Test Variance Explained by Individual Subject Differences

Random Components

Groups	Name	SD	Variance	ICC
ID	(Intercept)	0.481	0.231	0.102
Residual		1.427	2.036	

Note. Number of Obs: 192, groups: id 32

The Digit Task

The Digit model was specified with "frequency" as the dependent variable, "Digit score" as the fixed effect, and a random intercept (effect) for each participant. Again, contrary to the first hypothesis, the Digit Stroop Task exhibited no main effect on intrusion frequency $p = .266$, $R^2 = .122$. Further results can be found in Table 5. Additionally, the random components analysis detected a small amount of variability on the subject level (see Table 6).

Table 5

Fixed Effects Parameter Estimates for Memory Intrusion Frequency Predicted by Digit Task

Fixed Effects Parameter Estimates

				95% Confidence Interval				
Names	Effect	Estimate	SE	Lower	Upper	df	t	p
(Intercept)	(Intercept)	1.0907	0.236	0.629	1.55	27.0	4.6259	< .001
Digit	-1 - -2	1.1250	0.813	-0.469	2.72	27.0	1.3833	0.178

Table 6

Digit Task Variance Explained by Individual Subject Differences

Random Components

Groups	Name	SD	Variance	ICC
ID	(Intercept)	0.436	0.190	0.0852
Residual		1.427	2.036	

Note. Number of Obs: 192, groups: id 32

Memory intrusion frequency and Impact of Event Scale

To test hypothesis two, that intrusion frequency would be predicted by event distress as reported on the IES-R, the first model was specified with "frequency" as the dependent variable, "IES" as the fixed effect, and a random intercept for each participant. The analysis did not reveal a statistically significant main effect of event distress on intrusion frequency across the days indicated by p <.136 and an effect size of R^2 .152. Nevertheless, the second hypothesis was not confirmed. Further results can be found in Table 7. Individual differences in reported distress were detected by the random components analysis, with the random effect variance and intraclass correlation coefficient suggesting some variability between subjects (see Table 8).

Table 7

Fixed Effects Parameter Estimates for Memory Intrusion Frequency Predicted by Event Distress

Fixed Effects Parameter Estimates

				95% Confidence Interval				
Names	**Effect**	**Estimate**	**SE**	**Lower**	**Upper**	**df**	**t**	**p**
(Intercept)	(Intercept)	1.152	0.216	0.729	1.57	27.8	5.34	< .001
IES-R	0 - -1	0.848	0.563	-0.255	1.95	26.4	1.51	0.144

Table 8

Event Distress Variance Explained by Individual Subject Differences

Random Components

Groups	**Name**	**SD**	**Variance**	**ICC**
ID	(Intercept)	0.496	0.246	0.109
Residual		1.417	2.009	

Note. Number of Obs: 182, groups: id 32

Exploratory Analysis

To further explore H2, the IES-R subscales assessing avoidance, hyperarousal, and intrusions were analyzed with post hoc linear regressions. The findings revealed that participant's reported distress related to intrusions (see Table 9) and hyperarousal (see Table 10) significantly predicted the total amount of memory intrusions they experienced in the week after

the experiment. An increase in intrusion related distress and an increase in hyperarousal resulted in an increase in memory intrusions.

Table 9

Memory Intrusion Frequency Predicted by Intrusion Subscale of IES-R

Model Coefficients - frequency

Predictor	Estimate	SE	t	p
Intercept [a]	5.19	0.900	5.77	< .001
intrusion:				
1 – 0	4.67	1.799	2.59	0.015

Table 10

Memory Intrusion Frequency Predicted by Hyperarousal Subscale of IES-R

Model Coefficients - frequency

Predictor	Estimate	SE	t	p
Intercept [a]	6.04	0.809	7.46	< .001
hyperarousal:				
1 – 0	4.46	2.289	1.95	0.060

