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Moderating Effects of Sleep Difficulties on Relations between Posttraumatic Stress Disorder Symptoms and Positive Memory Count

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Abstract

Objectives.—Posttraumatic stress disorder (PTSD) severity relates to positive memory retrieval difficulties. One variable potentially influencing this relation is sleep difficulties. We examined moderating effects of sleep difficulties (duration and quality) on relations between PTSD severity and count of specific positive memories covarying for age, gender, and depression.

Methods.—Participants were an Amazon Mechanical Turk-recruited trauma-exposed community sample of 205 respondents (M_{age}=35.44; 61.40% women).

Results.—Moderated regression analyses indicated significant interaction effects between sleep quality (b=.03; p=.036) and PTSD severity on specific positive memory count. Among individuals reporting better sleep quality, there were negative associations between PTSD severity and specific positive memory count (b=−0.04, SE=0.02, p=.010). Similar results were obtained for PTSD's intrusion and arousal clusters.

Conclusion.—Results support targeting sleep quality and PTSD severity to improve positive memory retrieval in PTSD and memory interventions, and the importance of considering sleep when examining links between PTSD and positive memory retrieval.

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Data Availability Statement. Data that support current study findings are available from the corresponding author (A.A.C) upon reasonable request.

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Keywords

Count of specific positive memories; posttraumatic stress disorder; sleep; moderation analyses; trauma-exposed community sample

Introduction

In contrast to the widely examined traumatic memories that characterize posttraumatic stress disorder (PTSD; Brewin & Holmes, 2003), positive memories reference meaningful experiences with favorable consequences (Bernsten, 2001). Emerging evidence indicates that the etiology and exacerbation of PTSD symptoms is associated with deficits in positive memory retrieval (Bryant et al., 2007; Contractor et al., 2018; Hauer et al., 2009). Yet, there is a limited understanding and examination of factors that may influence this relation (Contractor et al., 2021). A variable worth investigating is sleep difficulties, given that short sleep duration and poor sleep quality are associated with both PTSD (Germain, 2013) and memory processes (reviewed in Walker & Stickgold, 2006). In this regard, we examined if the nature and strength of the PTSD-positive memory relation depended on sleep duration and sleep quality.

PTSD and Positive Memories

PTSD, as a diagnostic construct, entails symptoms of intrusions, avoidance of traumatic reminders, negative alterations in cognitions and mood (NACM), and alterations in arousal and reactivity (AAR; American Psychiatric Association, 2013). Broadly, experimental and neurobiological research supports memory encoding and retrieval deficits among individuals with PTSD symptoms (Brewin, 2014; Brewin et al., 2007; Hayes et al., 2011; Johnsen & Asbjornsen, 2008). Beyond traumatic memories, positive memory retrieval difficulties relate to PTSD's etiology, maintenance, and severity (Bryant et al., 2007; Contractor et al., 2018; Contractor, Greene, et al., 2020; Hauer et al., 2009). Perhaps, biased attention towards negatively valenced information (Fani et al., 2012), a tendency to focus on negative and traumatic memories (Sutherland & Bryant, 2005), and emotional numbing and dysregulation processes (Contractor et al., 2021; Litz et al., 2000) may contribute to difficulties retrieving specific positive memories among trauma-exposed individuals with PTSD symptoms (Sutherland & Bryant, 2005; Wingenfeld et al., 2013).

Notably, empirical (Contractor, Banducci, et al., 2020; Contractor et al., in press), theoretical (Contractor et al., 2018), and intervention (Moradi et al., 2014) literature supports that accessing and processing specific positive memories decreases PTSD symptom severity and improves mood. In this vein, research has shown that retrieving positive memories following a stressor is associated with a dampened cortisol response and more activity in brain areas related to effective emotion regulation (Speer & Delgado, 2017). Despite this research indicating associations between PTSD and positive memories, as well as an interest in discussing positive memories by clinicians (Contractor, Caldas, et al., 2020) and trauma-exposed clients (Caldas et al., 2020), existing PTSD interventions primarily target traumatic memories (Contractor, Weiss, Forkus, et al., 2020). Although such interventions effectively treat PTSD (Schnurr, 2017), they have low retention rates and are not effective for all clients

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(Garcia et al., 2011; Hembree et al., 2003; Resick et al., 2002). Hence, processing positive memories may be a promising intervention target for trauma-exposed individuals who do not benefit from or prefer interventions that primarily target traumatic memories (Contractor, Weiss, & Shea, 2020). To promote such research, we need to examine contextual factors that may influence relations between PTSD and positive memory retrieval; an important variable for consideration is sleep difficulties for reasons elaborated below.

PTSD and Sleep Difficulties

Sleep difficulties are important features differentiating individuals with vs. without PTSD (Breen et al., 2019), and predict PTSD following traumatic experiences (Babson & Feldner, 2010). Indeed, individuals with PTSD symptoms experience shorter sleep duration (Krakow, Melendrez, et al., 2001), as well as other sleep disturbances such as insomnia and nightmares (Kobayashi et al., 2007; Taylor et al., 2016). The sleep architecture profile (i.e., structure and physiology of sleep) among individuals with PTSD indicates a tendency for less restorative sleep and greater sleep deprivation (Kobayashi et al., 2007), both of which interfere with the processing of traumatic memories. Consistent with a negative reinforcement perspective, individuals with PTSD symptoms perceive nighttime awakenings and subsequent arousal as protective to avoid distressing trauma stimuli in nightmares (Krakow, Hollifield, et al., 2001), and to avoid feared loss of control during sleep (Harvey et al., 2003). Such beliefs may maintain vigilance and lower awakening thresholds during sleep (Kramer & Kinney, 2003). From a neuro-biological perspective, individuals with PTSD experience heightened sensitivity of the noradrenergic system (Pillar et al., 2000), heightened amygdala activity, and impaired medial prefrontal cortex functioning (Germain et al., 2008), all of which may impair sleep. Lastly, individuals with PTSD symptoms may engage in less physical activity (Vancampfort et al., 2016) and may experience comorbid conditions such as substance use (Schierenbeck et al., 2008); each of these factors has been associated with impaired sleep (Feige et al., 2006; Kredlow et al., 2015). Relatedly, sleep disturbances may relate to poor daytime coping, which, in turn, may contribute to greater post-traumatic distress (Harvey et al., 2003).

