SEXUAL TRAUMA AS IT RELATES TO MENTAL HEALTH, MEMORY AND THE PASSING OF TIME

by

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ABSTRACT OF THE THESIS

Sexual trauma as it relates to mental health, memory and the passing of time

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Sexual trauma is a serious social and mental health problem that affects more than 25% of women worldwide, with comparable rates in the United States [1,2]. Survivors of sexual trauma frequently suffer from distorted thoughts about the self and the world but less is known about the processes related to autobiographical memories and time. The following project has three primary aims: 1) to identify mental health symptoms, 2) memory-related outcomes, and 3) temporal changes in college-aged women with and without sexual trauma during adolescence and young adulthood.

Experiment 1 tested depressive, anxiety and trauma-related symptoms as well as ruminative thoughts in women with sexual trauma versus women with no history of sexual trauma. It was hypothesized that women with sexual trauma would report greater numbers of depressive, anxiety and trauma-related symptoms and ruminative thoughts compared to controls. During Experiment 1, women were interviewed for trauma history with the Structured Interview for DSM-5, and then completed self-report questionnaires for depression, anxiety, trauma-related cognitions and rumination. Women with sexual

trauma (n=34) reported significantly more depressive, anxious, and trauma-related symptoms, as well as ruminative thoughts (all p's < 0.01), when compared to those measures in controls (n=94). Correlations among these measures were highly significant ($p < 0.001$, n=128).

Experiment 2 evaluated the details surrounding an autobiographical memory of the most stressful event of one's past, as well as temporal and spatial cognition. Participants completed the Autobiographical Memory Questionnaire and the Symmetry Span, Temporal Separation and Spatial Discrimination tasks. Women with sexual trauma (n=34) reported significantly more temporal and spatial details related to the vividness and significance of a past stressful autobiographical memory compared to controls (n=94), $p < 0.001$. Furthermore, women who reported heightened vividness of the memory reported higher numbers of ruminative and trauma-related thoughts ($p < 0.001$). Despite these differences in memory recall, no differences in spatial and temporal cognition tasks unrelated to stress were observed (all p's > 0.05). These data suggest that sexual trauma can increase the vividness of intense stressful life memories, which may contribute to or minimally interact with their heightened rumination and trauma-related thoughts.

In Experiment 3 we tested time sensitivity and subjective time estimation in women with sexual trauma and controls with a temporal bisection task. During training, participants make temporal judgments of stimulus durations (ranging from 400ms-1600ms) presented as a red circle on a black computer screen. Participants classified probes as being "short" (closer to 400ms duration) or "long" (closer to 1600ms duration) with a keyboard press. The task yields a measure of time sensitivity (i.e., threshold of Just

Noticeable Difference) and time of perceived subjective equality (or the bisection point), defined as the point when an individual responds “short” or “long” with equal frequency. Women with sexual trauma (n=24) significantly differed from controls (n=75) on the time point of subjective equality (ST = 940ms; controls 830ms, $p < 0.05$). Overall, women with sexual trauma underestimated the duration of most time intervals compared to controls. These data suggest women with sexual trauma experience time as moving slower. There were no group differences in time sensitivity ($p > .05$).

Overall, data from these three experiments suggest that women with sexual trauma ruminate more often, suffer from symptoms of depression, anxiety and trauma, recall past stressful events with heightened vividness, and may process time differently as compared to women without the same trauma history.

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Introduction

Sexual violence and aggression are some of most stressful of all human life experiences. It was recently estimated that more than 30% of women worldwide experience physical or sexual violence (WHO 2013), with similar estimates (27%) in the United States [2]. Exact statistics are difficult to obtain because many women do not report the event, and many fail to seek medical assistance. Of the seemingly infinite sources of trauma, sexual assault is the most likely to induce Posttraumatic Stress Disorder (PTSD) [2,3] a category of mental illness characterized by symptoms of re-experiencing the trauma, avoiding reminders of the trauma, negative cognition and mood and hyperarousal [4]. Because women are four times as likely as men to experience sexual assault and nine times as likely to experience rape [2], it is no surprise that PTSD is common among women who have experienced sexual trauma. Women ages 18 to 24 are at the highest risk of experiencing sexual assault compared to other age groups [5]. While rates are high in female college students – one in five female undergraduates report sexual trauma during college – 32% of female non-students report sexual trauma [6].

People who experience a severe stressful life event often re-experience the event in the form of flashbacks, avoidance behavior, numbness or hyperarousal according to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) [7]. Survivors of sexual assault in particular frequently suffer from symptoms of anxiety, depression, hyperarousal or numbness, as well as exaggerated startle responses [8,9]. These responses vary within and among individuals, depending on the age when the event occurred, whether violence is chronic or acute, and the context of the event [10,11]. Most studies in adults have been conducted with women in the community who are suffering from a variety of psychiatric disorders, potentially tied to a history of trauma. These study characteristics are important because the results tend to represent the population at large. Nonetheless, it is likewise important to assess the consequences of sexual trauma in women of college age because incidence is high in this population, and because they may experience distinctive outcomes from women recruited from clinical populations.

Rumination is the tendency to repeatedly rehearse thoughts oftentimes about the past. The ruminative process can produce thoughts of self-blame and if sustained over time, can contribute to a negative state of living or a feeling of being "stuck in the past" [12]. Some ruminative thought patterns help with coping, but others potentially exacerbate psychological and physiological problems, such as disrupted sleep or hypervigilance. Reliving the experience serves to further integrate the memory into a person's life story, which can induce yet more stress-related symptoms [13]. A number of studies indicate that ruminative thoughts are often associated and in some cases related to symptoms of depression but their occurrence as a result of trauma and in particular sexual trauma is less well-established [14–16].

In three set of experiments, we assessed depressive and anxiety symptoms, ruminative and trauma-related thoughts, memory-related outcomes, and temporal processes in college-aged women with and without a history of sexual trauma. We included college-aged women who had suffered sexual assault either during adolescence or adulthood to rule out consequences of childhood sexual abuse, which has been studied more extensively. Our goal here was to identify changes in mental health outcomes in a population of adult women who were not necessarily seeking out medical or psychological help and yet may be experiencing changes in mental health as a result of their history. In the first experiment, it was hypothesized that women with sexual trauma would report more mental health symptoms of depression, anxiety and posttraumatic cognitions. We further hypothesized mental health symptoms would be elevated and would relate to an increase in ruminative thoughts. To test these hypotheses, we recruited female college students who either had or had not experienced sexual trauma as an adolescent or young adult. They underwent a clinical interview and thereafter filled out self-report questionaires for symptoms of depression, anxiety, trauma, and ruminative thoughts.

Method

Participants

128 college-aged women (M_{age} = 19.63 years, *range* 14 years; 30.5% Asian; 31.3% White; 18% Black; 10.9% Hispanic/Latina; 9.4% More than one race/Other/Unknown)

participated in testing at a northeastern university. Participants were included if they were able and willing to provide informed consent. Participants were excluded if they were over 40 years of age or receiving or taking psychological or pharmacological treatments beyond stable dose (>6-wks). Ninety-four participants (n=94) did not experience sexual trauma and served as controls. Of participants who reported history of sexual trauma (n=34), 10 participants reported sexual assault without sexual intercourse (includes unwanted touching of sexual organs or being forced to touch the sexual organs of another without consent) and 24 participants reported sexual assault with intercourse. Incidences of sexual violence occurred during adolescence or young adulthood, at or after age 12. Nine participants who experienced sexual abuse during childhood but not during adulthood were excluded from analyses. One participant was excluded due to a history of psychotic episodes. These same individuals also participated in Experiments 2 and 3.

Materials

All participants were assessed for trauma history with the Structured Clinical Interview for DSM-5 [7] by a doctoral psychology graduate student trained in conducting clinical interviews. We defined trauma exposure as direct exposure to ‘‘an event or events that involved actual or threatened death, serious injury or sexual violation to the self” according to the Diagnostic Statistical Manual of Mental Disorders [DSM-5; 4]. Participants also completed several self-report assessments of psychological function. The *Beck Depression Inventory* [17] is a 21-item questionnaire that measures symptoms of depression. BAI and BDI scores are added and can range from 0 to 63. Scores higher than 18 are considered moderate to severe depression. The *Beck Anxiety Inventory* [18] is a 21-item questionnaire that measures symptoms of anxiety. Scores higher than 18 are consistent with moderate to severe anxiety. The *Posttraumatic Cognitions Inventory* [19] is a 33-item questionnaire that assesses thoughts and emotions concerning the most stressful event from the past. Items include “*I have to be on guard all the time*” and “*I feel like I don’t know myself anymore*.” Scores on the PTCI indicate to what extent the participant has negative cognitions about the self or the world, or feels self-blame as a result of the stressful event. Individuals with no trauma history also take the questionnaire and answer according to the most stressful event from their past. Higher PTCI scores are

indicative of more negative posttraumatic cognitions and are associated with greater numbers of PTSD symptoms [20]. The *Ruminative Responses Scale* [15] is a 22-item questionnaire that assesses thoughts and responses to depressed mood and affect (min 22; max 88). The RRS contains 3 subscales: depressive ruminations, which relate to the rehearsal of depressive events, brooding ruminations, which are often non-adaptive and emotion-laden, and reflective ruminations, which are not as maladaptive but self-focused [16,21].

Procedure

Participants were provided informed consent, assessed for trauma history with a structured clinical interview and completed a series of self-report questionnaires of depression, anxiety, trauma-related cognitions and rumination. Subsequently, the participants completed questionnaires and tasks reported in Experiments 2 and 3. Upon completing testing, participants were debriefed and compensated ($20 or research credits). Study procedures were approved by the university's Institutional Review Board.

Results from Experiment 1

Thirteen participants were exposed to a traumatic event other than sexual violence (including physical assault as well as non-interpersonal events such as car accidents). A multivariate analysis of variance among the three groups (no-trauma controls, trauma-exposed not due to sexual violence (TE), trauma-exposed due to sexual violence (TE-SV)) was performed in order to test differences in outcome variables of depressive (BDI), anxiety (BAI), trauma-related symptoms (PTCI), and ruminative thoughts (RRS). While the sexual trauma group (TE-SV) did differ significantly from no-trauma controls on all outcomes (results discussed below), the trauma-exposed group (TE) not due to sexual violence did not differ from no-trauma controls on the BDI, BAI, RRS and PTCI (all p's > 0.05). Importantly, the TE group also did not significantly differ from the TE-SV group on BAI or RRS scores (p's > 0.05), indicating that anxiety symptoms and the tendency to ruminate observed in the sexual trauma group might be due to trauma exposure, rather than the specific experience of sexual violence. Still, the sexual trauma group did significantly differ from the TE group ($p < 0.05$) on PTCI scores and BDI scores, indicating that sexual

trauma was associated with an increase in posttraumatic cognitions and depressive symptoms, above and beyond exposure to a traumatic event. Because we are most interested in the consequences of sexual trauma history, we included the 13 participants with trauma exposure unrelated to sexual violence in the control group for the remainder of the analyses reported in Experiment 1.