Discussion

Using a novel variation of a well-established paradigm, this study sought to investigate how inhibitory control and event related distress relates to intrusion frequency after exposure to a trauma analogue. The hypotheses expected inhibitory control (H1) and event distress (H2) to predict the frequency of memory intrusions. It was the first study of its kind to implement this combination of tasks and measures to specifically evaluate their ability to predict the occurrence of trauma analogue memory intrusions. To test inhibitory control (H1) as a factor in intrusive memory outcomes, the implemented tasks targeted the response inhibition and interference control domains of inhibitory control (Wessel & Anderson, 2023). The Go/NoGo required

participants to stop prepotent motor responses, and the Stroop Color and Word Test and Digit Stroop Task required participants to exert interference control by inhibiting prepotent responses to incongruent information. The present study was interested in how performance in these tasks may correlate to the frequency of reported memory intrusions, theorizing a possible link between inhibitory control in the lab and the controlling of intrusive memories outside the lab. To test event distress (H2) as a vulnerability factor in the development of intrusive memories, the Impact of Event Scale (IES-R) was administered on the final day of longitudinal data collection. The present study was interested in how emotionality and event distress related to the trauma analogue might correlate with memory intrusion frequency, theorizing a possible link between event distress as a vulnerability factor of memory intrusions. The present study offers critical insights into potential factors contributing to the development of intrusive memories.

Does Inhibitory Control Predict Memory Intrusions?

To investigate whether inhibitory control scores predicted the frequency of memory intrusions in a nonclinical trauma analogue exposure, this work implemented well-established neuropsychological and cognitive tasks to test participant's inhibitory control ability. In testing the H1 and accounting for individual differences, the Go/NoGo, Stroop Color and Word Test, and Digit Stroop Task were modeled to reveal their relationship with the dependent variable, memory intrusion frequency. The Go/NoGo model did not provide evidence to indicate that performance in this task could predict memory intrusion frequency in the given sample. Although the study demonstrated a mentionable amount of subject variance that should be explored in future studies, the overall results suggest that findings are limited or may be masked by factors such as an underpowered sample. Similarly, the Stroop Color and Word Test did not predict the frequency of memory intrusions. Possible explanations for this will be discussed in the next paragraph. The Digit Stroop Task, which was the only inhibitory control measure tested after the trauma analogue exposure, also failed to provide evidence in support of the first hypothesis. Again, these findings may likely be due to a number of factors including issues related to methodology and the underpowered sample. The statistically insignificant findings also raise consideration for elements of inhibitory control that were not present in this study such as direct training in how exactly to exert inhibitory control over thoughts.

While arguments of inhibitory control as a domain general mechanism have emerged, this form of cognitive control is still known to be differentially employed based on one's behavioral goals. While it is unknown which form of inhibitory control relates more, both motor and response forms of inhibition have been shown to relate to the handling of unwanted thoughts and intrusive memories (Castiglione & Aron, 2021; Wessel & Anderson, 2023). While previous studies have shown that inhibitory control can modulate the development of intrusive memories (Streb et al., 2016), the present study did not find this using the Go/NoGo, Stroop Color and Word Test, Digit Stroop Task.

Go/No–Go Task

The Go/NoGo was a computerized task that targeted the motor inhibition domain of inhibitory control by requiring participants to inhibit automatic motor response action. This task was described as surprisingly difficult by participants. While motor inhibition and cognitive inhibition have usually been classified as separate domains of inhibitory control, recent evidence suggests a domain-general view of inhibitory control (Wessel & Anderson, 2023) which reasons that, while inconclusive, behavior stopping and retrieval stopping should have some overlapping relationship if executed by the same underlying mechanism. The Go/NoGo is one of the most common behavioral paradigms used to measure response inhibition (Raud et al., 2020). For these reasons, it was selected for the interests of this study. While cognitive inhibition begins to gain acceptance as an explanatory mechanism, fundamental questions about what is actually known about processing demands of particular inhibitory tasks remain. For example, Noreen and MacLeod (2015) explored inhibitory control across a wide range of commonly used memory and behavioral tasks and found no relationship between behavioral inhibition measures (e.g., Go/NoGo) and cognitive inhibition measures (e.g., Think/No-Think task). Besides targeting different domains of inhibitory control, one possible reason for this discrepancy may be related to the fact that within something like the Think/No-Think paradigm, participants are extensively trained in how to suppress thoughts and practice repetitively, whereas in tasks like the Go/NoGo or Stroop, participants are not given inhibitory control training.