Positive Memories and Sleep Difficulties

Sleep impacts the encoding, stabilization, enhancement, and reconsolidation of new and old memories, including autobiographical memories (reviewed in Spencer et al., 2017; Walker & Stickgold, 2006) that shape one’s identity (Conway et al., 2004). This process is known as sleep-dependent memory processing (Walker, 2008). Impacts of sleep duration and quality on memory processes may occur via changes in neuronal plasticity (Walker & Stickgold, 2006), altered hippocampal activity (Yoo et al., 2007), deficits in cortical regions critical for learning and memory (Deak & Stickgold, 2010), and fragmentation of slow wave sleep (SWS) and rapid eye movement (REM) sleep (Walker, 2008; Walker & Stickgold, 2006). Cognitive consequences of sleep difficulties, such as deficits in executive functioning, attention, and working memory (Deak & Stickgold, 2010), may contribute to impaired ability to encode and retrieve autobiographical memories (Ros et al., 2009; Williams et al., 2007).

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Relevant to the current study, sleep difficulties such as shorter sleep duration may interfere with the encoding, consolidation, and retrieval of positive memories, as well as the integration of corrective information (even from positive memories) into traumatic memories (Krakow, Hollifield, et al., 2001; Pace-Schott et al., 2015). For example, Walker and Stickgold (2006) showed that sleep-deprived participants demonstrated reduced encoding and retrieval of positive words; Zare Khormizi et al. (2019) demonstrated that sleep-deprived vs. well-rested participants remembered fewer positive and more negative autobiographical memories; Gujar et al. (2011) demonstrated that sleep-deprived participants had a bias in the number of stimuli rated as emotionally pleasant; and Chambers and Payne (2014) demonstrated that sleep enhanced memory for positive objects and REM latency was related to a decline in positive memory consolidation. Relatedly, Barry et al. (2019) found that shorter sleep duration was associated with reduced count of specific memories; notably, this study did not differentiate between positive and negative memories. Further, poor sleep quality has been shown to relate to less positive affect (Bower et al., 2010), which, consistent with the mood-congruency hypothesis (Bower, 1981), may lessen positive memory retrieval.

Current Study

Drawing from the aforementioned research, sleep difficulties may influence relations between PTSD symptom severity and count of retrieved specific positive memories. Individuals with both greater PTSD symptom severity and more sleep difficulties may retrieve fewer specific positive memories than those experiencing greater PTSD symptom severity but fewer sleep difficulties. At the same time, those with lower PTSD symptom severity and fewer sleep difficulties may retrieve more specific positive memories than those experiencing lower PTSD symptom severity but more sleep difficulties. Such trends are attributed to the beneficial impacts of sleep on the memory retrieval and consolidation processes (reviewed in Spencer et al., 2017; Walker & Stickgold, 2006). To this end and unique to the existing literature, we examined main and moderating effects of sleep difficulties (sleep duration and quality) on relations between PTSD symptom severity and specific positive memory count.

We hypothesized significant negative associations (i.e., main effects) between (1) PTSD symptom severity and specific positive memory count, and (2) sleep difficulties and specific positive memory count. Next, we hypothesized amplifying moderating effects of sleep duration and quality on relations between PTSD symptom severity and specific positive memory count. Specifically, we expected stronger and significant negative associations between PTSD symptom severity and specific positive memory count at higher (vs. lower) levels of sleep difficulties (i.e., among individuals reporting shorter sleep duration and poorer sleep quality). As exploratory analyses, we examined study research questions for each PTSD symptom cluster such as intrusions, avoidance, NACM, AAR drawing from limited research indicating differential relations of PTSD symptom clusters with positive memory retrieval (Contractor et al., 2019; Contractor, Greene, et al., 2020). Evidence suggests significant relations of age, gender, and depression with PTSD (Norris et al., 2002; Rytwinski et al., 2013; Tolin & Breslau, 2007), sleep difficulties (Grandner et al., 2012; Krishnan & Collop, 2006; Tsuno et al., 2005), and positive memory retrieval (Bryant et al., 2007; Dijkstra & Kaup, 2005; Seidlitz & Diener, 1998). Thus, we included age,

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gender, and depression severity as covariates in the models. Results from this study will add to an understanding of the relationship between PTSD and positive memory retrieval, with potential implications to include a sleep component for PTSD and memory-based interventions.

Method

Procedure and Participants

The study was approved by the University of North Texas Institutional Review Board. Using the Amazon Mechanical Turk (MTurk) crowd-sourcing platform, we recruited participants who were 18 years and older, reported English language fluency, endorsed a stressful life experience, and reported no sleep apnea diagnosis. Participants who provided informed consent and completed the survey received $1.50. In total, 695 participants attempted the survey; we excluded 299 duplicate responses attributed to multiple attempts. Of the remaining 466 participants, we excluded 89 participants for not meeting inclusion benchmarks, 138 participants who failed attention and comprehension validity checks, 31 participants who did not endorse any/worst traumatic event on the Life Events Checklist for *DSM-5* (LEC-5; Weathers, Blake, et al., 2013), and three participants who missed > 30% item-level data on study's primary measures. The final sample included 205 individuals who averaged 35.44 years of age (*SD* = 11.40); 126 were female (61.50%). Ninety-one (44.40%) participants had probable PTSD based on the PTSD Checklist for *DSM-5* (PCL-5; Weathers, Litz, et al., 2013) cut-off score > 31 (Wortmann et al., 2016). Table 1 has detailed demographic information.

