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AN EXPERIENCE SAMPLING STUDY OF SLEEP DISTURBANCE, EMOTIONAL REGULATION AND POSTTRAUMATIC STRESS SYMPTOMS IN PREDICTING ALCOHOL USE AMONG OIF/OEF VETERANS

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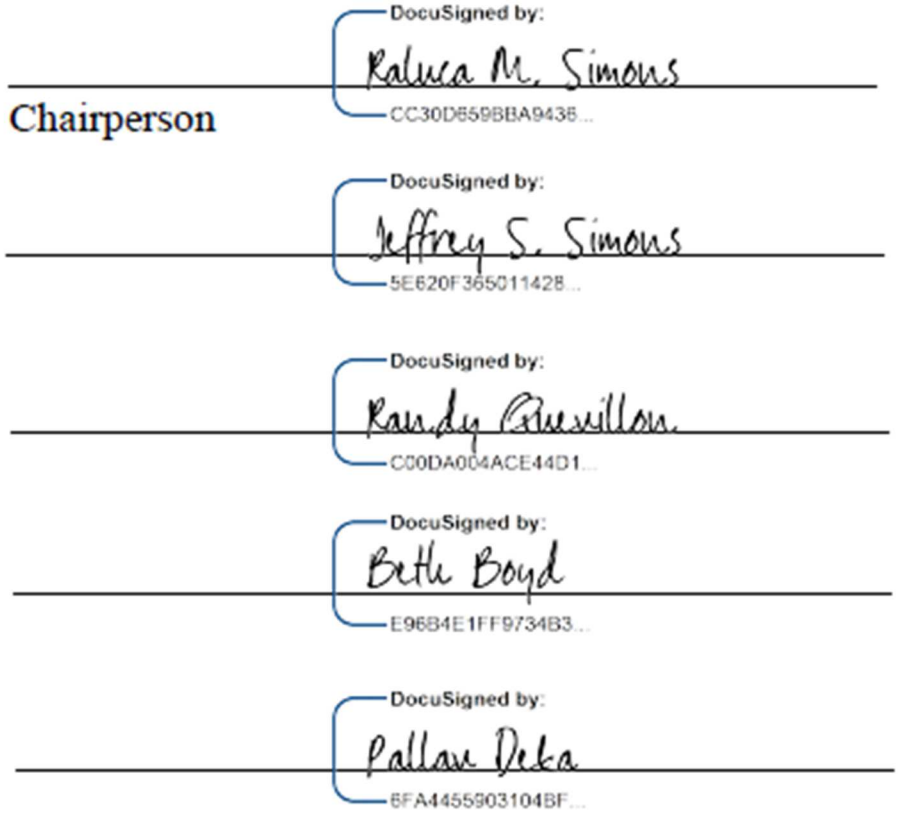
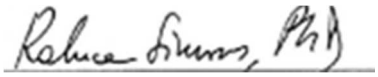


Abstract

Posttraumatic Stress Disorder (PTSD) is a common concern for veterans involved in the post-9/11 Iraq and Afghanistan conflicts (Epidemiology, 2017). Alcohol use is highly comorbid with PTSD in returning veterans (Seal et al., 2011). There are several models for the complex relationship between these two constructs including self-medication models or as an attempt to regulate emotion. Sleep disturbances have been linked to PTSD and alcohol use (Conroy & Arnedt, 2014) and could be driving the relationship. It is also possible that difficulties in emotion regulation could be part of this relationship either independently (Kelly & Bardo, 2016; Perlick et al., 2017) or in conjunction with sleep disturbances (Fairholme et al., 2013). This study used 14 days of experience sampling data collected from 59 veterans about PTSD symptoms, alcohol use, sleep disturbance, and emotion regulation. Participants answered several questions throughout the day using an application on their phone. They received an actigraph to approximate their sleep parameters including sleep efficiency and total sleep time. Multi-level modeling was used to explore the temporal relationships at the between- and within-subjects level of PTSD symptoms, alcohol use and problems, sleep disturbance and emotion regulation. Multimethod data collection using self-report, objective approximation of sleep measures (actigraphy), and experience sampling in the same study is innovative. Results of the study suggested that sleep disturbances did not have significant associations with PTSD symptoms, emotion regulation, or alcohol consumption in multilevel models, there were some significant correlations. Exploratory analyses using other objective sleep approximations and a subjective sleep variable mimicked these results. Future studies would benefit from a more diverse sample and a variety of assessment methods for subjective and objective experiences of sleep.

Dissertation Advisor 

Raluca M. Simons, PhD

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Introduction

Between 2002 and 2015, approximately 1.9 million veterans who have served in the post-9/11 Afghanistan and Iraq conflicts (Operation Enduring Freedom/Operation Iraqi Freedom/Operation New Dawn; OEF/OIF/OND) have been discharged from active duty (Epidemiology Program, 2017). Veterans struggle with significant clinical and functional impairment (Jakupcak et al., 2007). These impairments include increased occupational difficulties (Ginzburg, Ein-Dor, & Solomon, 2010), physical health problems (Ouimette, Goodwin, & Brown, 2006), interpersonal difficulties (Silverstein, Lee, Seligowski, & Worley, 2018), alcohol use (Adams, Boscarino, & Galea, 2006), difficulty regulating emotions (Radomski & Read, 2016), and sleep disorders (El-Gabalawy, Blaney, Tsai, Sumner, & Pietrzak, 2018; Short, Allan, & Schmidt, 2017). Healthcare costs for veterans in the first year of treatment are upwards of $2 billion (Reisman, 2016).

Approximately 58% meet diagnostic criteria for some mental disorder, with 32.3% meeting criteria for Posttraumatic Stress Disorder (PTSD) (Epidemiology Program, 2017). PTSD is highly comorbid with several mental health diagnoses including depression, anxiety, and substance use disorders (Debell, Fear, Head, Batt-Rawden, Greenberg, Wessely, & Goodwin, 2014; Flory & Yehuda, 2015; Spinhoven, Penninx, van Hemert, de Rooij, & Elzinga, 2014). Lifetime prevalence rates of PTSD across veteran populations, regardless of if they seek services at the VA, are estimated at approximately 6-31% (Richardson, Frueh, & Acierno, 2010). Similar rates of veterans experience subthreshold PTSD symptoms but do not meet full diagnostic criteria for PTSD (Bergman, Przeworski, & Feeny, 2017).

Of particular concern in this population is the use of alcohol. PTSD and alcohol use disorders have some of the highest comorbidity rates ranging from as much as 30% to 79% of those with PTSD also being diagnosed with alcohol use disorders (Pietrzak, Goldstein, Southwick, & Grant, 2011; Ralevski, Olivera-Figueroa, & Petrakis, 2014). Veterans who experience PTSD symptoms specifically, as opposed to other mental health symptoms, are twice as likely to engage in risky drinking than veterans without these symptoms (Jakupcak et al., 2010). Not only are these veterans more likely to experience more severe symptoms than if they were diagnosed with only one disorder (Blanco et al., 2013) but these disorders together lend themselves to treatment relapse and treatment resistance (Ouimette, Moos, & Finney, 2003). The positive association between PTSD symptoms and alcohol outcomes has been well documented in cross sectional (Claycomb et al., 2017; Ertl, Saile, Neuner, & Catani, 2016; Langdon et al., 2016; Simons et al., 2017), longitudinal (Berenz et al., 2016; Lee, Possemato, & Ouimette, 2017), and more recently experience sampling studies (Gaher et al., 2014; Possemato et al., 2017; Simons et al., 2018; Surette et al., 2015), where particiapnts completed several random questionnaires throughout observation periods. At the event level, experience sampling studies demonstrated a temporal association between PTSD symptoms during the day and subsequent alcohol use and problems (Gaher et al., 2014; Simons et al., 2018; Surette et al., 2015). The results of these studies point to a functional association between PTSD and alcohol use disorder symptoms, but the exact mechanism of this association is not fully understood.

While there are several theories about this underlying mechanism, the predominant theory in the literature is the self-medication hypothesis. Previous research suggests that those diagnosed with PTSD may use alcohol in an attempt to reduce their symptoms (Leeies, Pagura, Sareen, & Bolton, 2010; Khantzian, 2003; McFarlane, 1998; Stewart, 1996). This model has

been supported at the within-persons level, with veterans drinking more and having more alcohol-related problems on nights following increased PTSD symptom severity during the day (Gaher et al., 2014); however, it does not explain the entire relationship between these two constructs. In that same study, at the within- and between-person levels, PTSD symptoms had direct significant effects on alcohol problems, over and above levels of consumption, which may suggest broader emotional and behavioral dysregulation (Gaher et al., 2014).