Stroop Color and Word Test

The Stroop task is a classical neuropsychological test which targets the cognitive domain of inhibitory control by testing participant's ability to override incongruent information that interfered with the goal of the task. In a study which explored whether a poor inhibition ability is associated with intrusive memories, it was found that frequency of intrusive memories did not correspond to Stroop Color and Word Test measures in a healthy sample (Verwoerd et al., 2009). In contrast, Kertzman and colleagues (2014) found that, in a PTSD sample, Stroop Color and Word Test scores did correlate with re-experiencing symptoms. In this case, psychomotor speed explained nearly 10% of the predicted variance in the frequency of intrusive memories, suggesting that impaired interference control may be related to re-experiencing in a clinical sample. In the present study evaluating nonclinical participants, the Stroop Color and Word Test was measured by reaction time only. This could be one plausible reason for why the task poorly predicted the frequency of intrusive memories in a healthy sample. Future studies should also account for accuracy and not reaction time alone.

Digit Stroop Task

The Digit Stroop Task targeted the cognitive domain of inhibitory control by testing participant's ability to override incongruent information that interfered with the goal of the task. Nonetheless, for related but possibly different reasons, the digit task was not found to predict intrusion frequency. This task is distinct from the previous two in that it was the only inhibitory control test administered after the trauma analogue exposure. Considering the context of this experimental task, it is possible that the task itself served as a kind of intervention helping participants to process the trauma analogue memories the day after, thereby decreasing intrusive memories later. Through extensive study of suppression induced forgetting within the Think/No-Think paradigm, an ample amount of evidence suggests that suppression induced forgetting increases with the number of times that retrieval is stopped and broadly disrupts retention of the suppressed content (Nardo & Anderson, 2024)**.** Although this study cannot make claims regarding whether participants were or were not engaging in thought suppression when incidental reminders of the trauma analogue films flashed on the screen, it is imperative to consider the greater context in which this inhibitory control task took place. While only baseline trials were analyzed as the measure of inhibitory control for this study, there is a possibility that

while participants were engaging in the control task, they were also suppressing the emotional reminders or, perhaps, developing a habituated response – leading to a decrease in memory intrusions overall, masking the relationship between this inhibitory control task and thought intrusions. his possibility is speculative, however, especially given previous research concerning overall frequency of intrusive memories and thought suppression in the TNT task which found no relationship between retrieval suppression and intrusion frequency after a trauma analogue exposure (Streb et al., 2016; Wessel et al., 2008).

Does Emotional Distress Predict Memory Intrusions?

To investigate if event distress predicts memory intrusion frequency, the Impact of Event Scale (IES-R) was administered to participants after six days of reporting their memory intrusions. In light of current research, it was hypothesized that IES-R scores would predict memory intrusion frequency (H2). In testing and accounting for individual differences, the findings revealed that while the relationship between event distress and intrusive memories did vary among participants, there was not enough evidence to confirm this hypothesis. The 21-item IES-R consisted of statements such as, “I thought about it when I didn’t mean to” and “any reminder brought back feelings about it”. Participants were asked to rate how much each difficulty (reflected in the statement) distressed them in the past week. Exploratory analyses of the three subscales – assessing avoidance, hyperarousal, and intrusions – revealed that participant’s reported distress related to intrusions and hyperarousal significantly predicted the total amount of memory intrusions they experienced in the week after the experiment. This notable finding is in line with integrative models of emotional reactivity like the one proposed by Regambal and Alden (2009) which demonstrated a direct link between emotional reactivity, maladaptive coping strategies and intrusive memories in the trauma analogue film paradigm.