Measures

Life Events Checklist for DSM-5 (LEC-5; Weathers, Blake, et al., 2013). The LEC-5 is a 17-item self-report measure that evaluates experiences of lifetime trauma. An 18th item evaluated the most distressing trauma. Participants rated degree of exposure to each trauma with a 6-point nominal scale: *happened to me, witnessed it, learned about it, part of my job, not sure*, and *does not apply*. Endorsing either of the first four response options was considered a positive trauma endorsement consistent with the *DSM-5* Criterion A (American Psychiatric Association, 2013).

PTSD Checklist for DSM-5 (PCL-5; Weathers, Litz, et al., 2013). The PCL-5 is a 20-item self-report measure assessing past month PTSD symptom severity referencing the most distressing trauma on the LEC-5. Response options range from 0 (*not at all*) to 4 (*extremely*). The scale contains four symptom clusters: 1) intrusion, 2) avoidance, 3) negative alterations of cognitions and mood (NACM), and 3) alterations in arousal and reactivity (AAR). The PCL-5 has good psychometric properties (Wortmann et al., 2016). Cronbach's α for the current study were as follows: total scale = .95, intrusion cluster = .89; avoidance cluster = .86; NACM cluster = .89; AAR cluster = .86.

The Patient Health Questionnaire-9 (PHQ-9; Kroenke & Spitzer, 2002). The PHQ-9 is a 9-item self-report measure of depression symptom severity within the past 2 weeks. Response options range from 0 (*not at all*) to 3 (*nearly every day*). The PHQ-9 has excellent

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psychometric properties (Kroenke & Spitzer, 2002; Kroenke et al., 2001). In the current study, the Cronbach's α for the total scale was .92.

Autobiographical Memory Test (AMT; Williams & Broadbent, 1986). The AMT was used to determine the count of retrieved specific positive memories. Participants viewed 10 positively-valenced cue words (e.g., McNally et al., 1995), and received a prompt to retrieve a specific and meaningful memory of an event that happened to them in a period <24 hours (Williams & Broadbent, 1986). Instructions were adapted from prior studies (e.g., Henderson et al., 2002). Responses were coded on certain dimensions to derive a final code. As a broad category, responses were coded as *recalled* (i.e., individual retrieved a positive memory within the allotted time and described it) or *failed to recall* (i.e., individual did not retrieve a positive memory within the allotted time and/or did not describe it). A memory categorized as *recalled* was further coded as *specific* (i.e., memories of events that occurred at a certain place <24 hours), *extended* (i.e., memories of events that lasted >24 hours), or *categoric* (i.e., memories that are summaries of multiple recurring events; Bryant et al., 2007; Sutherland & Bryant, 2008; Williams et al., 2007). Memories categorized as *failed to recall* were further coded as *non-positive* (i.e., negative memory/statement as a response to the positive cue), *semantic associate* (i.e., semantic information not constituting personal memory), or an *omission* (e.g., did not retrieve memory within time limit, indicated "I can't think of a memory;" Sutherland & Bryant, 2008; Williams et al., 2007). Following the Coding and Assessment System for Narratives of Trauma (CASNOT; Fernández-Lansac & Crespo, 2017), a memory was coded a *non-positive* if the emotional tone and/or valence was rated as negative and received scores of 3–4 on a scale from 0 (completely positive) to 4 (completely negative). For this study, the total number of AMT responses coded as *specific* and *positive* was used as the count variable. Kappa values ranged from .62 to .93 suggesting substantial-almost perfect agreement for inter-rater reliability (Landis & Koch, 1977).

Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989). The PSQI is a 21-item self-report measure of sleep functioning referencing the past month. In the current study, we administered two PSQI items that create the sleep duration and sleep quality components of the PSQI scale. One item examined sleep quantity on a 0 to 3 scale (>7 hours = 0, 6–7 hours = 1, 5–6 hours = 2, and <5 hours = 3) and the other item examined sleep quality on a 0 (*very good*) to 3 (*very bad*) scale. Higher scores on these indices reflect greater sleep difficulties (i.e., shorter sleep duration and poorer sleep quality). The PSQI has adequate psychometric properties (Buysse et al., 1989); psychometric evidence supports the separate examination of the PSQI component scores (Bower et al., 2010; Nunes et al., 2008).

Statistical Analyses

All analyses were conducted using R (R Core Team, 2013). Assumptions of normality for the primary variables were examined, and zero-order correlations among the primary variables were calculated. Using the R package *apaTables* (R Core Team, 2013; Stanley, 2018), we conducted moderated regression analyses examining sleep quantity and sleep quality as simultaneous moderators. To test for moderation, variables were entered hierarchically: age, gender, depression severity, PTSD symptom severity, and both sleep indicators were entered in Step 1; the interaction terms between PTSD symptom severity

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and each sleep indicator were added in Step 2 (Aiken & West, 1991) after centering the predictor and moderator variables. When significant interaction effects were obtained, the R packages *interactions* (Long, 2019) and *reghelper* (Hughes, 2018) were used to conduct simple slope analyses at the mean and at one standard deviation (SD) above and below the mean values of the sleep indicator. Johnson-Neyman intervals were calculated using the R package *jtools* (Long, 2017) to examine exact values of the sleep indicator where the slope between PTSD symptom severity and positive memory count became significant. Semi-partial correlation coefficient squared (sr^2) was used as a measure of effect size. The following Cohen (1988) heuristics were used: small effect size, sr^2 =.02; medium effect size, sr^2 = .13; and large effect size, sr^2 = .26. As supplemental analyses, we ran the same models using (1) a total PTSD symptom severity score without two items examining nightmares (intrusion cluster) and sleep difficulties (AAR cluster), and (2) each of the four PTSD symptom cluster scores (with and without corresponding sleep items for the intrusion and AAR clusters).