To further complicate matters, in both PTSD and alcohol use disorders, sleep disturbances are often found. Sleep disturbance is theorized as having a relationship with PTSD symptoms and alcohol use. However, sleep research findings are just starting to accumulate, so the exact mechanisms of association with PTSD symptoms, emotional regulation and alcohol use are not fully known. Sleep disturbance is commonly thought of as the "hallmark" symptom of PTSD in returning veterans with as many as 93.5% experiencing difficulties with sleep onset or maintenance (Lew et al., 2010). Disturbed sleep prior to a deployment has also been shown to be a risk factor in the development of PTSD following deployment (Koffel, Polusny, Arbisi, & Erbes, 2013; van Liempt, van Zuiden, Westenberg, Super, & Vermetten, 2013). Disturbed sleep earlier in life can also be a risk factor in developing an alcohol use disorder later in life (Roane & Taylor, 2008; Wong & Brower, 2012; Wong, Brower, Fitzgerald, & Zucker, 2004; Wong, Brower, Nigg, & Zucker, 2010). Finally, while alcohol may initially act as a sedative and aid in sleep onset (Roehrs, Papineau, Rosenthal, & Roth, 1999) it later disrupts sleep causing an overall shorter sleep period (Conroy & Arnedt, 2014).

Sleep disturbances could have an important role in the relationship between PTSD and alcohol use. One possibility is that the sleep disturbances may aggravate PTSD symptoms, leading people to feel dysregulated and ultimately use alcohol for its sedative effect, as a form of

self-medication (Ancoli-Israel & Roth, 1999; Stein & Friedmann, 2005). In this framework, difficulties in regulating emotions might be an important missing puzzle piece in this relationship between sleep disturbance, PTSD symptoms, and alcohol use. Emotion regulation and sleep disturbances are transdiagnostic processes related to symptom severity (Fairholme et al., 2013). Emotion regulation has also been implicated in sleep research, with impaired sleep increasing emotional reactivity the following day (Baglioni, Spiegelhalder, Lombardo, & Riedmann, 2010; Deliens, Gilson, & Peigneux, 2014). Finally, emotion dysregulation leads to craving in those who are alcohol dependent and maintain the problematic alcohol use (Petit et al., 2015). One previous study demonstrated a significant relationship between the negative alterations in cognition and mood PTSD symptom cluster, sleep disturbance, and alcohol use (Surette et al., 2017). Deficits in emotion regulation are prevalent in those with PTSD (Seligowski, Lee, Bardeen, & Orcutt, 2015) and are included in the most recent diagnostic criteria, by way of changes in arousal and negative alterations in cognition and mood (APA, 2013). Alcohol can also impair sleep throughout the night (Conroy & Arnedt, 2014), which may further exacerbate PTSD symptoms the next day (Surette et al., 2015) restarting the process all over again.

There is minimal research that links these various constructs and no research, to our knowledge, that examines the temporal relationships. Cross-sectional research has shown that there are relationships between these various constructs (Fairholme et al., 2013). While there have been temporal studies looking at some of these relationships in isolation (Baglioni, Spiegelhalder, Lombardo, & Riedmann, 2010; Deliens, Gilson, & Peigneux, 2014; Gaher et al., 2014; Simons et al., 2018; Surette et al., 2017), no research has tried to understand these associations simultaneously or at least sequentially at the daily level. The current study aims to examine the between- and within person relationships between sleep disturbances, PTSD

symptoms, emotion regulation, and alcohol misuse using experience sampling modeling and objective sleep measures to see changes at the daily level. It is hypothesized that disturbed sleep will exacerbate PTSD symptoms the following day, leading to emotion dysregulation. Emotion dysregulation, in turn, will be associated with alcohol consumption and problems. The following literature review will begin with a discussion of the prevalence and current conceptualization of PTSD. Next, emotion regulation, followed by sleep disturbance, will be discussed. Throughout the literature review, alcohol use will be discussed in conjunction with these various constructs. Finally, these constructs will be discussed in regard to how they may change as a function of age and gender.

Literature Review

Posttraumatic Stress Disorder

Prevalence and Current Conceptualization

PTSD is a debilitating condition that develops following a traumatic event (APA, 2013). The lifetime risk for developing PTSD is 6.1% (Goldstein et al., 2016). Rates of PTSD tend to be even higher in groups with occupations that are more likely to encounter traumatic events, such as military members (APA, 2013). This disorder alone costs the United States more than $2 billion dollars in first-year treatment for veterans of the Iraq and Afghanistan conflicts (Reisman, 2016). PTSD has been identified as a serious concern for veterans who have been deployed in the Iraq and Afghanistan conflicts. It has even been called a “signature injury” for this cohort and substantial resources are used in the diagnosis and treatment of this disorder (Institute of Medicine, 2012). It is the leading diagnosis in the Department of Veterans Affairs Medical Centers and is associated with a 200% increase in hospitalizations for active duty military members (Armenta et al., 2018). Currently, it is estimated that approximately 32.3% of OEF/OIF

veterans meet the criteria for PTSD (Epidemiology Program, 2017). Those who directly experience combat exposure are at the highest risk for developing this disorder (Smith, Ryan, Wingard, Slymen, Sallis, & Silverstein, 2008).

PTSD is currently conceptualized as having four distinct symptom clusters: alterations in arousal and reactivity, intrusions, avoidance, and negative alterations in cognition and mood (APA, 2013). These symptoms occur in association with traumatic events. To meet the criteria for the disorder these symptoms must be present for more than a month following the event and cause some type of functional impairment. These impairments include changes in arousal and reactivity that can manifest following the traumatic event or worsen following the event. These changes can manifest in a variety of ways. Individuals may have difficulty concentrating in their everyday life. They may engage in reckless and self-destructive behaviors or they may have angry outbursts. Another possible change is that they may develop an exaggerated startle response and be hypervigilant. Finally, individuals may complain of sleep disturbances specifically related to sleep onset and/or maintenance.

Intrusive symptoms are symptoms that focus on re-experiencing the traumatic event in some way. To qualify, these symptoms need to be both intrusive and involuntary. A common symptom is experiencing a nightmare or distressing dream related to the event. Others may feel as if they are currently re-experiencing the event by way of flashbacks or hallucinations. These intrusive thoughts can be triggered by a variety of environmental cues (e.g. sounds, smells, locations where the traumatic event occurred).

Avoidance symptoms are present when an individual makes an effort to avoid reminders of the traumatic event. This may include avoiding places, people, or activities that could be linked to the traumatic event. The person may also use distraction techniques to avoid

remembering the event or to avoid managing the emotions that surface as a result of the event. In part, this can be considered a strategy to diminish the experience of other symptoms by way of avoiding cues. In the Lazarus and Folkman Coping Theory (1984) this is considered an emotion-focused coping style and often attributed to higher rates of avoidance and overall PTSD symptoms in veterans (Karstoft, Armour, Elklit, & Solomon, 2015).

The final symptom cluster is negative alterations in cognitions and/or mood. This is a newer symptom cluster, which first appeared in the DSM-5 (APA, 2013). Examples include a diminished interest in activities, estrangement from loved ones, and negative emotional states. They may experience negative self-evaluations, such as "I am a bad person," and a negative world-view, "The world is a chaotic and evil place." It is also possible that the individual will have a distorted view of the event or have trouble remembering important aspects of the event.

There has been a shift in the literature from looking at formal, discrete diagnoses to a focus on symptom clusters or dimensions of functioning and how they are related to different health-related problems and other disorders, such as mood and anxiety disorders (Brown & Barlow, 2009; Widiger & Samuel, 2005). Following trends in research to look at symptoms or dimensions of a disorder rather than if they simply meet diagnostic criteria or not (Stein, 2012); research shows that similar rates of veterans experience subthreshold PTSD symptoms but do not meet full diagnostic criteria for PTSD (Bergman, Przeworski, & Feeny, 2017). Veterans with subsyndromal symptoms, numbing and alterations in arousal have been associated with alcohol use (Harpaz-Rotem et al., 2014; Surette et al., 2015) and alterations in cognition and mood associated with alcohol use via sleep disturbances (Surette et al., 2017). Veterans within both categories, those that meet criteria for PTSD and those with subsyndromal symptoms, struggle with significant clinical and functional impairment (Jakupcak et al., 2007). These impairments

include increased occupational difficulties (Ginzburg, Ein-Dor, & Solomon, 2010), physical health problems (Ouimette, Goodwin, & Brown, 2006), interpersonal difficulties (Silverstein, Lee, Seligowski, & Worley, 2018), alcohol use (Adams, Boscarino, & Galea, 2006), difficulty regulating emotions (Radomski & Read, 2016), and sleep disorders (El-Gabalawy, Blaney, Tsai, Sumner, & Pietrzak, 2018; Short, Allan, & Schmidt, 2017).