Women with sexual trauma (n=34) reported almost twice as many depressive symptoms (M=17.94, SD=12.68) as scored on the Beck Depression Inventory (BDI) compared to controls with no sexual trauma (M=9.80, SD=8.38), $t(43.86) = -3.48$, $p < 0.001$ (equal variances not assumed) (Fig 1A). Women with sexual trauma reported twice as many anxiety symptoms (M=12.65, SD=11.52) as assessed on the Beck Anxiety Inventory (BAI) compared to controls (M=6.30, SD=6.27), $t(40.28) = -3.05$, $p < 0.01$ (equal variances not assumed) (Fig 1B). Women with sexual trauma also reported 30% more posttraumatic symptoms (M=124.09, SD=37.48) assessed on the Posttraumatic Cognitions Inventory (PTCI) compared to controls (n=94; M=87.06, SD=31.30), $t(126) = -5.60$, $p < 0.001$ (Fig 1C) and 17% more ruminative thoughts (M=54.21, SD=13.56) as assessed on the Ruminative Responses Scale (RRS) compared to controls (M=45.91, SD=15.43), $t(126) = -2.77$, $p < 0.01$ (Fig 1D).

Greater numbers of posttraumatic cognitions were highly correlated with reports of ruminative thoughts and symptoms of depression and anxiety. Specifically, women who reported more posttraumatic cognitions on the PTCI also reported more depressive symptoms on the BDI, $r = 0.76$, $p < 0.001$ (Fig 2A), more anxiety symptoms on the BAI, $r = 0.67$, $p < 0.001$ (Fig 2B), and more ruminative thoughts (higher RRS scores), $r = 0.61$, $p < 0.001$ (Fig 2C) across all participants (n=128). These data suggest that those women who reported greater numbers of trauma-related cognitions, also felt more depressed and anxious, and spent more time thinking about past negative feelings of being down or sad.

Discussion for Experiment 1

Experiment 1 examined symptoms related to depression, anxiety and trauma, as well as ruminative thoughts in college-aged women with and without sexual trauma. Women with sexual trauma reported significantly more depressive and anxiety symptoms, posttraumatic cognitions, and ruminative thoughts compared to controls without

sexual trauma history (Fig 1A-D). According to results from the SCID, most participants with sexual trauma did not meet diagnostic criteria for a depressive or anxiety disorder. However, these same women reported significantly more symptoms of depression as detected by the Beck Depression Inventory (Fig 1A) and twice as many symptoms of anxiety as detected by the Beck Anxiety Inventory (Fig 1B). It is generally accepted that BDI scores greater than 18 indicate moderate depression, while those between 11-16 are associated with mild mood disturbance, and scores of 10 or less are consistent with the normal "ups and downs" of life [17]. In our study, women with sexual trauma reported a mean BDI score of 18, consistent with moderate depression. With respect to anxiety, BAI scores less than 21 are associated with low anxiety [18]. Women with sexual trauma were considerably less than 21 with a mean of about 12. Overall, these data indicate a significant albeit moderate elevation of anxiety and depressive symptoms following sexual trauma and suggest a rather widespread, albeit low-level activation in stress-related physiological systems, i.e. the autonomic nervous system for anxiety and hypothalamic-pituitary adrenal system for depression.

Foa and colleagues developed the Posttraumatic Cognitions Inventory (PTCI) to assess altered cognitions related to traumatic life experiences [19]. These types of thoughts include those related to oneself (i.e., sees oneself as blameworthy, isolated, unreliable, responsible), others (i.e., sees them as untrustworthy) and the world (i.e., sees it as a dangerous place). As expected, women with sexual trauma reported significantly more trauma-related cognitions (Fig 1C). Their average scores were greater than 120 while scores for those without sexual trauma were closer to 85. In other studies, individuals with PTSD tend to report scores greater than 100 and as high as 133 [19]. We did assess for PTSD in our sample and approximately 29% of women with sexual trauma met diagnostic criteria for current PTSD (n=10) according to the SCID-5 criteria (at least 6 total PTSD symptoms). Overall, women with PTSD averaged 12 total current PTSD symptoms (*SD*=3.54, range 8-19), which is considerably higher than the diagnostic threshold. As expected, these women displayed significantly higher PTCI scores overall (above 150). Even excluding participants with PTSD, the mean PTCI score for the remaining participants exposed to sexual trauma was greater than 100. These results are perhaps unusual because Foa and colleagues [19] have suggested that trauma without PTSD is associated with

scores less than 49; however the numbers reported in their study included data from non-interpersonal trauma events such as accidents in addition to interpersonal events like sexual assault. Our present data are generally consistent with prior reports that women who experience sexual assault tend to score higher on the PTCI, compared to other non-interpersonal related traumas [19,22,23]. Some have reported PTCI scores closer to ours in trauma populations without PTSD [22]. It is potentially important that women in our study without sexual trauma history reported a high number of trauma-related cognitions compared to other studies [19]. The purpose of the questionnaire is to assess the person's reaction to the event more so than the event itself. Therefore, we do not know what the stressful event was – either for controls or the violence group for that matter.

With the SCID, we did assess whether participants experienced potentially traumatic events, which were defined as a threat to the physical integrity of the self, including non-interpersonal events such a car accident and non-sexual interpersonal traumas including physical abuse. Thirteen women reported a past traumatic event other than sexual trauma. However, women with sexual trauma reported significantly higher PTCI scores (n=34; M=124.09, SD=37.48) compared to women exposed to a traumatic event other than sexual violence (n=13; M=92.31, SD=28.21) as well as to no-trauma controls (n=81; M=86.22, SD=31.85), which were already higher-than-average. These data suggest that college women in general are experiencing greater numbers of trauma symptoms but the response to sexual violence supersedes those responses.

Rumination is the process of repeatedly rehearsing depressive, brooding and/or reflective thoughts about the past. In the present study, we document an 17% increase in ruminative thoughts in women who have suffered sexual trauma in adolescence or young adulthood (Fig 1D). To our knowledge, the present study is the first to report a greater tendency to ruminate in college-aged women with sexual trauma who do not meet criteria for MDD but are nonetheless suffering with significant symptoms of depression, anxiety and trauma-related cognitions. This result was somewhat surprising because ruminative thoughts are most often associated with clinical depression and not trauma, *per se* [16,24–26]. That said, a few studies have established a relationship between rumination and trauma. One study reported that high levels of rumination were associated with greater perceived stress in college-aged and community populations of female survivors

of interpersonal violence, although the relationship was accounted for by depressive symptoms (higher levels than in our sample) [27]. Others have reported intrusive thoughts like rumination accounted for the greatest variance in persistent PTSD [28] and another suggested that participants with PTSD and depression ruminated more compared to non-traumatized participants with depression [29]. Interestingly, in the latter study, people with PTSD suggested that their ruminations (described as uncontrollable and involuntary) more frequently triggered intrusive memories of the trauma and critical life events in general compared to trauma-exposed people with depression [29]. The study included both men and women but did not specifically assess sex differences in symptoms, and did not distinguish between different trauma types. It would be interesting to know whether ruminative patterns of trauma memories are exacerbated in women with a history of sexual violence compared to men or survivors of other trauma types.

The numbers of studies specifically related to cognition and the emotional aftereffects of sexual trauma in young adult women are sparse. Overall, they suggest women who were victims of sexual assault during adolescence engaged in more frequent violence perpetration and risky behavior compared to non-interpersonal trauma-exposed controls and no-trauma controls [42]. Additionally, women with sexual trauma were significantly more likely to develop a lifetime Substance Abuse Disorder or Eating Disorder compared to victims of physical assault and no-trauma controls [30]. Overall much of the research on sexual trauma in young adult women is conducted in community samples with clinically diagnosed Posttraumatic Stress Disorder (PTSD). In the present study, over one quarter of the women with sexual trauma met diagnostic threshold for current PTSD, which includes symptoms of re-experiencing the event (i.e. flashbacks or nightmares), avoidance (of thoughts as well as places or people associated with the event), negative cognitions or feelings (like self-blame), and hyperarousal (such as hypervigilance or heightened startle reaction). As a group these women reported a current number of PTSD symptoms (i.e. 12) that was quite above the diagnostic threshold of 6. These symptoms have to be present in the past month and cause distress to meet diagnostic criteria for current presentation of the disorder. Some of the symptoms assessed with the self-report questionnaires of depression, anxiety and trauma quite likely also capture many current PTSD symptoms of negative cognitions and mood and hyperarousal. Those women who

are re-experiencing the event in the form of flashbacks or intrusive thoughts (as assessed by the SCID) quite possibly are ruminating more, and more depressed and anxious. In fact, correlational analyses demonstrate just that – all PTSD symptom clusters significantly correlated with BDI, BAI, PTCI and RRS scores across the entire sample (n=128; all p's < 0.001). However, we chose not to discriminate women with PTSD from the other women who have experienced sexual trauma but are not suffering from current PTSD for this Experiment and for Experiments 2 and 3 due to the small group sizes. When women with PTSD are included in the sexual trauma group, the group overall exhibits moderate levels of depression, low levels of anxiety and high numbers of trauma-related thoughts, and significantly more of each when compared to controls. These women also have a greater tendency to ruminate about their negative thoughts and mood. Therefore, we conclude that while the women are "high functioning" with respect to college enrollment, many are nonetheless struggling with moderate mental health symptoms, which likely impinge on their overall health and sense of well-being.

Experiment 2:
Memory-related outcomes associated with sexual trauma

Introduction

Most studies suggest that memory changes with time as it is rehearsed or avoided and thus becomes sensitized, degraded or even disrupted through reactivation and rehearsal processes [31]. Meanwhile, memory becomes associated with more neutral experiences in the present [9]. Memories of an extremely stressful life event can come back to the victim days or even weeks after the event and do not necessarily follow a coherent narrative [7,32,33]. As with emotional outcomes, the memorial response depends on when and where it occurred, how long it lasted, and the circumstances surrounding the event, not to mention individual differences. The effects of trauma on memory are well studied, although controversial. Women who have experienced sexual trauma often reflect on and rehearse the event itself as well as the conditions and context associated with the event, but whether those reflections differ in quality or quantity from other memory processes is debatable. For example, some suggest that learning and memory processes which regulate the trauma memory are not necessarily different from those that govern autobiographical memory more generally [34,35]. It is often reported that memories for the traumatic experience itself can be disrupted or rather enhanced during both voluntary and involuntary recall [13], while more general memory function is not as vulnerable [36].

Despite these findings, it is unclear whether sexual trauma persistently interferes with learning and memory processes unrelated to the experience but that are nonetheless necessary for effective everyday performance in college-aged women who experienced sexual trauma as adolescents or young adults. Therefore, in the present study, we examined how someone with and without sexual trauma would rehearse a stressful autobiographical memory and how that memory would be experienced. In other words, what aspect of the memory are most vivid – sensory details, the time and place where it occurred, the feelings during and around the experience or how the experience relates to the rest of one's life history? We hypothesized that women with sexual trauma would reflect more

on a stressful memory and this reflection would be experienced as a rehearsal of sensory details in time and place. We further hypothesized that the increase in sensory and contextual details would be related to the occurrence of ruminative thoughts about the past. We also tested memory-related processes unrelated to autobiographical memory, and predicted that these cognitive processes would not differ between women with sexual trauma history and controls.