Results

All primary variables had a normal distribution. The PCL-5 total score ranged from 0–77 (M = 28.21, SD = 18.81, median = 29, skewness = 0.21, kurtosis = −0.96). Although normally distributed, the PCL-5 total score was slightly positively skewed because of this being a trauma-exposed community sample vs. a clinical sample. Zero-order correlations (Supplemental Table 1) indicated associations between (1) greater PTSD symptom severity (total and each PTSD symptom cluster) and shorter sleep duration and poorer sleep quality (excluding non-significant relations between sleep quality and avoidance severity); (2) shorter sleep duration and poorer sleep quality; and (3) poorer sleep quality and greater count of specific positive memories. Notably, the results using PTSD symptom severity score (total and each cluster) with and without the sleep items were similar in magnitude; hence, we present results encompassing the sleep items.

We have provided the R code and results for the PTSD symptom clusters as Supplemental Material. See Table 2 for detailed results of the moderation regression analyses. For main effects, there was a significant association between poorer sleep quality and a greater count of specific positive memories, accounting for age, gender, depression severity, PTSD symptom severity, and sleep quantity. There was a significant moderating effect of sleep quality on the association between PTSD symptom severity and count of specific positive memories (effect sizes were small in magnitude). Simple slope analyses indicated negative associations between PTSD symptom severity and specific positive memory count at 1 SD below the mean value for sleep quality (i.e., better sleep quality; b = −0.04, SE = 0.02, p = .010), but not at 1 SD above the mean for sleep quality (i.e., poorer sleep quality; b = 0.003, SE = 0.02, p = .884; Figure 1). Johnson Neyman analyses revealed that when sleep quality (centered) values were less than −.16, the slope between PTSD symptom severity and specific positive memory count was statistically significant at $p < .05$ (range of observed values of sleep quality was [−1.15, 1.85]; Figure 2). Similar moderation effects of sleep quality were found for the association between individual PTSD symptom clusters of intrusions and AAR and specific positive memory count (Supplemental Table 2;

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Supplemental Figures 1 and 2). There were no significant main or moderating effects for the variable of sleep quantity as seen in Table 2.

Discussion

Broadly, traumatic experiences influence sleep and memory processes which both characterize PTSD symptomatology. In this regard, the current study examined potential interacting effects of PTSD symptom severity and sleep difficulties (duration and quality) on count of specific positive memories in trauma-exposed participants. Primarily, results indicated that sleep quality modified associations between PTSD symptom severity (total, intrusion cluster, AAR cluster) and specific positive memory count. Theoretical and clinical implications are outlined below.

To begin with, study findings partially supported hypothesized moderating effects of sleep difficulties on relations between PTSD symptom severity and count of specific positive memories. For the PTSD total score, we found that among individuals reporting better sleep quality, (1) greater PTSD symptom severity was associated with fewer specific positive memories and (2) lower PTSD symptom severity was associated with more specific positive memories. For the PTSD symptom clusters, we found that among individuals reporting better sleep quality, (1) greater intrusion and arousal severity was associated with fewer specific positive memories; and (2) lower intrusion and arousal severity was associated with more specific positive memories. Among individuals with poorer sleep quality, there were no significant associations between PTSD symptom severity (total and subscale) and specific positive memory count. While partially unanticipated, these findings pave way to examine some potential explanations furthering research on PTSD, sleep, and positive memories.

First, better sleep quality may relate to greater retrieval of memories broadly (reviewed in Spencer et al., 2017; Walker & Stickgold, 2006), and specifically, more intrusive traumatic and negative memories (Baran et al., 2012) among trauma-exposed individuals. Such intrusive memories, if not therapeutically addressed, may contribute to the exacerbation and maintenance of PTSD severity (Iyadurai et al., 2019), including PTSD's intrusion symptom cluster because such memories are a component of that cluster. Further, these intrusive memories, via activation and inclusion of distressing content such as negative thoughts and affect (Bohanek et al., 2005), may prevent easy retrieval of and access to positive memories. Relatedly, PTSD's intrusion symptoms have been shown to relate to diminished working memory, which, in turn may limit positive memory retrieval (Brewin et al., 1999; Kuyken & Brewin, 1995). Thus, intrusive traumatic memories may further influence the moderating role of sleep in the PTSD-positive memory relation; this pathway warrants empirical investigations. Second, better sleep quality may relate to lower PTSD severity as evidenced by existing research (Kobayashi et al., 2007; Krakow, Melendrez, et al., 2001); their interaction may contribute to improved retrieval of positive memories via the (1) memory-enhancing function of better sleep (reviewed in Spencer et al., 2017; Walker & Stickgold, 2006), and (2) mood-congruency effects of improved mood and positive cognitions parallel to lower PTSD severity (Bower, 1981; Fredrickson, 2001). Such results are consistent with previous studies suggesting that better sleep may aid encoding of positive

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stimuli and positive memories (Sterpenich et al., 2009; Tempesta et al., 2015; Zare Khormizi et al., 2019).

Third, perhaps the beneficial impacts of better sleep are outweighed by detrimental impacts of PTSD's arousal symptoms on positive memory retrieval. To elaborate, neuroimaging results demonstrate that more arousal symptoms relate to greater glucocorticoid secretion, which negatively impacts hippocampal activity (Kim & Diamond, 2002); this contributes to poorer trauma-related memory processes (Hayes et al., 2011) potentially generalizing to positive memory retrieval. Further, arousal symptoms may relate to fewer cognitive resources, in turn reducing positive memory retrieval (Harvey et al., 1998). Also, research has shown that greater reckless behaviors (a PTSD arousal symptom) associate with fewer sensory details and coherence of retrieved positive memories (Banducci et al., 2020), possibly attributed to difficulties regulating positive emotions following positive memory retrieval among individuals with PTSD symptoms (Weiss et al., 2020). Lastly, hypervigilance (a PTSD arousal symptom) may involve biased attention to and appraisal of threatening stimuli and cues (Kimble & Hyatt, 2019), reducing attention to positive experiences and memories. Future research would benefit from focally examining each of the PTSD arousal symptoms using validated multiple-item scales for those constructs; examples include the 5-item Brief Hypervigilance Scale (Bernstein et al., 2015) to examine the hypervigilance symptom and the 16-item Posttrauma Risky Behaviors Questionnaire (Contractor, Weiss, Kearns, et al., 2020) to examine the engagement in self-destructive/reckless behaviors symptom.