This shift to a dimensional approach also has important treatment implications. Research using a dimensional approach has shown differences in mental health service utilization. Specifically, prominent intrusive symptoms and negative alterations in cognition and mood have been uniquely associated with veterans initiating and staying in treatment (Harpaz-Rotem, Rosenheck, Pietrzak, & Southwick, 2014; Smith et al., 2017). Transdiagnostic approaches can be used to focus in on these dimensions across disorders, saving time and money in populations with comorbid conditions (Arnfred et al, 2017; Mansell, Harvey, Watkins, & Shafran, 2008; Tsai, 2017).

Posttraumatic Stress Symptoms and Associations with Alcohol Use

Alcohol use is also a concern for OEF/OIF veterans and oftentimes is seen as a problematic part of the military culture (Ames & Cunradi, 2004/2005). OEF/OIF veterans tend to have demographic features that lend themselves to heavy alcohol use including multiple deployments, being male, and in their early 30s (IOM, 2013). This is not to say that female veterans are immune to this problem, with approximately 20% of female veterans involved in the Afghanistan and Iraq conflicts meeting the criteria for alcohol use disorders (Burnett-Zeigler et al., 2011). Oftentimes, alcohol use in the military has been seen as useful in aiding morale or helping units bond (Jones & Fear, 2011), but with the high rates of alcohol use disorder

following deployments, it is now more important than ever to explore these problematic drinking behaviors.

After being exposed to a traumatic event, it is common for an individual to experience problematic alcohol use and PTSD (Pietrzak, Goldstein, Southwick, & Grant, 2011). There are high comorbidity rates of 28% - 63% of veterans having both PTSD and alcohol use disorders (Bowe & Rosenheck, 2015; Ralevski, Olivera-Figueroa, & Petrakis, 2014; Seal et al., 2009). In veteran samples, PTSD-AUD comorbidity has been associated with physical health problems (Ouimette, Goodwin, & Brown, 2006), occupational problems (Davis et al., 2012; Schnurr, Lunney, Bovin, & Marx, 2009), interpersonal problems (Meis, Erbes, Polusny, & Compton, 2010), and suicidal ideation (Leeies, Pagura, Sareen, & Bolton, 2010; Rojas, Bujarski, Babson, Dutton, & Feldner, 2014). Veterans with comorbid PTSD and AUD experience more severe symptoms and lower quality of life than if they were diagnosed with either disorder alone (Blanco et al., 2013). Individuals with comorbid PTSD-AUD are also less likely to benefit from treatment and more likely to relapse than individuals with either disorder alone (Ouimette, Moos, & Finney, 2003). Currently, there are no empirically supported treatments that are considered the gold standard for comorbid PTSD-AUD (Ralevski, Olivera-Figueroa, & Petrakis, 2014; Taylor, Petrakis, & Ralevski, 2016). *Seeking Safety* (Najavits, 2002) is a present-focused treatment that can be conducted individually or in a group-modality, and was developed specifically to target PTSD-AUD symptoms concurrently. Yet, while it showed efficacy in some studies (Boden et al., 2012, Najavitz et al., 2020; Norman et la., 2010; Searcy & Lipps, 2012), it did not in other studies (Hien et al., 2012; Lenz, Henesy, & Callender, 2014). Currently, this treatment is considered as having strong research support, according to Division 12 of the APA, and has been

used with a variety of populations ("Seeking Safety for PTSD with Substance Use Disorder," 2016).

PTSD and alcohol use have a complicated relationship, with some studies showing PTSD symptoms preceding alcohol use (Gaher, et al., 2014; Jacobsen, Haller & Chassin, 2013; Jakupcak et al., 2010; Ouimette, Read, Wade, & Tirone, 2010) and alcohol use preceding PTSD symptoms (Jacobsen, Southwick, & Kosten, 2001; Stewart, Pihl, Conrad, & Dongier, 1998). There are several different theories for the relationship between alcohol use disorders and PTSD. Research has shown that alcohol use occurs subsequently to PTSD symptoms (Gaher, et al., 2014; Haller & Chassin, 2013; Jakupcak et al., 2010; Ouimette, Read, Wade, & Tirone, 2010), supporting the self-medication hypothesis that veterans are using alcohol to alleviate PTSD symptoms (Leeies, Pagura, Sareen, & Bolton, 2010). However, there is also research that suggests PTSD symptoms occur second to alcohol use (Jacobsen, Southwick, & Kosten, 2001; Stewart, Pihl, Conrad, & Dongier, 1998). It is possible that other regulatory deficits may account for both PTSD symptoms and alcohol use and maintain the comorbidity. Another possibility is that difficulties with emotion regulation are responsible for the relationship between PTSD symptoms and alcohol use (Dvorak, Arens, Kuvaas, Williams, & Kilwein, 2014; Miller, Vogt, Mozley, Kaloupek, & Keane, 2006; Read, Merrill, Griffin, Bachrach, & Khan, 2014; Simons et al., 2017) in that people struggle with impulse control, making them more likely to use alcohol.

There is also research to indicate differential associations between PTSD symptom clusters and problematic alcohol use, although some mixed findings exist. For instance, symptoms in the Arousal cluster have been significantly associated with both increases (Hellmuth, Stappenbeck, Hoerster, & Jakupcak, 2012; Simons et al., 2005) and decreases (Simons et al., 2005) in alcohol use. In respect to the Intrusive cluster, some studies found

significant associations between intrusive symptoms and alcohol misuse (Kaysen, et al., 2014; Simons et al., 2005), while others did not (Debell, et al., 2014). Avoidance symptoms are more complicated, with research splitting these symptoms into emotional numbing and avoidance symptoms. Emotional numbing was associated with alcohol misuse (e.g., continuing to drink despite doctors' warnings and health concerns, not attending to responsibilities due to alcohol use, interpersonal difficulties while drinking alcohol); while avoidance symptoms were not (Jakupcak, Tull, McDermott, & Kaysen, 2010; McDevitt-Murphy, Murphy, Monahan, Flood, & Weathers, 2010; Scott et al., 2013). Finally, in line with the changing conceptualization of PTSD symptom clusters, research has also shown an association between dysphoric arousal and alcohol disorder (Trautmann, et al., 2015). Dysphoric arousal is a unique PTSD construct, determined using confirmatory factor analysis, that would combine anxiety-related PTSD symptoms and depressive PTSD symptoms, such as irritability and diminished interest in activities respectively, that points to the broad emotional dysregulation experiencing in PTSD (Simms, Watson, & Doebbeling, 2002). Separating these symptoms into their own construct, creating a five-factor model using confirmatory factor analysis, demonstrated a better fit for the conceptualization of PTSD and emphasized the importance of depression and anxiety-related symptoms (Elhai et al., 2011).

In summary, comorbid PTSD and AUD is a serious concern in the veteran population (Bowe & Rosenheck, 2015; Ralevski, Olivera-Figueroa, & Petrakis, 2014; Seal et al., 2009) often leading to serious health concerns (Ouimette, Goodwin, & Brown, 2006) and making treatment exceedingly difficult (Ouimette, Moos, & Finney, 2003). While the self-medication model (Leeies, Pagura, Sareen, & Bolton, 2010) has been the most popular for the maintenance of this comorbidity, recent research points to a different mechanism underlying this relationship

(Dvorak et al., 2014; Miller et al., 2006; Read et al., 2014; Simons et al., 2017). It is possible that difficulties in emotion regulation may be responsible for maintaining this relationship between PTSD and AUDs. In the next section, emotion regulation and its connection to both PTSD and alcohol use will be discussed.

Emotion Regulation

Emotion regulation generally refers to how an individual manages and modifies their emotional responses. People may try and regulate their own emotions or someone else's emotions (Gross & Jazaieri, 2014). This regulation seeks to impact the duration, intensity, type, and quality of the emotional response through either effortful or automatic means (Mauss et al., 2006). An example might be trying to act happy at a party even though you just learned that you did not get the promotion you were hoping to get. Emotion regulation happens whenever, whether consciously or unconsciously, emotions are modified.

One way to understand emotion regulation is to look at emotion regulation strategies. These strategies can either be adaptive or maladaptive in nature. The adaptive value of the strategy is dependent on the context, awareness of the emotions, and overall end-goal (Peña-Sarrionandia, Mikolajcsak, & Gross, 2015).

Overall, there are five time points in which an individual can modify their emotional responses (Gross, 1998). These time points can be thought of as different domains in which there are various strategies. These domains are situation selection, situation modification, attentional deployment, cognitive change, and response modulation. Situation selection includes choosing to engage or avoid certain situations. Situation modification focuses on adjusting a situation to change the emotional impact. Attentional deployment is choosing which information we will pay attention to alter our emotions. Cognitive change, which can again be effortful or automatic, is

when we change how we think to change the way we feel. Finally, response modulation is a family of strategies that is reactive in nature and comes after a response has already been generated.