Emotional distress may be a vulnerability factor in the development and persistence of intrusive memories. As discussed in the introduction, Intrusive memories are involuntary and distressing thoughts, usually accompanied by vivid mental imagery which repeatedly protrude into consciousness following a traumatic experience (Herz et al., 2020). A systematic review of intrusive memories of distressing events states that in pathological samples, distress about the intrusive memories is actually a key conceptual component – highlighting the fact that it is not

just that the intrusive memory occurs, but that it actually causes extreme distress. The review critically asserts that if the goal of trauma analogue experiments is to better understand clinical phenomena, these studies should focus more on intrusive memory distress and not just frequency alone (Marks et al., 2018). As discussed, it is still not fully understood why some individuals develop posttrauma symptoms and others do not (Tortella-Feliu et al., 2019). The IES-R findings of the present study help identify specific vulnerability factors, like emotional distress, which can improve prevention and treatment strategies in clinical populations (Kessler et al., 2014).

General Discussion

The past decades of psychological and cognitive research has demonstrated a consistent link between inhibitory control, emotional distress, and intrusive memories. However, the extent, strength, and magnitude of these relationships has been historically inconsistent (James et al., 2016; Marks et al., 2018) and the present study is no different. Although not fully understood, empirical evidence in both clinical and nonclinical populations note the distinctly divergent temporal nature and convergent characteristic nature of intrusive memories between these populations (Bomyea & Lang, 2016; Holmes & Bourne, 2008; Streb et al., 2016). While nonclinical intrusive memory research has shown a predictable decrease of re-experiencing symptoms over days and weeks, clinical research has shown a chronic persistence of intrusive memories over months and years (Tortella-Feliu et al., 2019) Yet, both bodies of literature show converging evidence that intrusive memories are consistently characterized by their involuntary and emotionally distressing nature in PTSD and non-PTSD samples alike (James et al., 2016). This has raised interest in the common underlying mechanisms of intrusive memories. Inhibitory control has been greatly implicated as a potential moderator in posttraumatic outcomes, suggesting that, while PTSD is known to impair inhibitory control function (DeGutis et al., 2015), inhibitory control itself may indeed be a risk/resilience factor against memory intrusions (Hammar et al., 2023). Similarly, emotional distress related to intrusive memories has been linked with deficient inhibitory control (Streb et al., 2016).

Clinical research has begged the question of protective factors in the prediction of intrusive memories (Kessler et al., 2014). The present study explored inhibitory control and intrusive memory distress as two such possible factors. Historically, research has characterized

thought suppression (executed by inhibitory control) as a maladaptive coping strategy (Ehlers & Clark, 2000). Recently, emerging evidence has proposed that it may be an adaptive strategy, showing links between inhibitory control and an increased ability to suppress unwanted thoughts thereby improving mental health (Gagnepain et al., 2017; Mamat & Anderson, 2023). The findings of the present study help shed light on this by showing that raw inhibitory control tasks could not reliably predict the occurrence of intrusive memories. Perhaps if participants had been explicitly instructed and trained in how to suppress unwanted thoughts or memories, the result would have been different; as in the case of Mamat and Anderson (2023), who found great improvement from inhibitory control training. Future research should explore the difference between intrusive memory outcomes when inhibitory control is trained rather than taken as an innate ability.