Fourth, individuals with poor sleep (duration/quality) may experience other health concerns such as depression, cognitive impairment, and altered metabolic function (Itani et al., 2017; Pinkston et al., 2019); these factors, beyond PTSD symptom severity, may influence the retrieval of positive memories. Fifth, perhaps, in the absence of co-occurring sleep difficulties, PTSD symptoms may be more salient or have more detrimental impacts on positive memory retrieval. In this regard, few individuals endorsed very poor sleep (only 3% endorsed "very bad" sleep quality and 4% endorsed very short sleep duration [<5 hours]); this restricted distribution on range of scores may have impacted our ability to detect hypothesized associations between PTSD symptoms and positive memory count among those with more sleep difficulties (Sackett & Yang, 2000; Wiberg & Sundström, 2009). Lastly, retention intervals (i.e., consistency of retrieved memory content across time), which were not assessed in this study, could have impacted study findings in the light of research indicating that poor sleep quality (but not sleep duration) is associated with worse autobiographical memory performance for longer vs. shorter retention intervals (Murre et al., 2014).

Notably, main and moderating effects differed and were significant for sleep quality vs. quantity. In terms of main effects, poorer sleep quality, but not sleep quantity, was related to more specific positive memories. Further, moderating effects were found for sleep quality, but not sleep quantity, on the association between PTSD symptom severity (total, intrusion cluster, and AAR cluster) and specific positive memory count. Study findings should be considered in the light of differences between these two sleep indicators. Although sleep quality and quantity overlap to some extent (in part because shorter sleep duration may

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contribute to an individual's lower rating of their sleep quality), they are qualitatively different sleep indicators (Buysse, 2014). Also, sleep duration may be somewhat easier to quantify than the more subjective index of sleep quality (Buysse, 2014). Sleep quality is comparatively a broader concept that captures a more holistic heuristic of overall sleep (e.g., duration, depth, efficiency, latency, satisfaction; Buysse, 2014), which may be more important for positive memory retrieval than sleep duration alone. Indeed, consistent with our study findings, sleep duration and quality have been found to differentially relate to health indicators (Hayashino et al., 2007; Mihalik et al., 2013). Research indicates that poor sleep quality is associated with more physical and psychological health complaints; and less positive affect and life satisfaction (Hayashino et al., 2007; Pilcher et al., 1997). Sleep duration is less consistently associated with mental and physical health; research suggests these associations may be quadratic rather than linear (i.e., both very short and very long sleep are associated with poorer outcomes; Ong et al., 2017; Zhai et al., 2015). Additionally, we only used one item to examine sleep duration and sleep quality, which also could have influenced study findings, given single item measures of constructs tend to be less reliable. Future studies should use more reliable and valid domain-specific measures of the heterogenous construct of sleep to examine potential replication of study findings.

Current study findings have theoretical and clinical implications. First, results support targeting sleep improvement (particularly sleep quality) in trauma treatments (Spoormaker & Montgomery, 2008) and in memory-based interventions (Feld & Diekelmann, 2020) to influence better retrieval of specific positive memories and/or lower PTSD symptom severity (especially intrusions and arousal). In terms of treatments, such a recommendation may perhaps translate to combining Cognitive and Behavioral Therapy for Insomnia with trauma-focused treatments such as Prolonged Exposure (Colvonen et al., 2019) or with memory-based interventions such as Memory Specificity Training (Moradi et al., 2014). Better sleep in combination with lower PTSD symptom severity could impact positive memories in either encoding, consolidation, or retrieval phases (reviewed in Spencer et al., 2017; Walker & Stickgold, 2006); nuanced investigation of these processes is a worthwhile area of future research. Alternatively, improvements in sleep quality may facilitate improvement in positive memory retrieval which may have downstream impacts on lower PTSD symptom severity. In this regard, there are beneficial impacts of positive memory retrieval; positive memory retrieval aids mood regulation by reducing an over-focus on negative content and increasing attention on positive content (Joormann et al., 2007; Rusting & DeHart, 2000). Such enhanced positive affect is further associated with health-protective biological responses (e.g., less cortisol production), positive health behaviors (e.g., more physical activity), social support, adaptive coping, and better mental health (Fredrickson, 2000; reviewed in Lyubomirsky et al., 2005; reviewed in Steptoe et al., 2009). Positive memory retrieval also enhances adaptive cognitions because accompanying positive affect enhances positive interpretations of experiences (Rusting & DeHart, 2000), self-esteem (Steel et al., 2015) and positive content in thoughts (Fredrickson, 2001).

Second, results support literature indicating that improved sleep should not be just a secondary treatment target of PTSD interventions (Germain et al., 2017). In fact, sleep disturbances are viewed as comorbid conditions of PTSD and as factors that contribute to and maintain PTSD symptoms (Germain et al., 2017). They also hinder PTSD treatment

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effectiveness by impairing memory and learning processes important for trauma treatment targets and by reducing coping skills (Craske et al., 2008; Germain et al., 2008). Hence, sleep improvement needs to be a core target of PTSD interventions (Germain et al., 2017). Indeed, cognitive-behavioral therapy for sleep has been found to concurrently improve sleep quality and PTSD severity (Germain et al., 2007). Relatedly, results provide greater impetus to examine sleep-specific mechanisms linking positive memories and PTSD symptoms. Third, because better (vs. poor) sleep quality seemed to more strongly influence negative associations between PTSD severity and positive memory count, clinicians may benefit from paying attention to therapeutic changes and correlates when clients report better sleep quality. Lastly, study results can inform the Positive Memory-PTSD model (Contractor et al., 2018), which outlines hypothesized mechanisms linking positive memories to PTSD symptoms. This model would benefit from incorporating sleep-related constructs in those hypothesized mechanisms.