Emotion Regulation in Posttraumatic Stress Disorder and Alcohol Use

Some theories of PTSD stress the importance of emotional processes in the development and maintenance of the disorder (Ehlers & Clark, 2000; Foa & Rothbaum, 1998). While emotional responses that are important to our goals are seen as adaptive (Scherer, Schorr, & Johnstone, 2001), if they are inappropriate, given the context, then they need to be regulated (Gross, 2001). Individuals diagnosed with PTSD tend to have deficits in emotion regulation (Seligowski, Lee, Bardeen, & Orcutt, 2015). People experiencing high PTSD symptoms need to exert more effort in regulating their emotions due to this heightened emotional state. This may mean that it is difficult to modulate emotions, leading to either emotional lability or numbing. This broad emotional dysregulation, has been demonstrated to be the most important factor in those suffering from PTSD symptoms (Seligowski et al., 2015).

Under this assumption, people diagnosed with PTSD have a pathological disruption in their self-regulatory efforts (Kashdan, Breen, & Julan, 2010). Self-regulation is necessary to alter behavioral and/or emotional responses to events. If people are unable to complete these actions, then they may experience functional impairment in their daily life and a diminished quality of life. Prior research has shown that veterans are less responsive to positive, reward cues following combat-related traumatic stressors (Litz, Orsillo, Kaloupek, & Weathers, 2000; Orsillo, Batten, Plumb, Luterek, & Roessner, 2004). This may suggest that veterans suffer from an overregulation of emotion, lending itself to avoidance of trauma-related stimuli and emotional numbing.

Deficits in emotion regulation skills play a central role in alcohol use (Kober & Bolling, 2014; Sher & Grekin, 2007). Alcohol-dependent individuals show difficulty identifying their emotions (de Timary et al., 2008), emotional empathy (Marinotti et al., 2009), and emotional intelligence (Cordovil de Susa Uva et al., 2010). Cross-sectional studies suggest that inefficient regulation strategies lend themselves to both craving and maintenance of alcohol use disorders (Petit et al., 2015). Laboratory settings and longitudinal studies indicate that higher levels of negative affect lead to increased urges to drink and use of alcohol (Birch et al., 2004; Falk, Yi, & Hilton, 2008; Gamble et al., 2010; Sinha et al., 2009). Finally, in veterans, emotion regulation has been implicated as the link between PTSD symptom severity and alcohol use as a transdiagnostic process (Simons et al, 2017; Simons, Wills, & Neal, 2014; Tripp & McDevitt-Murphy, 2015).

Much of the research on emotion regulation, PTSD, and alcohol uses trait-based measures to explore these associations. Currently, there is little research assessing emotion regulation strategies, PTSD symptoms, and alcohol use at the daily level. What is needed is to look at the state level of emotion regulation and its associations with PTSD symptoms. Recently, a state-level scale has been developed (Lavender, Tull, DiLillo, Moore, & Gratz, 2017). Due to PTSD being most associated with broad dysregulation at the trait-level, research could benefit from exploring PTSD symptoms throughout the day and their impact on how people manage or regulate their emotional state. Emotions are dynamic and shift based on environment, cognitive appraisal, and physiological symptoms (Scherer, 2009). PTSD symptom severity also changes frequently throughout the day (Pedersen et al., 2015; Simons et al., 2014), accounting for why someone may have a good day, in regards to symptom severity, or a bad day. Experience Sampling Methods give researchers insight into the dynamic nature of these

constructs and allow for researchers to discuss temporal associations. Cross-sectional studies can hypothesize relationships but do have the specificity or the temporal associations.

Sleep Disturbance

Definition and Prevalence

Sleep plays an important role in maintaining emotional and physical well-being (Institute of Medicine, 2006). Sleep disturbances or disorders happen when there is a change in the normative sleep architecture. Sleep architecture, or the structural organization of normative sleep patterns, can be broken down into two main categories: rapid eye movement (REM) sleep and nonrapid eye movement (NREM) (Dijk & Lazar, 2012). There are various NREM stages that provide different benefits for the body and a different depth of sleep. These stages can be characterized by differences in brain waves, muscle tone, and eye movements. Humans move throughout these stages in a cyclical manner throughout the course of the night (Peigneux, Urbain, & Schmitz, 2012). When a sleep stage is missing or the movement between these stages becomes irregular, a sleep disturbance or a more severe sleep disorder can occur (Zepelin, Siegel, & Tobler, 2005).

Sleep problems are common in Americans with over 50 million Americans suffering from some type of chronic sleep disorder (National Heart, Lung, and Blood Institute, 2003). Currently, there are approximately 90 distinct sleep disorders listed in the International Classification of Sleep Disorders (American Academy of Sleep Medicine, 2005). These disorders can be divided into two broad categories: parasomnias and dyssomnias. Parasomnias are unusual experiences and/or behaviors that occur when sleeping and may include disorders such as nightmare disorder or sleepwalking. Dyssomnias are characterized by a disruption in a

domain of sleep. This may mean that a person has abnormal amount or quality of sleep. Dyssomnias include disorders such as insomnia or narcolepsy (Ohayon, 2011).

In America, sleep is increasingly becoming compromised. On average, an adult needs 7-9 hours of sleep per night for optimal health (Hirshkowitz, et al., 2015). However, more and more adults are reporting that they are sleeping 6 hours or less (Center for Disease Control and Prevention, 2009). There are various reasons for the decrease in sleep duration in adults. The National Sleep Foundation (NSF) suggests that increasing number of electronic devices (NSF, 2015b), prevalence of shiftwork (NSF, 2015a), and inability to prioritize their sleep time (NSF, 2018) all factor in to the decline in sleep duration.

Veterans experience a significant amount of sleep disturbances including Insomnia and Obstructive Sleep Apnea [OSA] (Krakow, Ulibarri, Moore, & McIver, 2015; Mysliwiec et al., 2013). The number of veterans seeking healthcare due to sleep-related problems has been rising steadily (Alexander et al., 2016; Caldwell, Knapik, & Lieberman, 2017). This is a concern for the military because these impairments impact physical and emotional health, operational readiness, increase health-care costs (Troxel et al., 2015) and have poorer treatment outcomes for psychological disorders (Colvonen, Ellison, Haller, & Norman, 2019; Mesa, Dickstein, Wooten, & Chard, 2017). Additionally, PTSD is associated with the highest prevalence of sleep disorders in veteran populations (Alexander et al., 2016).

Even if there is no evidence of a formal sleep disorder, sleep disturbances can cause marked impairments. Sleep disturbances have a deleterious effect on physical health. Sleep loss has been associated with an increased risk of cardiovascular diseases, increased risk for diabetes, obesity, and age-specific mortality (IOM, 2006). There is also a bidirectional relationship between sleep disturbances and psychiatric disorders. It used to be thought that sleep

disturbances were due to psychiatric disorders but newer research suggests that it may also be the case that sleep disturbances may be a risk factor in developing new psychiatric disorders (Krystal, 2012).

Sleep Measurement. There are a variety of ways to measure sleep in adults. Researchers will use polysomnography, actigraphy, various self-report measures, or a combination of these measurements to study sleep. Each of these measurement types has strengths and weaknesses in a research setting.

The gold standard for measuring sleep is polysomnography (PSG; Rundo & Downey 3rd, 2019). This technique uses several electrodes placed on the skin of the skull, face, chest, and legs. The main measures in this technique are electroencephalography, electrooculography, and electromyography. Electrocardiograms and measurements of respiration from respiratory bands and oximeters can also provide additional information for diagnosing sleep disorders.

Electroencephalography (EEG) uses metal electrodes placed on the scalp to measure electrical activity within the brain. These electrodes are placed in the International 10-20 system, a measurement system where the scalp markers or electrodes are placed to correlate with specific cerebral structures, such as the parietal or temporal lobe (Homan, Herman, & Purdy, 1987). Using this system is important for reproducibility between- and within-subjects. The electrical activity picked up by these electrodes is then digitized and cleaned for any remaining artifacts (Peigneux, Urbain, & Schmitz, 2012). Sleep technologists can then identify different patterns based on frequency and amplitude that are most commonly found in specific stages of sleep.

Electrooculography (EOG) uses electrodes placed on the face to measure eye movements. Electrodes can be placed to capture both vertical and horizontal movements by the eye and result in waking eye movements (WEMs), slow eye movements (SEMs), and rapid eye movements

(REMs) (Chokroverty, Bhatt, & Goldhammer, 2005). When a person is awake, quick movements or "deflections' might indicate a person is blinking or saccadic movements, sharp and abrupt movements, might indicate that someone is looking around their environment (Avidan, 2005). SEMs are commonly found in non-REM (NREM) sleep stages and disappear during REM sleep (Chokroverty, Bhatt, & Goldhammer, 2005). REMs are found during REM sleep and are characterized by short bursts of activity in all directions (Chokroverty, Bhatt, & Goldhammer, 2005).