Limitations

As mentioned previously, the present study and its findings are limited by a number of factors. The sample was a small, fairly educated group that through an extensive pre-screening process were selected based on criteria which controlled for the presence of psychological disorders. The exclusion of any individuals with significant mental health or trauma history helped ensure that the sample was mentally well. Had the criteria allowed for clinical or subclinical psychological symptoms, the findings may have been different based on a larger variance in executive function, but ethical considerations did not allow for this. Nevertheless, variance in executive function, mental well-being, and unknown factors still could not be completely controlled and these individual differences do limit the findings of the present study. Additionally, due to resources and the demanding nature of the experiment, the sample was relatively small,o which greatly limits the power of any statistical results. Furthermore, the present study explored data which was collected in the context of a broader project, so participants underwent a host of experimental procedures. The interplay of these experimental components and how they might have impacted performance and subjective experience is not easily determined. Lastly, the Stroop Color and Word Test may have presented a methodological error by neglecting accuracy in accounting for inhibitory control ability in the task. Similarly, the Digit Stroop Task was a novel variation based on research, but the specific stimuli still lack

empirical evidence compared to the Go/NoGo, for example. Thus, the nature of the sample and experimental methodology should be considered.

Conclusion

The findings of this study expand existing research relating to inhibitory control, emotional distress, and intrusive memories. The findings may shed light on the current research gap and ongoing debate regarding the role of inhibitory control in the development of intrusive memories by highlighting the importance of task selection in laboratory settings. The present study concludes that future research which endeavors to extrapolate the translational effects of inhibitory control on intrusive memories from inside the lab to a naturalistic setting should consider utilizing tasks which provide inhibitory control training. Additionally, the findings may shed light on existing research and the current gap by highlighting how emotional distress related to the intrusions themselves and accompanying hyperarousal seem to most directly contribute to the occurrence of intrusive memories. The present study further concludes that future research which endeavors to disentangle the relationship between emotional reactivity and intrusive memories should focus more on aspects of distress which are directly linked to a sense of hyperarousal and the intrusions themselves.

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Appendix

Figure 2

The Impact of Event Scale Completed by Participants on Final Day of Study

IMPACT OF EVENT SCALE-REVISED

Daniel S. Weiss, PhD & Charles R. Marmar, MD

Instructions: Below is a list of difficulties people sometimes have after stressful life events.

Please read each item and then indicate how distressing each difficulty has been for you DURING THE PAST SEVEN DAYS with respect to_____, how much were you distressed or bothered by these difficulties?

Not at all=0, Little bit =1, Moderately=2, Quite a bit = 3, Extremely= 4

Sr.No	Statement	0	1	2	3	4
1.	Any reminder brought back feelings about it					
2.	I had trouble staying asleep.					
3.	Other things kept making me think about it.					
4.	I felt irritable and angry.					
5.	I avoided letting myself get upset when I thought about it or was reminded of it.					
6.	I thought about it when I didn't mean to					
7.	I felt as if it hadn't happened or wasn't real					
8.	I stayed away from reminders about it.					
9.	Pictures about it popped into my mind.					
10	I was jumpy and easily startled.					
11	I tried not to think about it.					
12	I was aware that I still had a lot of feelings about it, but I didn't deal with them.					
13	My feelings about it were kind of numb.					
14	I found myself acting or feeling like I was back at that time.					
15	I had trouble falling asleep.					
16	I had waves of strong feelings about it.					
17	I tried to remove it from my memory.					
18	I had trouble concentrating.					
19	Reminders of it caused me to have physical reactions, such as sweating, trouble breathing.					
20	I had dreams about it.					
21	I felt watchful and on-guard.					
22	I tried not to talk about it.					

Avoidance Subscale = mean of items 5, 7, 8, 11, 12, 13, 17, 22

Intrusion Subscale = mean of items 1, 2, 3, 6, 9, 16, 20

Hyper arousal Subscale = mean of items 4, 10, 14, 15, 18, 19, 21

Note: The IES-R is not a diagnostic or screening tool for PTSD; rather, it relies on a patient's own report of symptoms and is used to gauge response no sooner than two weeks after a traumatic event, as well as to evaluate recovery.