Study findings need to be interpreted in the light of limitations. First, this study was cross-sectional; longitudinal studies with larger sample sizes are needed to examine causal inferences between these variables. Second, self-report measures have the potential of response biases; future research would benefit from using clinician-administered measures and objective measures, especially those assessing sleep architecture. Third, collecting data using MTurk has some concerns such as sample biases for data collected via the internet (e.g., self-selection; Kraut et al., 2004), lack of control over the research environment (Thomas & Clifford, 2017), low-quality data (Chmielewski & Kucker, 2020), computer programs that automatically complete research studies (Chmielewski & Kucker, 2020), and deception tendencies such as attempting the survey mulitple times or faking study eligibility (Hauser et al., 2019). That said, we highlight that MTurk's subject pool is diverse compared to traditional internet-recruited samples; MTurk generates reliable data (Buhrmester et al., 2011; Mischra & Carleton, 2017; Shapiro et al., 2013); MTurk, by providing the opportunity for anonymity and physical distance when completing surveys, may facilitate disclosure of sensitive and personal information (Shapiro et al., 2013); MTurk has demonstrated utility for trauma research by capturing individuals with PTSD in a cost and time-effective manner (van Stolk-Cooke et al., 2018); and MTurk samples do demonstrate varied psychological symptoms (Arditte et al., 2016). Further, we utilized recommended steps to enhance data quality: participation was restricted to MTurk individuals with a ≥90% approval rating (i.e., to MTurk workers with a high proportion of surveys approved by researchers; Hauser & Schwarz, 2016; Shapiro et al., 2013); use of validity checks to ensure attentive responding and comprehension; and exclusion of individuals missing too much data or attempting the survey multiple times (Aust et al., 2013; Buhrmester et al., 2011; Hauser et al., 2019; Oppenheimer et al., 2009). Lastly, the generalizability of study findings is restricted to the characteristics of the current sample; future research should explore this question in larger, more diverse, and clinical samples.

Despite these limitations, the current study is the first to examine moderating impacts of two distinct sleep indicators on relations between PTSD symptom severity and specific positive memory count. Broadly, findings emphasize (1) targeting both improved sleep quality and lower PTSD symptom severity to improve positive memory retrieval; (2) investigating relevant clinical factors (e.g., presence of intrusive memories, regulation of

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positive emotions) when encountering better sleep quality yet greater PTSD symptom severity affecting reduced positive memory retrieval; (3) focusing on improved vs. poor sleep quality when examining relations between PTSD and positive memory count; and (4) examining impacts of sleep processes on positive and traumatic memories. Replication and further extension of this work may inform PTSD and memory-based interventions with an integrated sleep component to improve post-trauma clinical targets, and may provide a framework to investigate interactive sleep- and memory-based factors in relation to PTSD.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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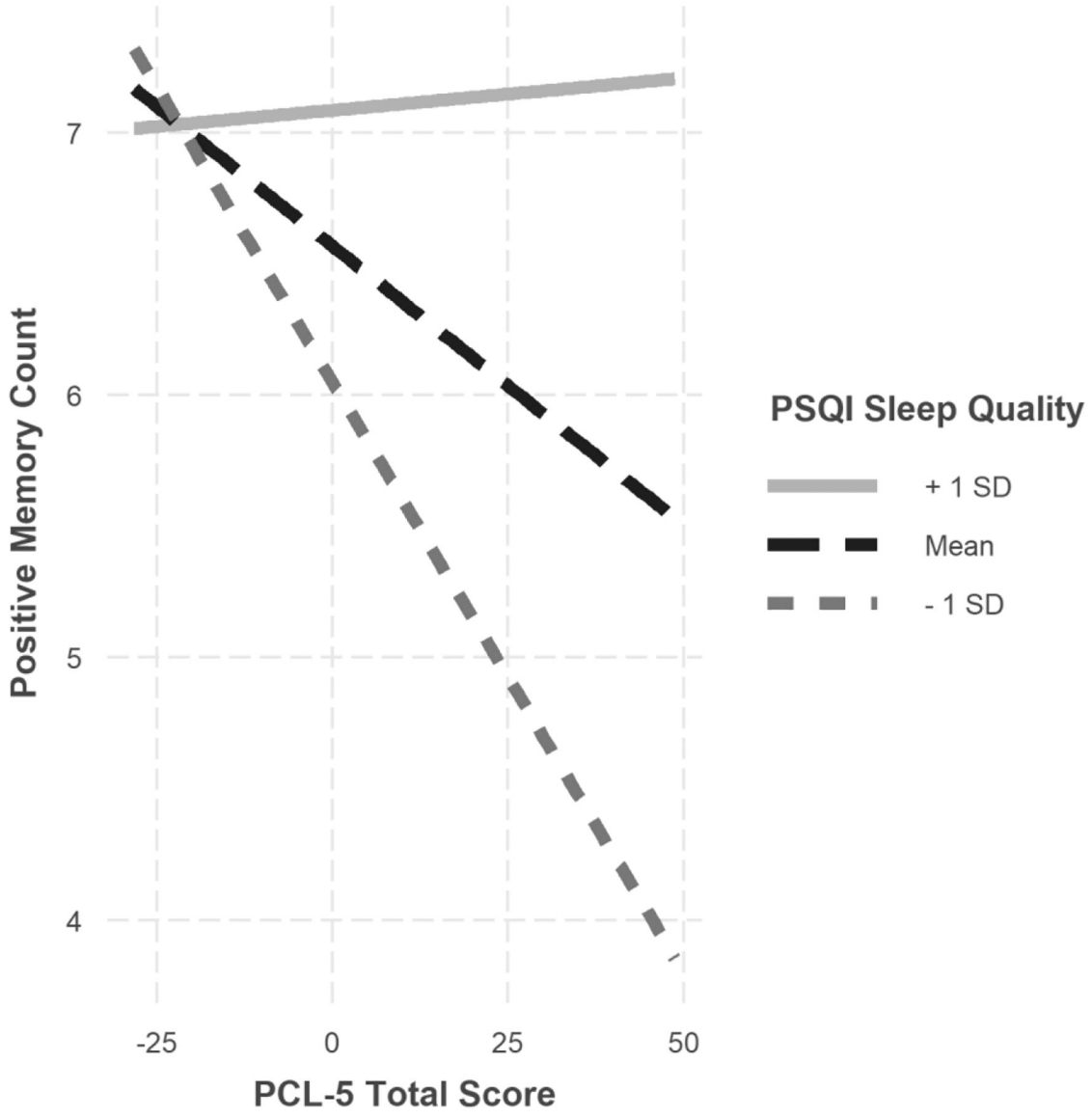