Electromyography (EMG) uses electrodes placed on various parts of the body to measure muscle tone throughout sleep cycles (American Academy of Sleep Technologists, 2012). Muscle tonality changes throughout sleep cycles with muscle atonia commonly occurring during REM sleep (Cygan, Oudiette, Leclair-Visonneau, Leu-Semenescu, & Arnulf, 2010). Often, these electrodes will be placed on the chin and on the shins during sleep studies (Pandi-Perumal, Spence, & BaHammam, 2014). The chin EMG are useful indicators of overall muscle tonality and to assess for bruxism while sleeping. The electrodes placed on the shin can help assess for periodic limb movements which can also disrupt sleep.

The last channels that are seen on most PSGs are focused on heart rate and respiration. A standard electrocardiogram (ECG), two electrodes placed on the chest, provides for a basic measure of cardiac functioning (Pandi-Perumal, Spence, & BaHammam, 2014). Heart Rate Variability (HRV) can also be estimated using the information from ECGs and providing additional information about sleep stages, as well as the body's ability to recover from stress (Stein & Pu, 2012). Respiratory events are also important to screen for during a PSG. Thoracic and abdominal respiratory bands and a nasal cannula are used to identify respiratory events

during sleep stages (Pandi-Perumal, Spence, & BaHammam, 2014). These channels are beneficial to account for any cardiac or respiratory events during various sleep stages.

With PSG, sleep technicians are able to diagnose sleep disorders fairly easily. Unfortunately, PSG is very expensive and usually it needs to be completed in a laboratory setting, making it difficult for more naturalistic research programs. It can also be disruptive to a participant's sleep due to the number of electrodes necessary to measure sleep. For this reason, researchers began to search for other ways to unobtrusively measure sleep.

One instrument that is less intrusive is actigraphy watches. Using the predictable state of immobility that characterizes sleep, researchers have found a way to differentiate between sleep and wakefulness using wrist movements. This is accomplished by having a watch that uses an accelerometer to measure activity levels worn on the non-dominant wrist (Ancoli-Israel, 2005). In most of these watches, researchers can choose how often to collect data, with most creating a data point every minute. There are a variety of algorithms used to process actigraphy data but overall, the American Academy of Sleep Medicine concluded that actigraphy is a useful tool in estimating sleep patterns and assisting in the assessment of sleep disorders (Smith, McCrae, Cheung, Martin, Harrod, Heald, & Carden, 2018).

These devices are inexpensive and widely accessible to researchers, making it a useful tool in sleep research (Silva & Kemp, 2021). Actigraphy has been shown to be useful as a valid means for approximating total sleep time and wakefulness after sleep onset when compared to PSG (Marino, et al., 2013). These watches can be used for long periods of time, giving researchers the ability to examine sleep patterns in natural environments more reliably than with PSGs (Silva & Kemp, 2021). Actigraphy has also been used successfully with veteran

populations and may be more beneficial than sleep diaries due to problems some veterans may experience in recalling their sleep data (Nazem, Forster, Brenner, & Matthews, 2016).

Finally, researchers can use self-report sleep measures. These are an attractive option due to their low cost and the limited time they take for both the researcher and the participant. Many sleep questionnaires provide both qualitative information, such as a participant's mood or how well they believe they slept, and quantitative information, such as sleep duration or how often they woke up throughout the night (Seow, Abdin, Chang, Chong, & Subramaniam, 2018). However, when compared to PSG and actigraphy, it appears that self-report measures may not be accurately measuring or estimating sleep but rather the perception of good sleep (Berger, Obeid, Timmons, & DeMatteo, 2017). This information can be beneficial in a research setting, depending on a researcher's hypothesis.

In conclusion, there are several different ways to measure the various sleep parameters. Researchers must decide what is most important, and most feasible, given their research budget and hypotheses. Ideally, a researcher would use some combination of the aforementioned tools to get the most well-rounded view of a participant's sleep habits.

Sleep Disturbance and Posttraumatic Stress Symptoms

Sleep disturbance is one of the most common symptoms following a deployment (Hoge et al., 2007; King et al., 2017); with as many as 93.5% of OEF/OIF veterans reporting difficulties with either sleep onset or maintenance (Lew et al., 2010). Sleep disturbances prior to being deployed have also been shown to be a risk factor in later developing posttraumatic stress symptoms (Koffel, Polusny, Arbisi, & Erbes, 2013; van Liempt, van Zuiden, Westenberg, Super, & Vermetten, 2013). This suggests that sleep and PTSD are bi-directionally linked in the literature and important for further study in the veteran population.

Sleep disturbances are found in two of the symptom clusters. Nightmares are a diagnostic criterion in the intrusion's symptom cluster (American Psychiatric Association, 2013). Individuals may experience recurrent, distressing dreams and attempt to avoid sleep to minimize the chance of these dreams. This is consistent with theoretical models that suggest there is pre-sleep anxiety which leads to difficulty initiating sleep (Kobayashi et al., 2008). However, distressing dreams do not simply delay the onset of sleep, but can disrupt sleep throughout the night with nocturnal awakenings due to these dreams, creating difficulties in both sleep onset and maintenance (Babson et al., 2011). Difficulty falling or staying asleep is a diagnostic criterion within the changes in arousal and reactivity symptom cluster. This heightened state of arousal may delay sleep onset, consistent with hyperarousal-based theoretical models of sleep and PTSD problems (Woodward et al., 2003; Weston, 2014). This model suggests that hyperarousal drives the various symptoms clusters, including sleep disturbances but findings have been inconsistent in that hyperarousal may not account for the entire picture in rrgard to sleep disturbances (Bonnet & Arand, 2010).

Sleep disturbances following traumatic events and increased sympatho-vagal tone during REM sleep heighten the chance of developing PTSD (Harvey & Bryant, 1998, Koren, Arnon, Lavie, & Klein, 2002; Mellman, Bustamante, Fins, Pigeon, & Nolan, 2002; Mellman, Knorr, Pigeon, Leiter, Akay, 2004). The increased sympatho-vagal tone during REM sleep results in increased activity in the sympathetic nervous system (Knorr, Akay, & Mellman, 2003) and the noradrenergic system (Mellman & Hipolito, 2006). Those diagnosed with PTSD experience sustained hyperactivity in these systems, causing difficulties in regulating autonomic stress responses and arousal (Sherin & Nemeroff, 2011).

The study of neurobiological mechanisms underlying PTSD and sleep disturbances is still

a relatively new field. Existing models focus primarily on an increase in activity in the medial prefrontal cortex (mPFC) and the amygdala (Germain, Buysse, Nofzinger, 2008). In healthy individuals, there is a higher level of neuronal activity in the amygdala during REM sleep compared to NREM sleep and wakefulness states (Braun, et al., 1997; Maquet, et al., 1997; Nofzinger, et al., 2002) and higher activation in the mPFC during NREM sleep (Germain, Buysse, & Nofzinger, 2008). Compared to healthy controls, those diagnosed with PTSD show a hyper-responsiveness of the amygdala when viewing threatening stimuli and dampened responsiveness of the mPFC (Lanius et al., 2002; Lanius et al., 2003; Rauch et al., 2000; Shin et al., 2001; Shin et al., 2005). Both the amygdala and the mPFC also play a role in fear extinction and fear extinction recall in healthy individuals (Cheng, Knight, Smith, Stein, & Helmsetter, 2003; LaBar, Gatenby, Gore, LeDoux, & Phelps, 1998; Phelps, Delgado, Nearing, & Ledoux, 2004). The mPFC is crucial for inhibiting the responsiveness of the amygdala, thus with the mPFC being dampened in those diagnosed with PTSD, there is increased fear conditioning while struggling with fear extinction (Orr et al., 2000).

Currently, there are conflicting associations in the research using polysomnography to compare healthy controls and those diagnosed with PTSD. Some studies have shown the expected REM sleep anomalies showing increased activation in the amygdala in PTSD patients (Levin, & Nielsen, 2007; Mellman, Kumar, Kulick-Bell, Kumar, & Nolan, 1995; Mellman, Nolan, Hebding, Kulick-Bell, & Dominguez, 1997; Ross, et al., 1994), while others did not (Hurwitz, Mahowald, Kuskowski, & Engdahl, 1998; Woodward, Bliwise, Friedman, & Gusman, 1996). Amplified amygdala activation and reduced activation in the mPFC could be the reason for nightmares during REM sleep and contribute to difficulty falling asleep (Germain, Buysse, & Nofzinger, 2008). These functional abnormalities of the amygdala and mPFC are assumed to be

instrumental in the etiology and maintenance of PTSD, but they may also impact REM and NREM sleep (Germain, Buysse, & Nofzinger, 2008). Unfortunately, the neurobiological correlates of REM and NREM sleep in those diagnosed with PTSD have not been adequately explored.