Method for Experiment 2

Participants (same as reported in Experiment 1)

Materials

The *Autobiographical Memory Questionnaire* [37] is a 19-item questionnaire that assesses autobiographical memory. Given the breadth of items assessed by the AMQ, the questionnaire is not typically reported as a total score [35]. Rather the items are scored individually or in clusters, depending on the research question of interest. We were especially interested in the vividness of details related to the memory rather than accuracy of the memory itself. Therefore, we did not assess items concerning confidence of memory or dating the event. Participants were told to respond to the questionnaire in relation to an autobiographical memory of *the most stressful event of their life*. We included 12 individual items on the questionnaire that assess the rehearsal of the memory, sensory details ("*As I remember the event, I can hear it in my mind*" or "*see it in my mind*"), temporal and spatial details ("*As I remember the event, I know its temporal and spatial layout*"), emotional details (*"As I remember the event, I feel the emotions now that I felt then"*), and significance (*"the memory is significant in my life*"). We also computed a total score of the 12 items. Higher scores indicate greater vividness of details related to an autobiographical memory.

Working memory is a learning process whereby information is kept labile in short-term memory to calculate or make decisions in the present moment. The *Symmetry Span Task* developed by Engle and colleagues was used to assess working memory [38]. The task required participants to make assessments of symmetrical pictures while remembering the temporal order and spatial location of a set of squares individually displayed on a

grid. Participants were shown a picture and needed to determine if it was symmetrical or not. Immediately following, a square in a 4x4 grid appeared on the screen for 2 seconds. Pairs of pictures and squares were presented 2 to 5 times per trial, for 12 trials (3 blocks total). Following stimulus presentations, participants were asked to replicate the location of the squares in the order presented. The task required approximately twenty minutes to complete. Data from the working memory task yielded partial and absolute accuracy scores. A partial accuracy score is a sum of all correct responses regarding the sequential order and location of the squares. An absolute accuracy score is the sum of correct responses in completely correct trials, when the order and location of the squares were all correct during the trial (all-or-none system).

The *Temporal Separation Task* and *Spatial Discrimination Task* developed by the Psychology Experiment Building Language [39] were used to assess temporal and spatial cognition. During both tasks, two blue squares with a pattern of white dots are each presented for 1500 milliseconds sequentially on a computer screen. Participants are required to discriminate the patterns and indicate if the squares are the "same" or "different" with a button press on the keyboard. Participants completed 20 trials of both same and different conditions for a total of 40 trials per task. During the Temporal Separation Task the blue squares were separated by an interstimulus interval of 7000 milliseconds. During the Spatial Discrimination Task the squares contained a more complex pattern of white dots and were separated by a shorter interstimulus interval of 3500 milliseconds. Each task took approximately ten to fifteen minutes to complete.

Procedure

After providing informed consent and being assessed for trauma history with the structured interview, participants completed the Autobiographical Memory Questionnaire, the Symmetry Span Task, the Temporal Separation Task and the Spatial Discrimination Task. After the full testing session, participants were debriefed and compensated ($20 or research credits). Study procedures were approved by the university's Institutional Review Board.

Results from Experiment 2

First, the trauma-exposed (TE) group not due to sexual violence (n=13) was compared to no-trauma controls and the sexual trauma group using a multivariate analysis of variance on AMQ total score among the three groups (no-trauma controls, trauma-exposed or TE, sexual trauma or ST). The TE group did not differ from no-trauma controls on total AMQ score (p's > 0.05), though the ST group did differ from controls (results discussed below). Additionally, the ST group ($M=55.21$, $SD=12.95$) reported significantly more details related to an autobiographical memory of a past stressful event (assessed as a total score on the AMQ) compared to the TE group ($M=45.54$, $SD=7.90$), $p < 0.05$. These data indicate that sexual trauma specifically was associated with an increase in vivid details of a memory of a past stressful event, above and beyond mere exposure to a traumatic event. Given these findings and as reported in Experiment 1, we decided to group participants according to sexual trauma history rather than more general trauma exposure, due to the specific interest in the relationship between sexual trauma and memory. We report our findings from Experiment 2 below.

As a preliminary analysis, we first calculated the cumulative AMQ score from items 1-12 in order to determine whether women with sexual trauma differed from controls without sexual trauma. Women with sexual trauma ($M=55.21$, $SD=12.95$) reported 20% more details in general surrounding an autobiographical memory of a past stressful event compared to controls ($M=44.16$, $SD=13.68$), $t(126)= -4.09$, $p < 0.001$ (Fig 3A).

Considering the breadth of memory-related details assessed by the AMQ, we further analyzed 12 items individually for group differences. To correct for multiple comparisons and avoid Type 1 Errors, Bonferroni corrections were applied to a p-value of 0.05 (0.05/11 comparisons of 12 AMQ items = 0.005). Therefore, a p-value less than 0.005 was necessary to establish significance. While the scores from women with sexual trauma were higher for each AMQ item (a measure of details surrounding the memory), the group scores were significantly different for five items (Fig 3B). With the Bonferroni-corrected t-tests, women with sexual trauma indicated significantly more auditory details ($M=4.26$, $SD=1.88$) compared to controls ($M=3.21$, $SD=1.72$), $t(126)=-2.99$, $p < 0.005$; more visual details ($M=5.47$, $SD=1.52$) compared to controls ($M=4.26$, $SD=1.80$), $t(126)=-3.50$, $p <$

0.001; more temporal and spatial details (M=4.76, SD=1.89), compared to controls (M=3.44, SD=1.82), t(126)=-3.61, $p < 0.001$; more likely to recall the setting (M=6.00, SD=1.21), compared to controls (M=4.97, SD=1.59), t(126)=-3.44, $p < 0.001$. Additionally, they reported that the autobiographical memory was significantly more central to their life story (M=5.50, SD=1.81) compared to controls (M=4.10, SD=2.04), t(126)= -4.09, $p < 0.001$. Differences between women with sexual trauma (M=5.68, SD=1.34) and controls (M=4.71, SD=1.82), on actually remembering the event approached significance, with the Bonferroni correction limit: t(126)=-2.82, $p = 0.006$. Group responses did not differ significantly on the other six items assessed by the AMQ, $p > 0.005$. These data suggest a past stressful event holds greater significance in memory for women with sexual trauma compared to controls without sexual trauma, and that these women also recall a greater degree of temporal spatial details surrounding the memory related to controls; however and importantly, women with sexual trauma in general report greater details of a past stressful memory, including those related to the senses, context and significance when considering the memory recollection as a composite score.

Across all participants (n=128), women who reported more sensory, contextual and emotional details related to a past autobiographical memory of the most stressful event of their past reported greater numbers of ruminative thoughts, $r = 0.43$, $p < 0.001$ (Fig 4A) and greater numbers of posttraumatic cognitions $r = 0.43$, $p < 0.001$ (Fig 4B). These data indicate that those women who recall the most stressful event of their past with greater sensory and contextual detail, ruminate more and report more cognitions of self-blame and thinking the world is a dangerous place.

Participants were tested for spatial and temporal cognition with three working memory tasks of temporal and spatial cognition: the Symmetry Span Task [40], the Temporal Separation and the Spatial Discrimination tasks [39]. For technical reasons, we did not collect task data for 33 participants on the symmetry task or for 83 participants on the temporal and spatial tasks. Participant performance on the Symmetry Span Task was scored for partial and absolute accuracy. Partial scores were calculated by summing any correctly recalled squares by temporal order and spatial location. A participant received credit toward an absolute accuracy score if she indicated *all* of the squares' correct locations and order in a single trial. An independent t-test was conducted to determine whether

women with sexual trauma significantly differed from controls with no sexual trauma history on performance on the Symmetry Span Task. Women with sexual trauma (n=32) did not significantly differ from controls (n=63) on task performance, scored as either partial accuracy (ST: M=27.52, SD=6.34; controls M=27.52, SD=8.28), $t(93)=0.75$, $p > 0.05$ (Fig 5A), or absolute accuracy (ST: M=16.75, SD=7.23; controls: M=18.24, SD=9.98), $t(78.55)=0.89$, $p > 0.05$ (equal variances not assumed). Participant performance on the Temporal Separation and Spatial Discrimination tasks were scored for accuracy (%). Women with sexual trauma (n=29) did not significantly differ from controls (n=26) on Temporal Separation Task accuracy (ST: M=78.45%, SD=11.85%; controls M=82.69% SD=9.24%), $t(53)=1.47$, $p > 0.05$, or on Spatial Discrimination Task accuracy (ST: M=76.03%, SD=10.78%; controls: M=74.23%, SD=9.67%), $t(53)=-0.64$, $p > 0.05$ (Fig 5B-C). These data indicate that even though women with sexual trauma reported significantly more psychological symptoms, ruminative thoughts and details of an autobiographical memory of a past stressful event, they did not significantly differ in spatial and temporal cognition compared to controls with no sexual trauma.

Discussion for Experiment 2

Findings from Experiment 2 report women with sexual trauma report greater numbers of details related to an autobiographical memory of their most stressful event in the past (Fig 3A-B). These details are especially related to the temporal and spatial context of the memory and are punctuated by heightened auditory and visual details compared to women without sexual trauma. Furthermore, women with sexual trauma consider the memory as more central to one's life story compared to women without sexual trauma. It should be noted that we did not ask participants to identify the event or the details of the memory itself but rather to indicate their interaction with the memory of the event. It seems likely that women with sexual trauma were thinking and reporting on the individual circumstances surrounding the sexual trauma, but we do not necessarily know this. Also, we cannot know what types of events the control group was reporting on. That said, it is perhaps unsurprising that women with sexual trauma remember the event as especially significant to their life story. These data may suggest that memories for stressful life events are more visually vivid and perhaps meaningful in women who have sexual trauma

when compared to women who do not have a similar history but are nonetheless reflecting on a stressful life event.

It was particularly striking that while women with sexual trauma reported more sensory and contextual details of the autobiographical event compared to controls, they did not report more emotion-laden details, as details of items such as "*reliving the event*" and "*feel the emotions that I felt then*" did not differ between groups. Furthermore, despite the fact that women with sexual trauma report a greater remembrance of the event and that this event is characterized by its setting, temporal and spatial layout, and auditory and visual vividness, the event does not necessarily fit "*a coherent story"* nor is it accompanied by a feeling of "*travel[ing] back to the time when it happened, that I am a subject in it again*." Therefore, women with sexual trauma reported on a past stressful event with more sensory and contextual detail but the memory did not follow a coherent narrative nor was it characterized by an emotion-laden setting. Furthermore, the vividness of the memory was not accompanied by re-experiencing emotions felt in the past during the event. And importantly, the memory was more temporally distant from the present as it was not characterized by a feeling of travelling back in time, as compared to the memory reported by controls. Despite the fact that women with sexual trauma view the most stressful event of their past as significant to their life story, and remember the event with temporal and spatial specificity and visual and auditory details, these women did not seem to relive the past event in an emotional or temporal way that was different from the memory of a past stressful event recalled by controls.