Figure 1.

Moderating impact of sleep quality in the relation between PTSD symptom severity and specific positive memory count.

Note. PSQI is the Pittsburgh Sleep Quality Index; PCL-5 is the Posttraumatic Stress Disorder Checklist for DSM-5; Simple slopes are shown at the mean and at +/− 1 standard deviation (SD) above and below the mean of sleep quality. For sleep quality, higher values indicate poorer sleep. Both the PSQI and PCL-5 were centered at the mean.

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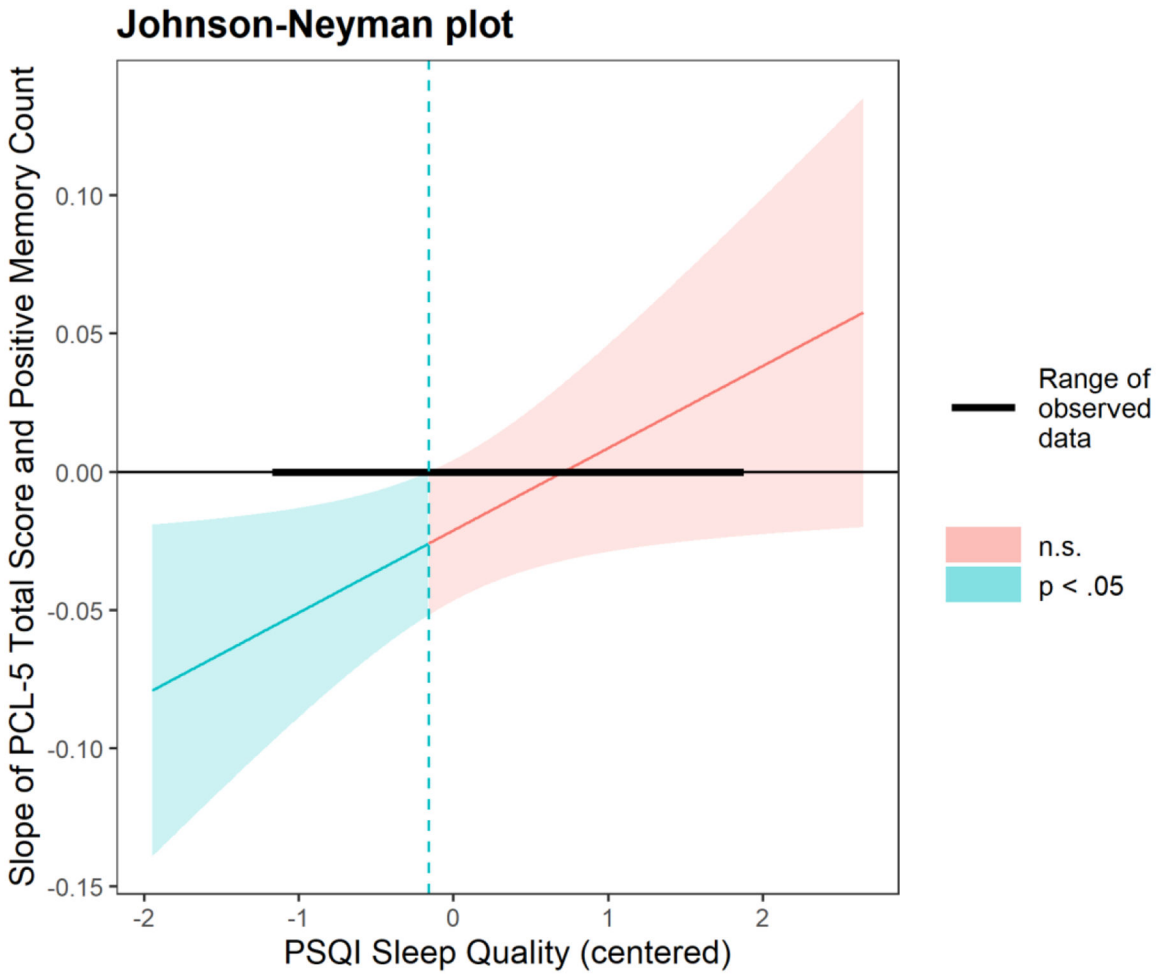

Figure 2.

Johnson-Neyman plot for probing the moderating effects of sleep quality on the association between PTSD symptom severity and specific positive memory count.

Note. PSQI is the Pittsburgh Sleep Quality Index; PCL-5 is the Posttraumatic Stress Disorder Checklist for DSM-5; When PSQI Sleep Quality (centered) is outside the interval −0.16 to 11.11, the slope of PCL-5 Total Score and Positive Memory Count is $p < .05$. The range of observed values of PSQI Sleep Quality (centered) is −1.15 to 1.85.