Sleep Disturbance and Emotion Regulation

While the association between emotion regulation and sleep is well-known, at the between-person level, it is unclear the direction of this relationship. Previous research suggests that sleep disturbance lends itself to emotional reactivity and difficulties in emotion regulation (Baglioni, Spiegelhalder, Lombardo, & Riedmann, 2010; Deliens, Gilson, & Peigneux, 2014). Using a sleep deprivation protocol and an event-related fMRI design, sleep deprivation the night prior impacted emotion regulatory strategies the following day (Yoo, Gujar, Hu, Jolesz, & Walker, 2007). Sleep deprivation can also increase negative reactions to goal-thwarting events and decrease positive emotions when events are goal-enhancing (Zohar, Tzischinsky, Epsten, & Lavie, 2005).

Prior research also suggests that it is important to study these processes together, rather than in isolation because they appear to be transdiagnostic processes that are associated with the severity of symptoms (Fairholme et al., 2013). Sleep disturbance and emotion dysregulation can lead to relapse (Ebert, Hopfinger, Bockting, & Berking, 2017; Harvey, 2011) and exacerbate mood disorder, trauma-related disorder, and anxiety related disorder symptoms (Fairholme et al., 2013; Klumpp et al., 2017; Pickett, Barbaro, & Mello, 2016). Furthermore, theorists suggest that emotion regulation and sleep disturbance have a reciprocal relationship, in that sleep disturbance can increase negative mood while decreasing the ability to regulate these emotions and

difficulties in emotion regulation can disrupt that night's sleep (Harvey, Murray, Chandler, & Soehner 2011).

Sleep Disturbance and Alcohol

The relationship between sleep disturbance and alcohol use is likely bidirectional, with disturbed sleep associated with greater alcohol consumption and alcohol consumption disrupting normal sleep patterns (Conroy & Arnedt, 2014). Alcohol is considered a depressant and may be used to initiate sleep (Roehrs, Papineau, Rosenthal, & Roth, 1999). However, alcohol has also been shown to disrupt the restorative aspects of sleep, impairing overall sleep quality throughout the night (Stein & Friedman, 2005). Individuals who are dependent on alcohol show difficulty in transitioning from sleep to full wakefulness, less time in REM sleep, and an overall shorter total sleep time (Conroy & Arnedt, 2014). However, problematic sleep patterns can also precede alcohol consumption. Longitudinal studies demonstrated that sleep disturbances earlier in life predispose people to risky alcohol use (Roane & Taylor, 2008; Wong & Brower, 2012; Wong, Brower, Fitzgerald, & Zucker, 2004; Wong, Brower, Nigg, & Zucker, 2010).

Sleep, PTSD, Emotion Regulation, and Alcohol

Previous research has looked at these various relationships in isolation. For example, research shows, via cross-sectional and longitudinal studies, that there are strong relationships between sleep disturbances and alcohol use (Arnedt, Conroy, Armitage, & Brower, 2011; Wong & Brower, 2012; Wong, Brower, Nigg, & Tucker, 2010) and between sleep and PTSD (Koffel, Polusny, Arbisi, & Erbes, 2013; van Liempt, 2012; van Liempt, van Zuiden, Westenberg, Super, & Vermetten, 2013). One cross-sectional study showed differential associations between PTSD symptom clusters, sleep disturbance, and alcohol use (Surette et al., 2017). After removing sleep-related questions, however, only negative alterations in cognition and mood were associated with

sleep disturbances. In this study, arousal symptoms associated with alcohol problems, regardless of sleep disturbances.

In respect to daily associations, there is a suggestion of a temporal sequence for how these problems play out. In a previous study of 90 veterans, sleep disturbances exacerbated PTSD symptoms the following the day, but an elevated level of PTSD symptoms did not necessarily mean the participant could expect a difficult night of sleep (Surette et al., 2015). As discussed later in the current study section, we are basing the directional hypothesis of the proposed study on these previous findings in which sleep disturbances proceeded (rather than followed) PTSD symptoms.

Sleep disturbances and emotion dysregulation are both etiological and maintaining factors for a variety of psychological disorders, however they are often studied in isolation rather than in an integrated model. Currently, there is only one other known study that attempts to integrate sleep disturbances, emotion regulation, PTSD symptoms, and alcohol problems (Fairholme et al., 2013). Both sleep disturbance and emotion dysregulation, using the Difficulties in Emotion Regulation Scale (Gratz & Roemer, 2004) to account for emotion dysregulation, were associated with unique variance in both PTSD and alcohol dependence. While this study speaks to the importance of sleep disturbance and emotion dysregulation in both PTSD and alcohol misuse, its cross-sectional design limits the ability to make conclusions about the temporal sequence of these events. Further research is needed to elucidate a model that not only integrates these constructs (i.e., sleep disturbance, PTSD symptoms, emotional regulation and alcohol use) but that also looks at temporal associations at the daily level.

Covariates

Gender: Sleep, PTSD, Alcohol Use, and Emotion Regulation

There are some gender differences in sleep characteristics. Women tend to maintain longer periods of Slow Wave Sleep or the deeper, restorative stage 3 NREM sleep than men. Studies are conflicted over sleep latency, with some suggesting that women fall asleep faster and others suggesting that men do (Silva et al., 2008). Overall, men tend to complain more of excessive daytime drowsiness, have more apnea and arousal markers, and spend more time in the shallower stage 1 of NREM sleep (Ancoli-Israel, 2000; Kobayashi et al., 1998; Silva et al., 2008).

In the PTSD literature, there are also differences between men and women. Women are at an increased risk for developing the disorder following a traumatic stressor (Breslau & Anthony, 2007). Even if they do not meet the full criteria, they are more likely to exhibit symptoms than their male counterparts (Tolin & Foa, 2006). The research on veteran populations is more conflicted. Some research has shown female veterans to be as resilient as male veterans in the current conflicts (Jacobson, Donoho, Crum-Cianflone, & Maguen, 2016; Vogt et al., 2011), while other research suggests that veterans follow a similar pattern to civilians in that females are more likely to exhibit posttraumatic stress symptoms or develop PTSD (Hourani, Williams, Bray, & Kandel, 2015; Irish, et al., 2010; Skopp, et al., 2011; Smith et al., 2008).

It has been hypothesized that societal factors are slowly closing the gap in the gender differences in alcohol use (Erol & Karpyak, 2015). Historically, men are more likely to consume alcohol in higher quantities than women (Center for Behavioral Health Statistics and Quality, 2016) and to begin drinking at earlier ages (Buu et al., 2014). They are also more likely to report alcohol-related consequences (Benton, et al., 2004). Finally, women are more likely to use alcohol in larger quantities as a means of coping than men (Lehavot et al., 2014).

For emotion regulation, there is a popularly held belief that women are the more emotional gender with men being more likely to avoid expressing their emotions (Barrett & Bliss-Moreau, 2009). Women are more likely to engage in more internal strategies, such as rumination, to regulate their emotions than men, who engage in more active, external strategies (Nolen-Hoeksema, 2012). Women are also more likely to engage in a variety of emotion regulation strategies, more so than men (Tamres, Janicki, & Helgeson, 2002). Finally, men are more likely to engage in strategies that require minimal effortful control, making some of their emotion regulation strategies appear impulsive and focused on short-term rewards in an attempt to mitigate negative feelings (Nolen-Hoeksema, 2012). In summary, given the known gender differences in outcomes, the current study will include gender as an important covariate in all models.

Age: Sleep, PTSD, Alcohol Use, and Emotion Regulation

Throughout the lifespan, sleep architecture changes. Naturally, a person will experience changes in sleep onset and maintenance, how much time is spent in each stage of sleep, and overall sleep efficiency as a function of age. Generally, sleep efficiency, conceptualized as how well a person initiates and maintains sleep, declines with age (Carskadon & Rechtschaffen, 2005). In adults, this change in sleep efficiency is due to awakening earlier and an overall decrease in sleep consolidation (Dijk, Duffy, & Czeisler, 2000). Most importantly, stage 3 sleep or Slow Wave Sleep (SWS), fluctuates over the lifespan. As an infant more time is spent in REM sleep (Frank, 2011), later shifting to more SWS throughout childhood (Feinburg & Campbell, 2010). SWS further decreases throughout the middle years of age into the older adult years (Carrier et al., 2011; Moe, Vitiello, Larsen, & Prinz, 1995) This increases how often an individual wakes up throughout the night (Ancoli-Israel, 2005) and disrupts memory

consolidation (Walker, 2009). These changes in sleep across the lifespan can be explained by either a natural change in circadian rhythmicity or changes in sleep homeostasis (Skeldon, Derks, & Dijk, 2016).