We were particularly interested in a putative relationship between rumination and autobiographical memory, and specifically how repeated thought processes potentially contribute to and perhaps exacerbate how a person recalls the trauma and what details she remembers. Indeed, women who reported more vivid details surrounding an autobiographical memory of the most stressful event from their past had a greater tendency to ruminate (Fig 4A). As shown in Fig 4A, we detected a strong correlation between ruminative thoughts and autobiographical memories of a stressful event, suggesting that those individuals who were engaging in more ruminative thoughts were also more likely to remember the stressful event with greater sensory and contextual detail but without engaging in mental time travel or remembering the event as a coherent narrative. These same

women were also frequently reliving past negative moods by brooding, reflecting on and analyzing them. The fact that ruminative thoughts are often negative in nature and include thoughts like "*thinking about how sad you feel*", "*thinking about your shortcomings, failings, and mistakes*" or "*analyzing events to understand why one feels depressed or unmotivated*," indicates that women who vividly recalled past autobiographical memories appeared to be thinking more negative thoughts. Furthermore, women with higher numbers of posttraumatic cognitions reported more details surrounding the autobiographical memory of a past stressful event (Fig 4B). Trauma-related cognitions assessed on the Posttraumatic Cognition Inventory are also particularly negative and measure the degree to which one identifies with thoughts like "*I have no future*," "*I feel isolated*" and "*I am adequate*." Given these associations among autobiographical memories, ruminations and trauma-related thoughts were purely correlational it is impossible to know whether women with past sexual trauma are thinking more frequently about the traumatic event specifically, and whether this particular event is recalled with greater vivid detail. We are not claiming that ruminations cause heightened recollections of autobiographical memories or exacerbate traumatic cognitions or vice versa. Even if the data suggests that women with trauma are not reliving emotions present during the past stressful event, it is vivid in time and space in a way that appears to be associated (though not necessarily responsible for) ruminative thoughts of feeling sad and trauma-related thoughts of feeling inadequate or isolated, thoughts which are clearly pathological and hinder healthy functioning in the present. We present these data as meaningful in that they provide evidence for a potentially connected constellation of cognitive, memorial and emotional symptoms surrounding sexual trauma.

Working memory is a learning process, which allows the brain to hold and manipulate information in short-term memory, usually in service of completing a cognitive task or skill. For this study, we used a relatively standard test of working memory developed by Engle and colleagues [40], as well as two tasks that required the participant to discriminate between two stimuli across time. During the working memory task, individuals were asked to replicate the spatial location and temporal order of squares that were presented. The other two tasks tested the ability to discriminate spatial details of two patterns across time. The Temporal Separation Task included a longer time interval

and tested a person's ability to hold the pattern in working memory across a longer temporal interval, while the Spatial Discrimination task required that the person discriminate between more complex spatial patterns. According to our analysis, there were no group differences in performance on any of the three working memory tasks. Women with sexual trauma did not significantly differ in performance accuracy on any of the tasks of temporal and spatial cognition compared to women with no history of sexual trauma. Thus, despite significant increases in memories for the temporal and spatial layout of a stressful event as well as the setting of the event (described above) and ruminations about the past, temporal and spatial processes associated with working memory remain intact and highly functional. We would suggest that these data indicate that memory processes affected by sexual trauma tend to involve trauma memories, *per se* and not more general cognitive processes.

Experiment 3: Temporal processes associated with sexual trauma

Introduction

Memories for stressful life events are obviously embedded in the context of space and time and thus, the "when" and "where" of a stressful memory may be especially significant for victims of trauma. Results from Experiments 1 and 2 are consistent with this idea because young adult women with sexual trauma reported stressful memories with enhanced sensory detail as well as heightened temporal and spatial details as compared to controls without a similar trauma history. Across all women, reflections about a stressful life event related to the degree of rumination; women who reported more sensory and contextual details reported more ruminative thoughts in general. Based on these results, we considered the possibility that these acts of reflection and ruminations into the past impinge on one's experience of time as it elapses in the present. More specifically, we hypothesized that women with a history of sexual trauma would perceive time as moving more slowly, in part, because they have learned through rumination and rehearsal to parse out sensory and contextual details of events in time, even those stored in memory. Although no studies of this nature exist in the literature, there is indirect support for a general relationship between subjective time and arousal/stress. For example, it has been reported that affective state (arousal + valence) can relate to either a slowing down or speeding up of one's internal clock. Namely, depressed mood is associated with a slowly down of one's clock or an underestimation of time [41] and women with sexual trauma did report significantly more depressive symptoms. However, others report that mild stress (public speaking) is related to an overestimation of time [42].

In this final experiment, we considered the possibility that excessive reflections about the past coupled with vivid recollections of time and place can alter one's subjective sense of time. Specifically, we hypothesized that women with sexual trauma would express behavioral differences in their estimation of subjective time compared to women who did not have a similar history. We did not anticipate a change in overall perception of time, i.e. real time sensitivity. To test this novel idea, we assessed subjective time estimation and sensitivity in college-aged women with (n=25) and without (n=75) sexual trauma. Time variables were assessed with the Temporal Bisection Task.

Temporal bisection task

The temporal bisection task is widely used to test temporal processing in animals (including pigeons, rats, chimpanzees) as well as in humans [43]. During the temporal bisection task, participants are presented with a visual stimulus (red circle on black background) on a computer screen. They are initially trained with twelve presentations of two stimulus durations (one presented for a shorter duration of 400ms, the other presented for a longer duration of 1600ms). After learning to distinguish the intervals, intermediate probe stimuli are presented at durations between the short and long anchors, in addition to the anchors themselves. Participants are then asked to classify the probes as being "short" (closer to the 400ms duration) or "long" (closer to the 1600ms duration) with a button press on the keyboard (Fig 6).

The temporal bisection point is most often used in two ways: 1) time sensivity and the 2) subjective time estimation. Time sensitivity is the degree to which a person is able to distinguish between two time intervals that are closely related in time but are still distinct. For example, a person who is more sensitive to time might be able to distinguish between 1 second and 3 second intervals, where as a person who is less sensitive to time might only be able to distinguish between time intervals that are farther apart in time, say 1 second and 5 seconds. Subjective time on the other hand refers to how one experiences the passing of time; that is, is time experienced as passing by slow or fast? In general, the ability to discriminate between two temporal intervals during the temporal bisection task becomes easier the farther apart the two durations are in time. However, when a shorter and longer time interval are compared against the interval exactly in the middle, the shorter interval is easier to discriminate from the middle interval than is the longer interval [44]. This is partially because the psychometric function follows a logarithmic curve, and the properties of temporal processing appear to obey Weber's law. Weber's law states that the size of the "just noticeable difference" in stimulus discrimination is a distance threshold that is proportional to the magnitude of the stimulus and is used to determine a participant's degree of temporal sensitivity. A larger Weber ratio value indicates a larger threshold of discriminative ability, and thus less temporal sensitivity

overall. The Weber ratio is computed as the proportion of long responses at 75% minus the proportion of long responses at 25% over the proprotion of long responses at 50%.

Subjective time is inferred from the "Point of Subjective Equality" or "bisection point." This measure is computed from the number of long responses, meaning how often the person thought the probe trial was closer to the longest stimulus than to the shortest stimulus. At the Point of Subjective Equality (or PSE) the participant is responding "short" and "long" with equal frequency. In general, humans tend to bisect at the arithmetic mean (the halfway point between short and long anchors) when the overall temporal spread of the durations is spaced linearly; whereas when the spread of the durations is smaller or spaced logarithmically, humans tend to bisect near the geometric mean (square root of the product between short and long stimulus durations) [45,46], but of course there are differences across individuals. In our temporal bisection task, the geometric mean fell at 800ms and the arithmetic mean fell at 1000ms with the probe trials spaced every 200ms between 400ms to 1600ms.

The temporal bisection task is often used to test time sensitivity in non-human animals. Gibbon was one of the first to propose that animals process temporal information logarithmically, namely that the error in time estimation increases as the intervals become longer in time [47–49]. Since then, multiple studies that have assessed temporal discrimination in pigeons, chimpanzees, and rats, and have found that animals use different behavioral approaches to discriminate time intervals and these behaviors are driven by a variety of potential mechanisms [49]. Typically, non-human animals are able to discriminate between short and long visual or auditory stimuli and bisect at the geometric mean [50] though this is not always the case [46]. Similar to humans, the spread of the temporal durations used in the task can affect the bisection point and overall behavior of the animal. For example, it was first reported in rats that the bisection point became shorter if the probe durations were spaced logarithmically compared to linearly [51], presumably because logarithmically-spaced intervals contain more shorter intervals, which are easier to distinguish from the mean of the intervals as compared to longer intervals. This would lead the animal to respond "long" more frequently and thus cause a shift in the bisection point towards the shorter anchor. Furthermore there appears to be a bias to respond "long" more frequently than "short" in temporal bisection tasks [45]. We chose

to use stimuli ranging between 400ms to 1600ms because durations of shorter temporal intervals are easier to distinguish compared to longer intervals in time (following Weber's Law as described above) with intervals exceeding one second as difficult to distinguish [44]. We also chose these parameters because they match those in numerous studies, including the one in which bisection point was longer in subjects with depressed mood [41].

We reported in Experiment 1 that women with sexual trauma report greater numbers of depressive and anxiety symptoms and have a greater tendency to ruminate (Fig 1). Furthermore, these symptoms are highly associated with one another (Fig 2). These data are consistent with previous studies indicating women with sexual trauma frequently can experience panic attacks and increased anxiety [52,53]. In the first two experiments, we determined that young adult women with sexual trauma had a greater tendency to ruminate about the past, while experiencing depressive symptoms and anxiety about the future. They also reported that their personal memories for stressful events were rich in sensory and contextual details related to space and time. Taken together, these results suggest that this type of trauma history may lead victims to "live in the past." As such, one might propose that their sense of time has slowed down in order to do this. Therefore, we hypothesized here that women with sexual trauma history would demonstrate differences in their estimation of subjective time, as reflected by their Point of Subjective Equality when compared to the same outcome measure in women without a similar history. In contrast, based on the literature and an estimated guess, we hypothesized that women with sexual trauma would not demonstrate a change in Weber's ratio, a measure of time sensitivity.

Method for Experiment 3

Participants (same as reported in Experiment 1)

Procedure

After providing informed consent and being assessed for trauma history with the structured interview, participants completed the temporal bisection task. After the full testing session, participants were debriefed and compensated ($20 or research credits). Study procedures were approved by the university's Institutional Review Board.

Temporal Bisection Task (TBT) was used to assess time sensitivity and subjective time. Participants are initially trained to discriminate between two different time durations presented as a red circle on a black computer screen. The durations are "short" (400ms) or "long" (1600ms) and the participant is instructed to press "z" or "m" following each presentation. (The letter is irrelevant and purposely meaningless). Each button press is followed by feedback as to whether or not the choice was correct. There are 12 training trials, 6 per anchor. After learning to distinguish the intervals, intermediate probe stimuli are presented at durations between the short and long anchors for 90 test trials. The presentation of stimuli during testing consists of two presentations of each anchor for 10 total blocks total along with one presentation of each intermediate probe duration (600ms, 800ms, 1000ms, 1200ms, 1400ms) per block (10 blocks of 9 stimuli each) (Fig 6). Participants are told that the task continues as before (they are not aware that probes of different temporal durations are being presented) and are asked to continue making a button press of either "z" or "m." They do not receive feedback during test trials. Participants must learn that the stimuli are being presented for different durations of time, and that the button presses likewise correspond to the two different time durations. The temporal bisection task yields a proportion of long responses (%) for each temporal duration as well as the point of subjective equality (bisection point) and a measure of time sensitivity (indexed with the Weber ratio). As mentioned above, the point of subjective equality is time where a participant responds "short" or "long" with equal frequency.

Results from Experiment 3

Data from the temporal bisection task yielded accurate responses per trial across the seven stimulus durations. A short response to time intervals of 400ms to 800ms was categorized as correct and a long response to intervals of 1200 to 1600ms was categorized as incorrect. Responses to the 1000ms interval were always categorized as correct because it was the arithmetic mean. Total correct responses across all 90 trials were calculated for an average accuracy score per participant. Participants were categorized according to their accuracy score as either above 75% (accurate) or below 75% (inaccurate) on test trials. A chi-square test was performed for group (trauma, controls) by accuracy

(accurate, inaccurate) to assess differences in accuracy on the temporal bisection task. Women with and without sexual trauma did not significantly differ on accuracy on test trials, $p > 0.05$ (ST: M=64.7%; controls: M=79.1%). However, 29 participants were omitted from analyses due to poor accuracy that did not allow for calculations of time measures on the temporal bisection data.