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Table 1

Descriptive characteristics of the sample

Variable	Mean (SD)
Age	35.44 (11.40)
Years of schooling	15.35 (2.41)
Count of specific positive memories	6.69 (2.52)
PTSD total severity	28.21 (18.81)
PTSD total severity (not including items assessing nightmares and sleep disturbances)	25.33 (16.89)
PTSD intrusion severity	7.64 (5.19)
PTSD avoidance severity	3.50 (2.47)
PTSD NACM severity	9.30 (7.22)
PTSD AAR severity	7.77 (6.09)
Depression severity	7.27 (6.94)
Sleep quantity/duration	1.14 (.91)
Sleep quality	1.15 (.80)
	***n* (%)**
Gender	
Male	77 (37.60%)
Female	126 (61.50%)
Transgender	1 (.50%)
Gender queer	1 (.50%)
Employment status	
Part time	33 (16.10%)
Full time	143 (69.80%)
Retired	4 (2.00%)
Unemployed	19 (9.30%)
Unemployed student	6 (2.90%)
Relationship status	
Single	63 (30.70%)
Living with significant other	34 (16.60%)
Married	87 (42.40%)
Divorced	18 (8.80%)
Separated	2 (1.00%)
Widowed	1 (.50%)
Ethnicity	
Hispanic or Latino	17 (8.30%)
Not Hispanic or Latino	185 (90.20%)
Unknown	3 (1.50%)
Racial status (could endorse more than one category)	
Caucasian or White	172 (83.90%)
African American or Black	25 (12.20%)

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Variable	Mean (SD)
Asian	9 (4.40%)
American Indian or Alaskan Native	5 (2.40%)
Native Hawaiian/Other Pacific Islander	1 (.50%)
Unknown	0 (0%)
Income	
Less than $15,000	18 (8.80%)
$15,000 – $24,999	27 (13.20%)
$25,000 – $34,999	18 (8.80%)
$35,000 – $49,999	38 (18.50%)
$50,000 – $64,999	42 (20.50%)
$65,000 – $79,999	24 (11.70%)
$80,000 and higher	38 (18.50%)
Treatment for mental health/emotional problem (could endorse more than one category)	
Currently in therapy	28 (13.70%)
Been in therapy in the past	87 (42.40%)
Currently taking medications for mental health/emotional problem	42 (20.50%)
Have taken medications in the past for mental health/emotional problem	59 (28.80%)
Never received treatment (therapy/medications) for mental health/emotional problem	79 (38.50%)
Worst traumatic event endorsed on the LEC-5	
Natural disaster	30 (14.60%)
Fire or explosion	7 (3.40%)
Transportation accident	34 (16.60%)
Serious accident at work/home/during recreational activity	9 (4.40%)
Exposure to a toxic substance	0 (0%)
Physical assault	20 (9.80%)
Assault with a weapon	8 (3.90%)
Sexual assault	37 (18%)
Other unwanted/uncomfortable sexual experience	8 (3.90%)
Combat or exposure to war	1 (.50%)
Forced captivity	0 (0%)
Life-threatening illness	12 (5.90%)
Severe human suffering	3 (1.50%)
Sudden, violent death	17 (8.30%)
Sudden, accidental death	15 (7.30%)
Serious injury/harm/death you caused to someone else	4 (2.00%)

Note. PTSD is posttraumatic stress disorder; LEC-5 is Life Events Checklist for DSM-5; valid percentages were used to account for missing data; NACM is negative alterations in cognitions and mood; AAR is alterations in arousal and reactivity.

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Table 2

Moderated regression results of sleep difficulties and PTSD symptom severity on specific positive memory count

Predictors	*b*	*b* 95% CI [LL, UL]	sr^2	sr^2 95% CI [LL, UL]	R^2	*F*(df)
Step 1					.06	2.47 (6, 198) p=.035
Age	0.00 p=.917	[−0.03, 0.03]	.00	[−.00, .00]		
Gender	0.46 p=.213	[−0.27, 1.19]	.01	[−.02, .03]		
Depression Severity	0.03 p=.436	[−0.04, 0.10]	.00	[−.01, .02]		
PTSD Severity	−0.02 p=.069	[−0.05, 0.00]	.02	[−.02, .05]		
Sleep Quantity	−0.42 p=.076	[−0.89, 0.04]	.02	[−.02, .05]		
Sleep Quality	**0.70 p=.016**	[0.13, 1.26]	.03	[−.02, .07]		
Step 2					.11	2.97 (8, 196) p=.004
Age	−0.00 p=.986	[−0.03, 0.03]	.00	[−.00, .00]		
Gender	0.27 p=.462	[−0.45, 1.00]	.00	[−.01, .02]		
Depression Severity	0.02 p=.516	[−0.05, 0.10]	.00	[−.01, .01]		
PTSD Severity	−0.02 p=.104	[−0.05, 0.00]	.01	[−.02, .04]		
Sleep Quantity	−0.35 p=.137	[−0.81, 0.11]	.01	[−.02, .04]		
Sleep Quality	**0.65 p=.023**	[0.09, 1.21]	.02	[−.02, .06]		
PTSD Severity X Sleep Quantity	0.01 p=.507	[−0.02, 0.03]	.00	[−.01, .01]		
PTSD Severity X Sleep Quality	**0.03 p=.036**	[0.00, 0.06]	.02	[−.02, .06]		

Note. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant; *b* represents unstandardized regression weights; sr^2 represents the semi-partial correlation squared; *LL* and *UL* indicate the lower and upper limits of a confidence interval, respectively; bolded values represent significant (p < .05) results; PTSD is posttraumatic stress disorder. For gender: 0 = not female [reference group]; 1 = female.