PTSD changes across the lifespan. Prior research has suggested that young to middle-aged adults have higher prevalence rates of PTSD; however, more recent studies suggest that older adults are exposed to traumatic events at a higher rate (Reynolds, Peitrzak, Mackenzie, Chou, & Sareen, 2016). This suggests that the research in this area is mixed which could be due to several methodological factors such as the sample that is assessed or the use of different diagnostic criteria. Unfortunately, there is limited research examining lifespan development in PTSD. One comprehensive epidemiological study suggests that increasing age in associated with less severe PTSD profiles and lower odds of psychiatric comorbidity (Reynolds, et al., 2016).

There also may be some differences in symptom cluster expression across the lifespan. Older populations may not experience as many intrusive symptoms or avoidance symptoms if the traumatic event in question is farther in the past, suggesting that the recency of the event plays a role in recall of the event and the appraisal of the event (Pietrzak, Goldstein, Southwick, & Grant, 2012). Older adults may also be less likely to endorse negative affect, scoring lower on symptoms related to negative alterations in cognition and mood (Spaniol, Voss, & Grady, 2008), and they may describe symptoms in a more somatic way, particularly in regards to hyperarousal symptoms (van Zelst & Beekman, 2012). These changes across the lifespan may suggest that researchers should use different tools to assess PTSD dependent on the age bracket of the participant (Konnert & Wong, 2014), particularly if they are going to assess participants that are considered older adults or seniors (aged 65+).

In regards to alcohol use, risky drinking behaviors are more or less apparent as a function of age. Adolescents are more likely to engage in risky drinking behavior, such as binge drinking, and engage in risky activities while drinking, such as driving at high rates of speed, but they tend to drink less than young adults (Windle, 2016). Young adults, particularly in the emerging adulthood period, are more likely to engage in heavy drinking, especially if they are in college where it is seen as acceptable (Merrill & Carey, 2016). Finally, older adults tend to use alcohol less frequently than the younger cohorts, however, this might be changing as the 'Baby Boomer' generation transitions into older adulthood which creates a host of new problems including how to diagnose and treat this generation (Barry & Blow, 2016).

Finally, emotion regulation literature often focuses on infancy and early childhood, but these developmental processes continue throughout the lifespan (Zimmerman & Thompson, 2014). Emotion regulation is a complex process and it is not as simple as saying that the older a person is, the better they are at emotion regulation. Instead, the usefulness of a given emotion regulation strategy, such as suppression, may change as a function of age and social context (Cole, 2014). Cole (2014) suggests that researchers should recognize that the function of emotions at any given age may influence the regulation of these emotions, and that all emotions and their regulation need to be understood within a social context, regardless of age. In summary, age and gender are important covariates that will be statistically controlled in the study.

Present Research

In this study, experience sampling was used to examine temporal associations between sleep disturbance, PTSD symptoms, emotion regulation (through difficulties modulating emotional and behavioral responses), and alcohol use. Methodologically, experience sampling was used where variables were measured daily by random brief questionnaires, a morning

assessment, and an evening assessment. This captured veterans' daily experiences and fluctuations in symptoms throughout the day. An approximation of objective sleep was obtained using actigraphy. It is hypothesized that sleep disturbances will be significantly associated with PTSD symptoms and emotion regulation the following day, which in turn will be significantly associated with an increase in alcohol use, while controlling for age and gender (Figure 1).

Method

Participants

This data was collected as part of a pilot NIH grant for translational research funded via Great Plains IDeA-CTR (Dr. Raluca Simons, Principal Investigator, Dr. Jeffrey Simons, Co-Investigator). Participants were recruited from a database of previous veterans who have agreed to be contacted for research studies, from the university veteran's group, and via advertisements. Participants were between the ages of 18 and 60. Participants must have been deployed to either Iraq or Afghanistan at least once and have drank any alcohol in the past month. If they exhibited any suicidal ideation, psychosis, or severe substance use that would contraindicate participation, they were excluded. Participants were not excluded for comorbid conditions.

Power Analysis

A priori power analyses for the parent study determined that 90 participants, with 45 in the intervention and 45 in the control group, would be needed to achieve 80% power to detect an effect size of 0.53 between intervention and control with a significance level (alpha) or 0.05 using a one-sided two-sample t-test (Machin, Campbell, Fayers, & Pinol, 1997; Cohen, 1992). Unfortunately, only 59 participants were recruited. Post-hoc power analyses were then conducted. On average, the models had 51 individuals with 10 days of data. This information was used for the post-hoc analyses. For within-person correlations, a sensitivity analysis was conducted in G*power, indicating that with 510 Level 1 observations, power is at least 80% for

small correlations of >0.12. For between-person correlations, the sensitivity analysis indicated that with 51 observations, power would be 80% for medium to large correlations of >0.38. Then, A Monte Carlo simulation for a Mulitlevel Model with a continuous outcome, two continuous Level 1 predictors, and one continuous Level 2 predictor (Mooney, 1997). Data was simulated for 51 individuals with 10 days of data each. The within-person effects were assumed to be small (β=0.14) and the predictors weakly correlated (r=0.10) accounting for approximately 5% of the Level 1 variance. The level 2 effect was assumed to be medium (β=0.36) and and accounted for 13% of the variance at Level 2. The Monte Carlo simulation had 10,000 replicates. The simulation indicated power ≥ 86% to detect small within-person effects and a power of 75% to detect the medium between-person effects.

Procedure

Study Protocol

Participants were recruited to complete a 49-day study. A figure of the study design can be found in Figure 2. During the study, participants were asked to complete a battery of questionnaires during the baseline visit. Following Covid-19, changes were made to allow for consenting and beginning the study without the need for in-person appointments. Next, they were randomized to either an intervention group, where they completed an at-home PDF sleep intervention, or a control group. The PDF intervention was a series of psychoeducational PDFs based on Cognitive Behavioral Therapy for Insomnia designed to help participants improve their sleep hygiene (Ho et al., 2015). In the first two weeks of the study, participants in both groups answered questions in the morning, evening, and at random times throughout the day while wearing an actigraphy watch. For the first five weeks of the study, participants in the intervention group completed the PDF intervention. The last two weeks of the study consisted of

all participants responding to questions during the morning, evening, and at random times during the day while wearing an actigraphy watch for 24-hours a day over the recording period. For this study, the first two weeks of data were used. Further information about the data collected for this study will follow in the subsequent sections.

Recruitment. Participants were recruited using a pre-existing database of veterans who consented to be contacted for further studies, local veteran groups on campus, and via newspaper advertisements. Veterans who were between the ages of 18 and 60 at the start of the study, who had been deployed to either Iraq or Afghanistan and who had consumed alcohol in the past month were eligible. Participants were screened for current psychotic symptoms, suicidal ideations, or a severe substance use disorder. If any of these symptoms were severe and contraindicated participation in the study, they were excluded. They were then referred to the VA, a community mental health center, or the university mental health center. Participants received $25 during the first study visit and $150 per week contingent on the number of responses for the brief assessments completed on the MetricWire application on their phone. The intervention group received an additional $20 for completing the CBT-I intervention.

Baseline Visit. Participants were initially asked to read an informed consent form. This form detailed how their responses will be kept confidential, their right to decline to participate or cease participation at any time, and the purpose of the study. At the baseline appointment, a research assistant administered the MINI International Neuropsychiatric Interview (MINI; Sheehan et al., 1998). If the participant was still eligible, they completed a number of baseline measures including the PSQI, PSQI-A, PCL-5, and DDQ-M.

Experience Sampling Study. Eligible participants were issued an actiwatch to wear that measured activity for an approximation of sleep. Participants wore this watch for two weeks at

the beginning of the study and in the last two weeks of the study. They also downloaded the MetricWire application (MetricWire Inc., 2017) to their phone. MetricWire uses symmetric Advanced Encryption Standard, 256 bit encryption (AES-256) for data storage. Actigraphy data was transmitted over HTTPS (TLS 1.2). Participants were trained in using this application prior to leaving the laboratory. The MetricWire application asked various questions regarding alcohol use, PTSD symptoms, and emotion regulation at random intervals, approximately every two hours, as well as having a morning and evening questionnaire. Upon waking, the participants were able to request the morning assessment prior to 10:00 am. They then received random assessments, approximately every two hours, from 10:00 am until 2:00 am. These assessments were configured to be around two minutes long and consisted of the same questions at random times during the aforementioned time period. These assessments included questions regarding the participants physical location, PTSD symptoms, alcohol use, and difficulties in emotion regulation.These assessments came at random times and were not at the request of participants. If participants were unable to answer the questionnaires at that time, they would be skipped. Participants were able to shut off these assessments during the time that they were trying to sleep. The participants wore the watch and completed experience sampling questionnaires for the first two weeks and the last two weeks of the study. The first two weeks of data were used in this study.