Data from the temporal bisection task is typically plotted as the proportion of long responses across time. A Repeated Measures Analysis of Variance (ANOVA) was performed to determine if the sexual trauma group differed from controls in their response across the various stimulus durations, either indicating durations as "long" (that is, closest to the anchor of 1600ms which participants were trained on) or "short" (as compared to the 400ms anchor). Women with sexual trauma and controls did not significantly differ in the proportion of long responses across temporal duration, $p < 0.05$ (Fig 7B).

A 4th degree polynomial curve of best fit was fitted to each person's individual data in order to yield measures of point of subjective equality (time of 50% long responses/50% short responses) and time sensitivity (indexed with the Weber ratio) (Fig 7D). There were no group differences in time sensitivity (i.e. Weber's ratio), $t(97) = 0.47$, $p > .05$; the sexual trauma group (n=22) demonstrated a sensitivity threshold of 440ms (SE=30ms) and controls (n=73) demonstrated a sensitivity threshold of 460ms (SE=20ms) (Fig 7A). Women with sexual trauma (n=24) significantly differed from controls (n=75) on their point of subjective equality; women with sexual trauma displayed a longer bisection point at 940ms (SE=45ms) compared to controls who bisected at 830ms (SE=20ms), $t(97) = -2.46$, $p < 0.05$ (Fig 7C). Differences in the bisection point indicated that the sexual trauma group tended to report more temporal durations as "short" (i.e., closer to 400ms) while controls reported more durations as "long" (i.e., closer to 1600ms). These data indicate that women with sexual trauma underestimated the duration of temporal stimuli overall compared to controls who overestimated the duration of temporal stimuli. In addition, these findings suggest that women with sexual trauma experience time as moving slower compared to women who do not have sexual trauma history, but do not differ on their ability to distinguish between temporal intervals in the sub-second range.

Temporal outcomes and psychological symptoms

Correlations assessed the relationships among time measures (point of subjective equality and time sensitivity) and self-reported measures of depression, anxiety, rumination and autobiographical memory details. Across the entire sample (n=95), poorer time sensitivity (indexed by a larger Weber ratio) was mildly correlated with greater numbers of anxiety symptoms (assessed with the Beck Anxiety Inventory) $r = 0.24$, $p < 0.05$, as well as greater numbers of ruminative thoughts (assessed with the Ruminative Responses Scale), $r = 0.22$, $p < 0.05$, and heightened details related to an autobiographical memory of the most stressful event from one's past (assessed with the Autobiographical Memory Questionnaire), $r = 0.22$, $p < 0.05$. No significant correlations were found between the point of subjective equality (bisection point) and self-report measures, $p > 0.05$. These data suggest that those participants who displayed poorer time sensitivity had a greater tendency to ruminate, were more anxious and also had more vivid recollections of an autobiographical memory of a past stressful event.

Discussion for Experiment 3

During Experiment 2, we established a relationship between ruminations and autobiographical memory, especially the time and place for stressful memories. During Experiment 3, we examined differences in subjective time and time sensitivity related to sexual trauma during young adulthood in college-aged women. The present study is the first to our knowledge to assess subjective time and time sensitivity in a population of women with sexual trauma. Women with sexual trauma consistently underestimated the duration of temporal stimuli, and significant differences were found at the point of subjective equality (Fig 7C-D). Underestimation of the duration of temporal intervals compared to clock time is generally thought to be indicative of experiencing time as moving slower, compared to overestimating time durations. Prior studies have found college students with depression show a longer bisection point compared to non-depressed students [41] as do individuals exposed to acute stress [54]. Chronic stress, on the other hand, has been associated with a decreased time sensitivity, but no differences in subjective time [55]; however, these data were from a sample of healthy adult men who did not show high scores of perceived stress. Studies on interval timing in clinical populations or even

populations that suffer from subthreshold numbers of psychological symptoms, like ours reported here, are far and few between. Even though the women with sexual trauma in our college sample did not meet clinical thresholds of mood or anxiety disorders, they still were experiencing a range of symptoms that encompassed a constellation of psychopathology. Women with sexual trauma reported significantly higher numbers of depressive and anxiety symptoms and ruminative thoughts (Fig 1) and thus it is perhaps unsurprising that these women had a longer bisection point (Fig 7C-D). We are careful not to over interpret these findings however, because others have reported indirect relationships between one's bisection point and *how one experiences time*.

The temporal bisection point was longer in women with trauma history, but their sensitivity to temporal intervals appears unaffected (Fig 7A). Across the entire sample temporal sensitivity was mildly associated with symptoms of anxiety, ruminative thoughts, and the vividness of autobiographical memories of the most stressful event from one's past. That is, those women who displayed poorer temporal sensitivity on the temporal bisection task also reported greater numbers of anxiety symptoms and ruminative thoughts. These data suggest that those participants who displayed poorer time sensitivity had a greater tendency to ruminate, were more anxious and also had more vivid recollections of an autobiographical memory of a past stressful event. However, it is hard to say how meaningful these relationships are given the small *rho* values. Furthermore, we are unable to determine whether time is somehow responsible for symptomatology or if the anxious or ruminative state of an individual causes differences in time sensitivity.

Whether a longer bisection point (or shorter bisection point) directly maps onto a "slowing down" or "speeding up" of one's internal clock is not well-established or necessarily widely-accepted. As outlined by Gorea (2011), our physiological system is made up of multiple clocks that are quite likely operating at different speeds, and interval timing tasks such as the temporal bisection only capture a window of these functions [56]. Furthermore, disentangling subjective time and time estimation is difficult. Still, several groups have attempted to understand how time is affected by one's affective state and the effects of affective states on timing have been investigated since the 1950s. For example, there is evidence that high arousal states speed up one's internal clock. The presence of electric shock can speed up one's processing of time in humans while not necessarily in-

fluencing time sensitivity [57]. A study conducted by Meck and colleagues in rats demonstrated that presenting rats with a continuous foot shock caused animals to overestimate a signal duration [54], and others report that humans overestimate a 5-second duration during a state of high arousal [58]. We did not include a physiological measure of arousal and thus cannot compare these prior findings to our results. Women with sexual trauma in our population did report significantly more anxiety symptoms compared to controls (Fig 1B), but the level of anxiety still fell within a low range. These caveats notwithstanding, underestimating time is generally associated with a greater proportion of "short" responses or a longer bisection point on the temporal bisection task. Such a response is thought to indicate that one's internal clock is slower relative to someone who overestimates time.

A person's internal clock is thought to behave according to scalar properties. That is, estimation error in subjective time increases proportionally as the time intervals get longer [49]. John Gibbon originally described these properties in his scalar expectancy theory of interval timing [47,48]. He proposed that humans and animals keep time according to a pacemaker and an accumulator. During a timed stimulus, a "pacemaker" emits pulses at a steady pace, which are accumulated by an "accumulator"; the longer the stimulus duration, the greater the number of pulses stored in the accumulator. The pacemaker and accumulator make up the internal "clock." In order to compare different temporal stimuli, the brain compares accumulated pulses held in working memory to previously accumulated pulses stored in long-term memory. The comparison of information from working memory and that stored in long-term memory ultimately determines the decision made by the animal, i.e., to push a lever for food or make a button press indicating temporal duration of the stimulus. These properties can be reflected in the brain as well, at least to the extent that neurons in the rodent brain fire according to scalar properties during tests of interval timing [49].

Time estimation studies in people with neurological disorders have helped to shed light on how the human brain keeps time. For example, deficits in timing have frequently been reported in people with Parkinson's disease. Namely, that these individuals have difficulty timing two different intervals contemporaneously and such that they overestimate shorter intervals and underestimate longer intervals [59]. However, a 2008 study by

Wearden and colleagues [60] tested temporal processes using multiple timing tasks in a population of patients with Parkinson's disease and concluded that patients did not differ from controls on processes of time, and suggested motor deficits inherent in the disease were predominately what accounted for deficits in timing reported in other studies. These results indicate the difficulty in teasing apart confounds like motor deficits in addition to arousal and attention when studying interval timing. Still, research on populations treated with pharmacological drugs has helped elucidate how the brain keeps time in the sub-second range [61]. There is evidence that scalar properties of interval timing in humans is modulated at least in part by oscillating cortical inputs to the striatum and to other regions of the basal ganglia, along dopaminergic and GABAergic pathways that also interact with cholinergic inputs to cortical regions [49].

It goes without saying that the study of subjective time is difficult but it becomes especially complicated as it interacts with processes of attention and arousal. For example, it is difficult to ascertain whether differences in timing across various populations reflect "state" changes in arousal (or even attention) or more general "trait" differences in mood. For example, people with moderate depression as assessed on the Beck Depressive Inventory [17] underestimated time durations of 400ms-1600ms during the temporal bisection task [41]. However intriguing, the change could simply reflect a decrease in attention, as is common during depressive episodes [62]. Conversely, increases in anxiety have been associated with an overestimation of time. But in at least one study, the stimuli were embedded in angry and/or fearful faces, which might simply enhance attention and thereby shorten the bisection point [62]. Of course, the contribution of temporal sensitivity can be significant and may impinge on subjective times estimations. For example and not unexpectedly, individuals with psychotic symptoms were less able to distinguish temporal intervals and were more likely to underestimate time [63].

While it would seem that a deficit in time sensitivity would necessarily alter subjective time estimation, it is not always the case. One study investigated time perception in relation to dissociation, a symptom that can occur during trauma [64]. This study did not recruit trauma participants but rather induced dissociation during a mirror task that required healthy young adults to stare at their own face in a mirror for 10 minutes. Participants performed a time estimation task before and after the mirror task

where they were required to press a button on a watch continuously at 5-sec intervals for 5-min. Following the mirror task they reported symptoms of dissociative states according to the Clinican Administered Dissociative States Scale [65]. Acoss the entire sample, dissociative symptoms were moderately associated with worse time estimation. Thus, a "break with reality" may reduce real time estimation. Interestingly, induced dissociation was not associated with either the slowing down or speeding up of subjective time [64].

The difficulty in picking apart the influence of attention, arousal and motor control on temporal processing is complicated, and these influences should not always be thought of as independent constructs [62]. Lake and colleagues (2016) propose that attention influences the pace of the accumulator and arousal is implicated in the opening and closing of the "switch" in the pacemaker-accumulator model thereby influencing the number of pulses that pass from the pacemaker to the accumulator [62]. Along this line of reasoning, people with greater anxiety are thought to emit pulses at a faster rate, thus accumulating more pulses in the accumulator and overestimating temporal durations overall; however, many of these findings utilize emotional stimuli with varying degrees of saliency and do not always control for attentional differences due to the perceptual features of stimuli [62]. While prior literature on the influences of emotion and mood on temporal processing have manipulated the valence and arousal of stimuli, less is known about temporal processing in various clinical populations as mentioned above. Still, some studies have found that people with severe anxiety disorders like spider phobia or social anxiety disorder overestimate the time presentation of negative events [66–68], presumably due to a speeding up of their internal clock. Less is known about brain mechanisms underlying interval timing in trauma populations.

In the present set of studies, the trauma participants were able to discriminate temporal intervals as well as the controls and yet they still had a much longer bisection point. Also they were perfectly able to complete the working memory tasks and did so without any changes when compared to the controls. Based on these data, we have no reason to believe they were not paying attention and thus underesimated time because of it.

General Discussion

Data from three experiments were presented. In the first experiment we tested depressive, anxiety and trauma-related symptoms and ruminative thoughts in women with and without sexual trauma. Women with sexual trauma reported significantly more depressive, anxious, and trauma-related symptoms, as well as ruminative thoughts when compared to those measures in controls (Fig 1). Furthermore, these symptoms are highly associated with one another (Fig 2). In the second experiment we examined memory-related outcomes associated with sexual trauma. Women with sexual trauma reported greater numbers of details related to an autobiographical memory of their most stressful event in the past (Fig 3). These details were especially related to the temporal and spatial context of the memory and were punctuated by heightened auditory and visual details compared to women without sexual trauma though the memory lacked temporal coherence. Furthermore, women with sexual trauma considered the memory as more central to one's life story compared to women without sexual trauma. Those women who reported more vivid details surrounding an autobiographical memory of the most stressful event from their past also had a greater tendency to ruminate (Fig 4A) and reported higher numbers of posttraumatic cognitions (Fig 4B). In the third experiment, we examined differences in subjective time and time sensitivity related to sexual trauma during young adulthood in college-aged women with and without sexual trauma with the temporal bisection task. Women with sexual trauma consistently underestimated the duration of temporal stimuli, and significant differences were found at the point of subjective equality (Fig 7D). The present study is the first to our knowledge to assess subjective time and time sensitivity in a population of women with sexual trauma. Together these studies are the first to demonstrate that women with sexual trauma ruminate more often, suffer from symptoms of depression, anxiety and trauma, and recall past stressful events with heightened vividness as compared to women without sexual trauma history. While autobiographical memories appeared to be remembered with greater detail in women with sexual trauma history, other memory-related processes related to temporal and spatial cognition do not seem to be affected by sexual trauma. Finally and importantly, women with sexual trauma appeared to process time differently, by underestimating time as it passes and

thereby experiencing time as moving more slowly compared to controls without a similar history.

These results on autobiographical memories and trauma are particularly enlightening given current debates over how trauma affects memory-related processes that have gone back several decades. For example, it is often reported that fearful memories are disrupted and therefore are recalled in a disjointed manner or even some parts of the memory are inaccessible [31]. Sometimes the trauma memory returns to the victim as an incoherent narrative days or even weeks after the event occurred coupled with feelings of self-blame and confusion [7,33]. It appears that much of the research on trauma and memory differs depending on the age at which the abuse occurred. Those who have studied childhood sexual abuse victims report these individuals oftentimes dissociate from the event, display a disrupted sense of self and have difficulty remembering what happened during the abuse [69]. Given the differences in child and adult victims of sexual trauma, we chose only to include women who had experienced an event past puberty. In adults at least, the evidence appears to be clear that the trauma memories are actually recalled with great vividness and is not necessarily encoded by different mechanisms than other types of memory [34]. Specifically central aspects of the trauma are typically encoded well, and emotional memories, particularly ones that induce great stress to the system are remembered well [34,70]. Our data supports this view as women with sexual violence history tended to remember a past stressful event with greater vividness of sensory and contextual details (Fig 3B).

While it is impossible to recreate in a laboratory setting what actually occurs physiologically during a traumatic event, scientists have posited theories about how the trauma memory manifests in the body based on self-reports from survivors. A combination of heightened physiological state coupled with a robust emotional memory might cause the person to experience flashbacks to the point where she might relive the event repeatedly into the future, and re-experiencing is a key symptom of PTSD that exacerbates healthy functioning in the present. In these instances, hyperarousal can persist, thereby impairing functioning in the future, to the point at which the person perceives unexpected (though affectively neutral) stimuli in the present moment as triggering the fear memory and thereby threatening [9]. This can lead one to overgeneralize, associating

the horror and fear from the precipitating event with similar events in the past, as well as projecting that fear into the present and future context [32]. The overgeneralization of fear has been replicated in the laboratory setting, such that a person's memory of a neutral stimulus can become strengthened if it is related to events that were paired with shock during fear conditioning, even though the stimulus itself wasn't initially feared [71]. This provides evidence for how previously neutral information acquires affective value through its association with a feared stimulus, in a way that might potentially cause a person to fear the non-threatening stimulus in the future. Furthermore, details surrounding the event, such as sounds or visual details of what happened before the event, might later come back to the person if they were encoded during the traumatic event, and become associated with the feared stimulus itself. Similar processes of stimulus generalization were first reported in early animal studies, wherein an animal learns to fear a variety of stimuli or contexts that were previously not presented or associated with the feared stimulus [72,73]. Along the same lines, multiple studies have investigated the overgeneralization of memory for positive and negative experiences (unrelated to the traumatic event) in trauma populations. Overall, evidence points to the fact that trauma survivors tend to overgeneralize past negative autobiographical memories (and even positive memories) which can exacerbate mood-related symptoms into the future; however, these tendencies might differ depending on the degree of trauma-related symptoms that manifest following the traumatic event [74,75]. And still, this is not necessarily always the case, as one study found that adult women with sexual trauma did not report past autobiographical events or future-directed thoughts with any less (or more) specificity compared to no-trauma controls [76]. These findings are support by our data as we also found that women with sexual trauma do not overgeneralize autobiographical memories but rather report the event with *greater* sensory and contextual detail (Fig 3). Others have shown that ruminative thoughts might account for the overgeneralization of past autobiographical memories in a population of people with moderate to high depression (as assessed by the Beck Depression Inventory) [77]. While we did report that women with sexual trauma were moderately depressed and also had a greater tendency to ruminate, we did not find that these women overgeneralized their autobiograhical memory. In fact it was just the opposite, as these women reported the event with greater

detail than controls (Fig 3). Several of the studies that report a relationship between trauma and the overgeneralization of memory are in populations very different than ours, such as combat-related PTSD populations [78] or depressed populations without trauma [77]. It should be noted that the overgeneralization of autobiographical memories might be related to childhood sexual abuse, as young adult females with childhood sexual abuse history reported less specific positive and negative autobiographical memories compared to young adult females without a similar history [79]. Thus, perhaps much of the research on overgeneralization of autobiographical memory and trauma can be accounted for by when the abusive event occurred, similar to other research findings on how the traumatic memory is encoded with less specificity and in a disjointed manner in childhood sexual abuse survivors. Our study with adult women who experienced sexual trauma during young adulthood indicates memory-related processes, particularly those involving memories of the self and of a stressful nature, are in fact not overgeneralized but rather distinct in visual and auditory detail and specifically positioned in space and time. These heightened details are associated with traumatic cognitions and ruminative thoughts, both of which are quite negative and maladaptive in nature.

We were also interested in potential differences related to sexual trauma between the detailed recollection of autobiographical memories compared to other memory-related abilities like temporal and spatial cognition. Our findings that women with sexual trauma did not differ from controls on working memory is supported by others who found no differences on tests of working memory and cognitive flexibility (using digit-span and card-sorting tasks) among college students with and without PTSD related to interpersonal trauma and no-trauma controls [80]. However, that study included both female and male participants who had experienced childhood abuse across a broad spectrum of severity ranging from emotional abuse and physical neglect to sexual abuse, while our study only focused on sexual abuse in women during young adulthood. Nevertheless it appears that the lack of differences in working memory ability in all of these individuals, even some of whom had trauma history, might be due to the fact that these students are enrolled in school and thus may be considered more or less high functioning.

It should be noted that from the data reported in Experiments 1 and 2 it is difficult to tease apart those symptoms related to trauma exposure more generally and those related specifically to sexual trauma. Given that the sexual trauma group did not meet clinical threshold for Mood or Anxiety Disorders, it is not necessarily surprisingly that they did not differ significantly from other individuals exposed to a traumatic event other than sexual violence on depressive and anxiety symptoms and ruminative thoughts. Some of the trauma-exposed individuals experienced interpersonal trauma such as physical assault, which can also be associated with high numbers of PTSD symptoms, substance abuse, and anxiety and depression, approaching those found in victims of sexual assault [81]. Still as reported, posttraumatic cognitions were significantly higher in the sexual trauma group compared to the group exposed to trauma other than sexual trauma as well as no-trauma controls, suggesting that the experience of sexual trauma is uniquely followed by negative cognitions about the self and the world that disrupt healthy functioning.

Sexual trauma and the female brain

Sexual trauma has been associated with neural processes in a number of brain regions implicated in stress and learning to respond to stressful life experience [10]. For example, the hippocampus is often implicated because it is involved in the repeated acquisition of newly acquired memories, and incorporating this new information with existing memories of the self in place and time [82–84]. It is evident from animal studies that the hippocampus is necessary for modulating learning following an acutely stressful event, such that males learn a delay conditioning task with an intact hippocampus, but females do not following stress [85]. Recently, it was reported that state-dependent fear is mediated by inhibitory activity within the mouse hippocampus, which *enables* the encoding and retrieval of the fear memory [86]. It has been reported that the hippocampus exhibits “hypersynchrony” (i.e. poor signal variability) during MEG in a group of PTSD patients [87]. With fMRI, investigators reported that humans with PTSD (predominately related to physical or sexual assault) have an impaired ability to recall an extinguished fear memory several days after the event and this is characterized by less BOLD response in the hippocampus, compared to trauma-exposed subjects without PTSD [88]. Women

with assault-related PTSD demonstrate greater functional connectivity between the right amygdala and right hippocampus during exposure to a trauma memory as compared to a neutral control script [89], and decreased functional connectivity between the prefrontal cortex and amygdala compared to trauma-exposed women without PTSD [90]. Therefore, it is unsurprising that the human hippocampus would be impacted by a traumatic event. Still, while abnormalities in brain structure and function have been found in women with trauma exposure, this is not always the case. The number of studies that have examined potential alterations in brain function as a result of sexual trauma is far and few between, and it is difficult to disassociate differences in brain function due to the trauma itself from preexisting abnormalities [91,92].

The hippocampus is also involved in processes of rumination, which may mediate the relationship among self-reported stressful life events and depressive and anxiety symptoms in young adults [21]. It is generally accepted that ruminations interfere with the "normal" processing capacity of the hippocampus, a brain region necessary for acquisition of autobiographical memories. The encoding of spatial information is highly specific in the hippocampus and these spatial representations inform the recent and remote episodic memories dependent on the hippocampus [93]. In addition to integrating the spatial and temporal properties of episodic memory, the human hippocampus is involved in learning about time [83,84]. It has been reported that specific time cells in the mammalian hippocampus integrate spatial and temporal information and encode the information in a highly temporally specific way that directly implicates how episodic memories are stored in the mammalian brain [84]. Furthermore, studies on the local field potentials of CA3 and CA1 areas of the hippocampus are spatially and temporally coordinated that allows information to travel to distributed networks that support memory consolidation; these hippocampal "sharp wave-ripples" might serve as a cognitive biomarker for episodic memory [94]. Current hypotheses of how time is processed in the brain often refer to the striatal beat frequency (SBF) model of timing. These theories are primarily informed by animal studies as they are difficult to test in the human brain.

Along those lines, our lab recently developed an animal model to test the effects of sexual aggression on the female brain and more specifically, how these behaviors might disrupt processes of learning about time in female rats. The animal model is named Sexual

Conspecific Aggressive Response or SCAR [95]. During each SCAR episode, a sexually-experienced adult male is placed in the cage with a pubescent female rat for 30 min. During the social interaction, the adult male continuously chases the female around the cage, sniffing and tracking her ano-genital region while attempting to and oftentimes pinning her down. Corticosterone concentrations were significantly elevated in the female after these interactions, and furthermore, the female did not learn as well on a timing task [95]. The timing task was trace eyeblink conditioning, wherein the animal learns to associate an auditory stimulus with an unconditioned stimulus of eyelid stimulation, separated by a trace interval of 500ms. Learning to associate stimuli across time is dependent on new cells in the dentate gyrus of the hippocampus [96]. These data provide evidence as to how behaviors like sexual aggression can disrupt learning processes related to time in the female brain. While it is impossible to measure neurogenesis in the living human brain, these findings from animal studies serve as a model for how timing processes in women might become potentially disrupted following a sexually traumatic event. In an effort to understand the neural mechanisms of temporal processing and potentially find a neural biomarker of trauma, our lab is currently investigating the neural mechanisms of temporal processing using EEG during the temporal bisection task among healthy participants and those with trauma exposure due to sexual violence.

Figures

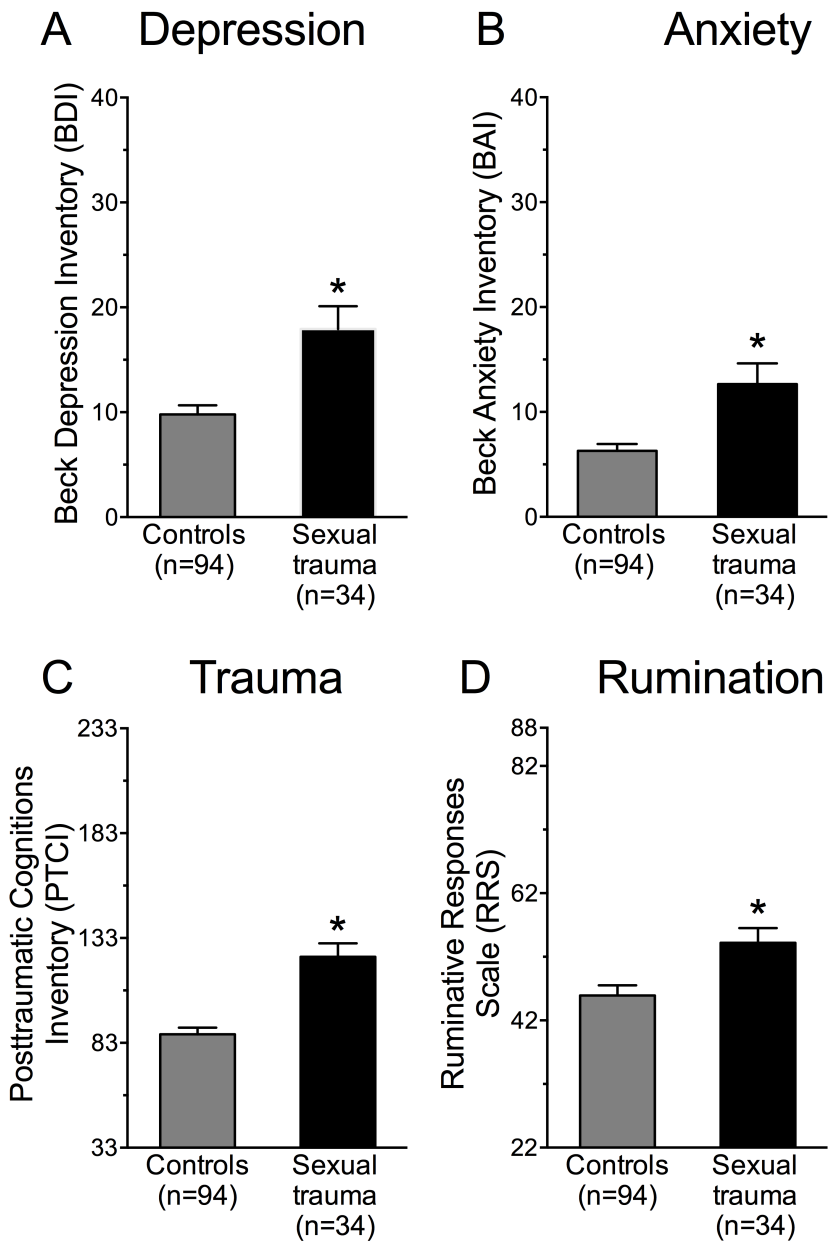

Fig 1. (A) Women with sexual trauma reported significantly more depressive symptoms as assessed by the Beck Depression Inventory (BDI), (B) greater numbers of anxiety symptoms as assessed by the Beck Anxiety Inventory (BAI), (C) more posttraumatic cognitions as assessed by the Posttraumatic Cognitions Inventory (PTCI), and (D) greater numbers of ruminative thoughts as assessed by the Ruminative Responses Scale (RRS) compared to college women with no sexual trauma history.

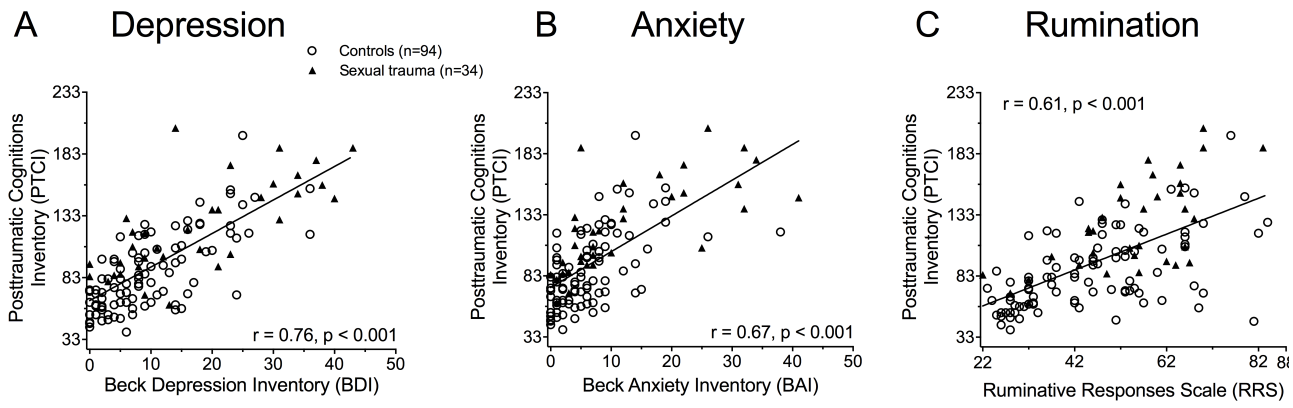

Fig 2. (A) Posttraumatic cognitions as assessed by Posttraumatic Cognitions Inventory (PTCI) significantly correlated with depressive symptoms as assessed by the Beck Depression Inventory (BDI), (B) anxiety symptoms as assessed by the Beck Anxiety Inventory (BAI) and (C) ruminative thoughts as assessed by the Ruminative Responses Scale (RRS) across all participants (n=128).

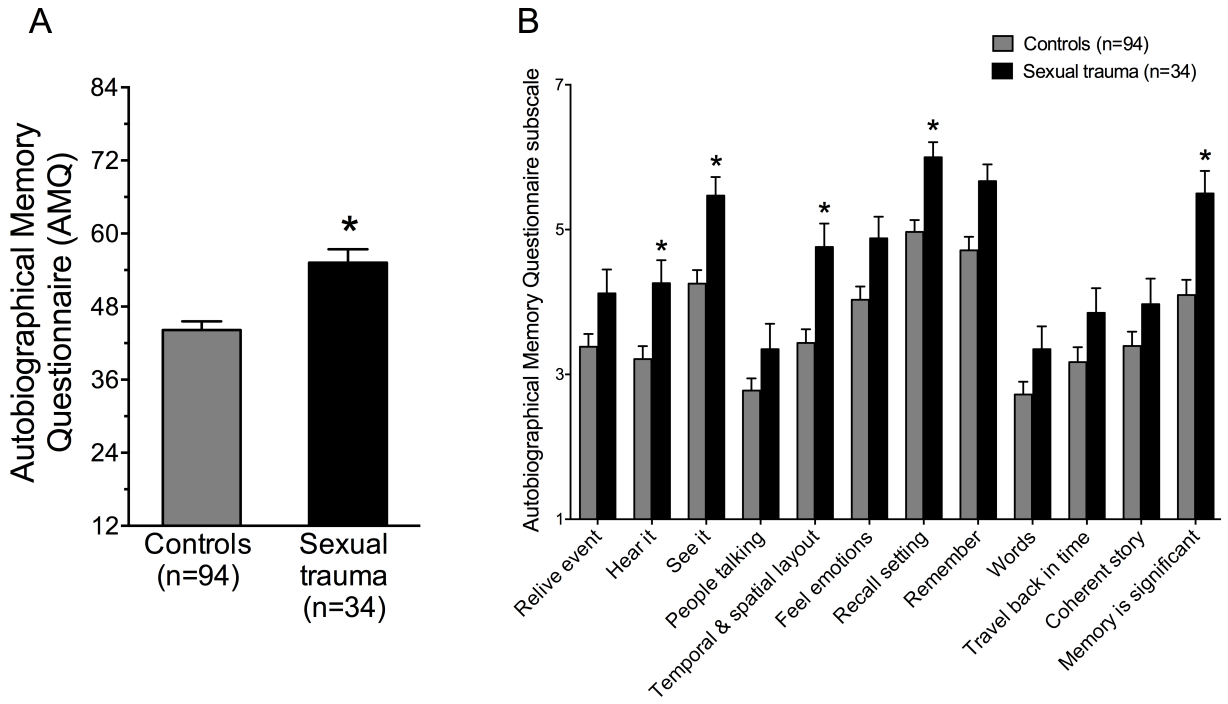

Fig 3. (A) Women with sexual trauma reported significantly more details of an autobiographical memory of the most stressful event from one's past compared to women with no sexual trauma as assessed by the Autobiographical Memory Questionnaire (AMQ). Average reported scores on 12 items of the AMQ were also analyzed. (B) Women with sexual trauma reported significantly more auditory, visual, temporal and spatial details related to the memory, recalled the setting to a greater degree and also reported greater significance of the memory in their life compared women with no sexual trauma.

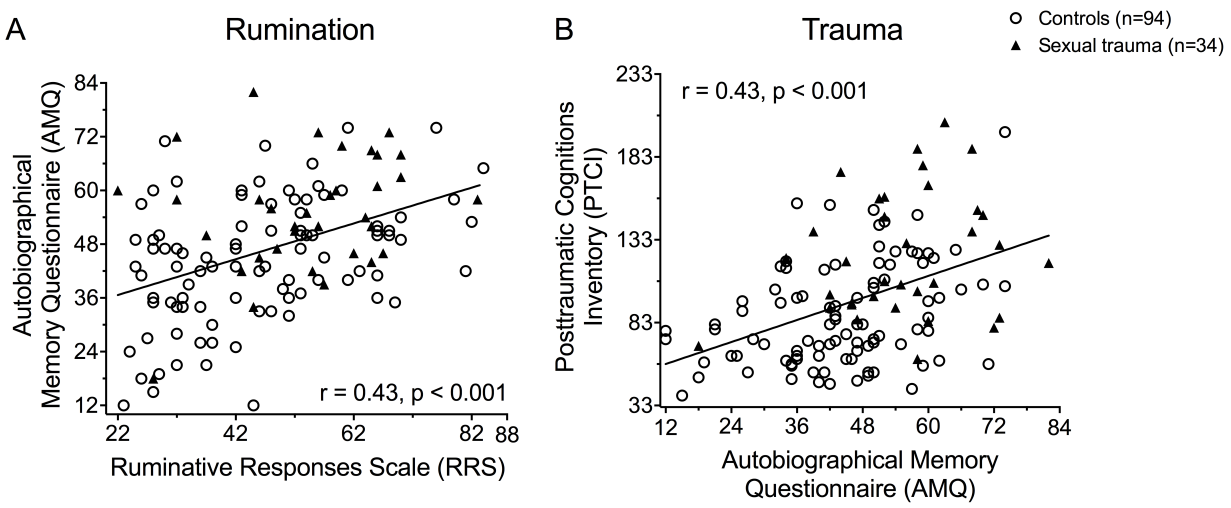

Fig 4. (A) Greater number of details of an autobiographical memory of the most stressful event assessed by the Autobiographical Memory Questionnaire (AMQ) significantly correlated with greater numbers of ruminative thoughts assessed by the Ruminative Responses Scale (RRS) and (B) posttraumatic cognitions as assessed by Posttraumatic Cognitions Inventory (PTCI) across all participants (n=128).

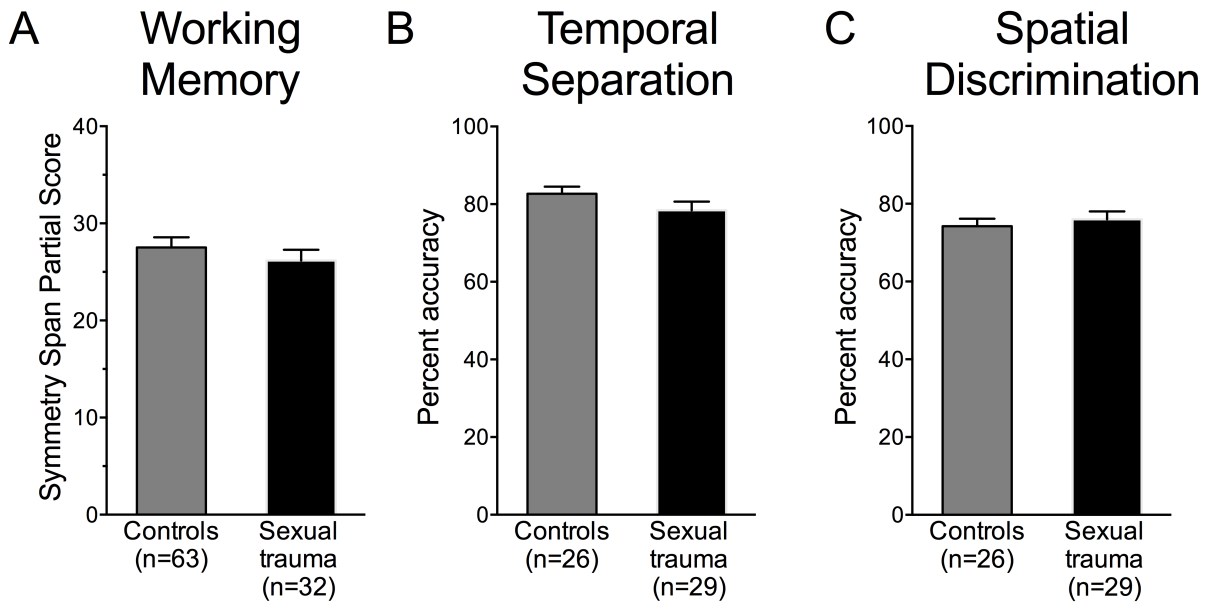

Fig 5. (A) Women with sexual trauma did not significantly differ from women without sexual trauma on partial accuracy scores on a task of working memory or on performance accuracy (%) on tasks of (B) temporal separation or (C) spatial discrimination.

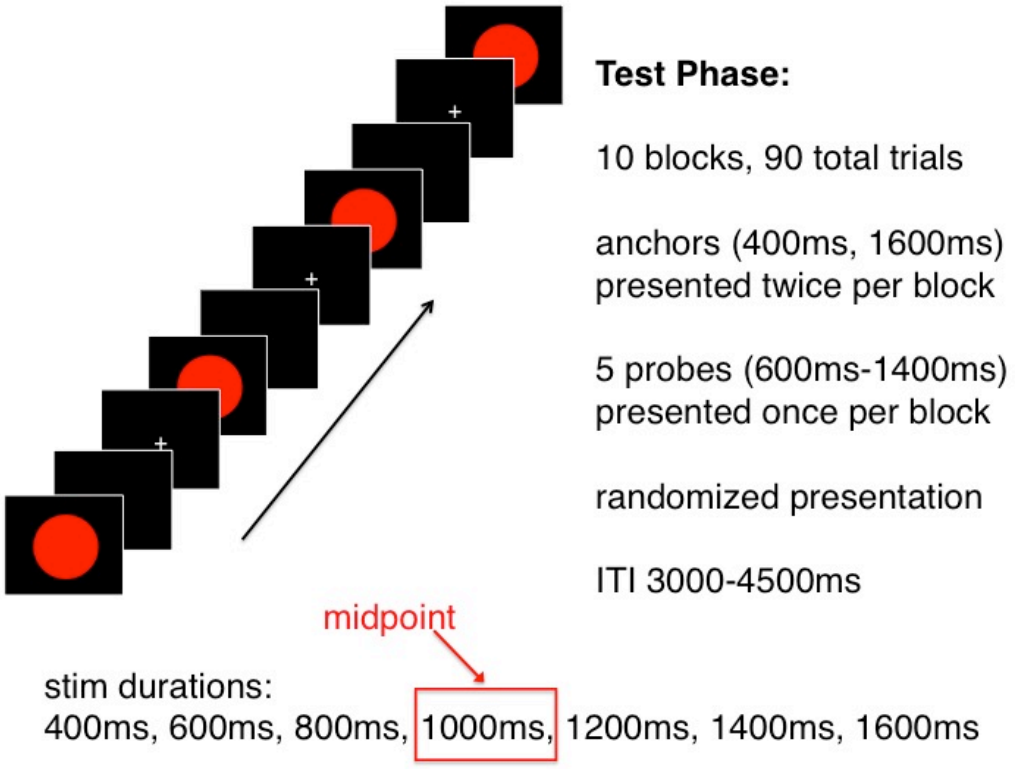

Fig 6. During the temporal bisection task, participants are presented with a visual stimulus (red circle on black background) on a computer screen. They are initially trained with twelve presentations of two stimulus durations (one presented for a shorter duration of 400ms, the other presented for a longer duration of 1600ms). After learning to distinguish the intervals, intermediate probe stimuli are presented at durations between the short and long anchors, in addition to the anchors themselves. Participants are then asked to classify the probes as being "short" (closer to the 400ms duration) or "long" (closer to the 1600ms duration) with a button press on the keyboard.

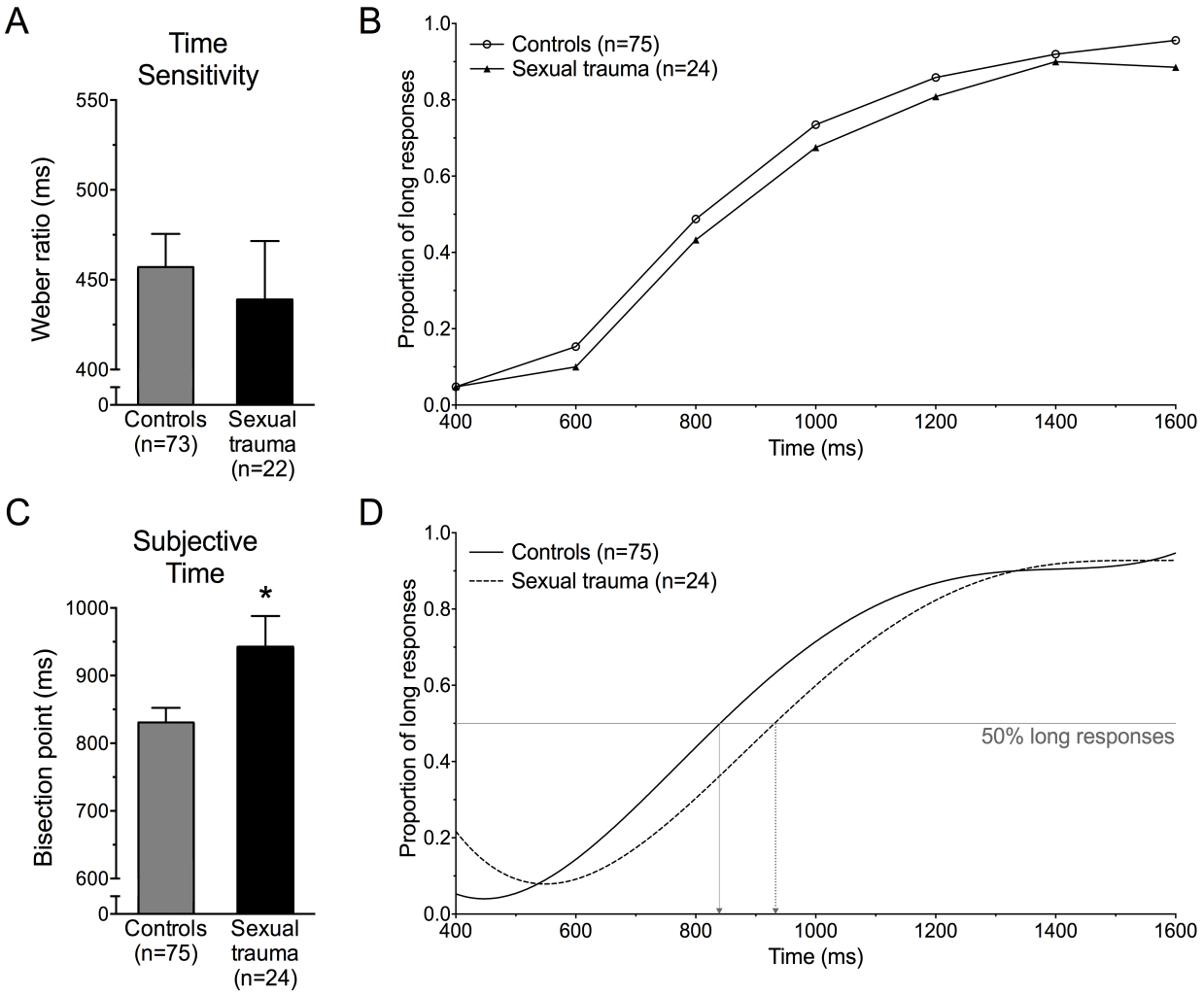

Fig 7. (A) Women with sexual trauma did not differ on time sensitivity (indexed with Weber ratio) compared to women with no sexual trauma history, (B) nor did groups significantly differ on the proportion of long responses plotted across time, though women with sexual trauma tended to underestimate temporal durations as compared to controls with no sexual trauma history. (C) Women with sexual trauma demonstrated a significantly longer point of subjective equality compared to women with no sexual trauma. (D) A 4th degree polynomial curve of best fit was fitted to each person's individual data in order to yield time measures of subjective time and time sensitivity.

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