Baseline Measures

Demographic Information. Demographic information such as age, gender, ethnicity, race, and military history were obtained from self-report. We also asked if the participants were using any devices at night due to sleep-disordered breathing or if they engaged in any shift work

(working overnight shifts or rotating shifts) over the past 6 months. This information was used to describe participants.

PTSD Symptoms. Posttraumatic Stress Disorder Symptoms was assessed using the PTSD Checklist – DSM-5 (PCL-5; Weathers, Litz, Keane, Palmieri, Marx, & Schnurr, 2013). Participants were asked about PTSD symptoms for the previous month and rated their symptoms on a 5-point scale with 0 = Not at all and 4 = Extremely. Participants received a score for overall symptom severity. The PCL-5 has demonstrated high internal consistency ($\alpha = .94$), discriminant validity, and convergent validity (Blevins, Weathers, Davis, Witte, & Domino, 2015).

Alcohol Consumption. Average alcohol consumption in the past month was measured using the DDQ-M (Dimeff, Baer, Kivlahan, & Marlatt, 1999). Participants were asked to fill in the average number of drinks they have and the average number of hours that they drink for a given day. The number of drinks were divided by the number of drinking days to get a measure of typical alcohol consumption. This was also used to describe the sample population.

Subjective Sleep Disturbances. Overall subjective sleep quality was assessed using the Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, & Kupler, 1989). The PSQI measures several domains including: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction for the previous month. The first four questions ask about the usual bedtime, length of time it takes to fall asleep, when the participant usually wakes up, and general sleep duration. Questions 5-8 use an anchored rating scale to determine general sleep disturbances (e.g., waking up in the middle or feeling too hot), if they use medication to fall asleep, if they have trouble staying awake during common daily tasks, or having enthusiasm to get things done, where 0 indicates that the participant has had no problem with these in that past month and 3 indicates that this

problem has occurred three or more times a week. The final question also uses an anchored rating scale, where 0 = Very Good and 3 = Very bad to ask about overall subjective quality of sleep. The seven component scales were added together to get an overall Global PSQI Score. If participants receive a 5 or higher, this indicates poor sleep quality. The PSQI has been shown to differentiate between 'good' and 'poor' sleepers, and has demonstrated a high internal reliability with an overall Cronbach's alpha coefficient of 0.83 (Buysse, et al., 1989). This measure provided a subjective sleep disturbance score for participants.

Trauma-Related Sleep Disturbances. Trauma-related sleep disturbances were measured using the Pittsburgh Sleep Quality Index Addendum for Posttraumatic Stress Disorder (PSQI-A; Germain et al., 2005). The PSQI-A includes seven different sleep disturbances that are commonly reported by adults with PTSD (e.g., nightmares of the traumatic experience). Items are rated on an anchored rating scale where 0 indicates no problem in the past month and 3 indicates three or more times a week. If a participant scores 4 or higher, this suggests that the participant has PTSD. This questionnaire has been validated in veterans (Insana, Hall, Buysse, & Germain, 2013). This was used to describe the study sample.

Emotion Regulation. Trait-based emotion regulation was measured using the Difficulties in Emotion Regulation Scale (Gratz & Roemer, 2004). The DERS includes 36 items with responses ranging from almost never to almost always. There are several subscales in the DERS including: a lack of emotional awareness, lack of emotional clarity, inability to engage in goal-direct behaviors, limited strategies to regulate emotions, limited acceptance of emotional responses, and difficulty with impulse control. We used the limited strategies to regulate emotions subscale for a trait-level measure that is similar to the state-level difficulties modulating emotional responses discussed below ($\alpha = .89$ in this sample). Previous research has

shown this scale to have high internal consistency (α = .93), good test-retest reliability, and acceptable construct and predictive validity (Gratz & Roemer, 2004).

Experience Sampling Measures

Objective Sleep Disturbances. The Readiband™ (Fatigue Science, Honolulu, USA) is an actigraphic device that has been shown to have good validity when compared to polysomnography (Russell, Caldwell, Arand, Meyers, Wubbels, & Downs, 2011). Participants were asked to wear these devices on their non-dominant wrists for 24 hours a day during two week recording periods at the beginning and the end of the study, with the exception of bathing or swimming. The first two weeks of data were used for this study. While the actigraph provides several sleep parameters, sleep efficiency, or the total time in bed divided by total sleep time, was used for an approximation of sleep disturbance. Total sleep time, or minutes asleep, was used for exploratory analyses.

PTSD Symptoms. PTSD symptoms were assessed during the nine random assessments throughout the day. Participants were asked which symptoms they have experienced in the past 30 minutes. They were able to select symptoms from a modified version of the PCL-5 (Weathers, Litz, Keane, Palmieri, Marx, & Schnurr, 2013). Items that were endorsed throughout the day were used as the within-person PTSD score in analyses. This version has been successfully used in a prior study with OIF/OEF veterans (Gaher et al., 2014).

Alcohol Consumption. Alcohol consumption was assessed throughout the day during the nine random assessments. Participants were asked how many standard drinks they had consumed over the past 30 minutes on an 11-point scale from 0 drinks in the past 30 minutes to 10 or more drinks in the past 30 minutes. The total number of drinks throughout the day was

used as an outcome variable. Previous research has supported the use of this type of assessment by comparing it with transdermal alcohol monitoring (Simons, Wills, Emery, & Marks, 2015).

Emotion Regulation. Participants were asked about their ability to modulate their emotions in the past 30 minutes using the Limited Ability to Modulate Current Emotional and Behavioral Responses Subscale (Modulate) of the State Difficulties in Emotion Regulation Scale (S-DERS; Lavender, Tull, DiLillo, Messman-Moore, & Gratz, 2015). There are 7-items that will be assessed on a 5-point scale, with 1 = not at all and 5 = completely. Examples of Modulate items include "My emotions feel overwhelming," or "I am having difficulty controlling my behaviors." Research suggests that the S-DERS is a reliable and valid measure of state-based emotion dysregulation (Lavender et al., 2017). Daytime assessment scores were averaged and the mean was used in the analyses.

Analysis Plan

Data Handling and Preparation

Stata 13 (StataCorp, 2013) was used to test the proposed analysis. Where appropriate, mean full-day scores and subscale scores were calculated. Analyses were conducted to examine the distribution, range, skewness, and kurtosis of variables. Variables of sleep efficiency, total sleep time, and elapsed time were scaled due to variance. Correlations of variables at the between- and within-person level were calculated. Gender and age were controlled for in the final models. Day of the week indicators and elapsed time in the study were also included in the models. The hypothesis was tested using a two-stage approach. Figure 3 provides a visual example of this approach.

Multilevel Models

Stage 1. In stage 1 residual scores were estimated for full-day drinks, PTSD symptoms scores throughout the day, sleep efficiency, and emotion regulation scores. These allow for an estimation of lagged within-person effects. These scores reflect deviations from a person's expected score on a given day with a person-mean of zero. A multilevel model was estimated for each of these four constructs. The models included elapsed time in the study, day of the week indicators, a dummy-coded variable for if the participants were in the intervention or not, and an interaction term for intervention by elapsed time in the study. This removed temporal trend and day of the week effects. Potential curvilinear effects were assessed using a squared elapsed time variable and an interaction with this variable and intervention. Each model included random intercepts and random slopes for time variables. In the alcohol consumption model, only elapsed time had a random slope in the quadratic model. Alcohol consumption was modeled using a negative binomial reference distribution as a count variable. An additional exposure variable was added to this model which was equal to the number of assessments completed that day. PTSD symptoms, sleep efficiency, and emotion dysregulation were modeled as continuous outcomes. Residual scores were then estimated for each model. In this stage, there were no significant associations between intervention or intervention by time variables and the outcome variables. These residual scores were used as predictors in the next stage. PTSD symptoms, alcohol consumption and emotion dysregulation were lagged by one day to have the preceding days scores as a predictor for the following day. These scores were also used to account for autoregressive effects in their respective models, to model how a preceding days score might predict the following day's score (e.g., how alcohol consumption the preceding day predicts alcohol consumption the following day). Sleep variables were inherently lagged since they were collected the evening before.

Stage 2. Next, the calculated residual scores of alcohol consumption, PTSD symptoms, sleep efficiency, and emotion dysregulation from experience sampling data were used as predictors in the analytic models. Use of the residual scores provides a robust test that controls for temporal trends, autocorrelation, and between-person variation. Specifically, PTSD symptoms, emotion dysregulation, and alcohol consumption residuals at $t - 1$ were used to predict the various outcomes at time t. There were three models, with alcohol consumption, PTSD symptoms, and emotion dysregulation as outcomes. Each included an autoregressive lagged effect, elapsed time, day of the week indicators, intervention, interaction effects of intervention and elapsed time, age, and sex. A random intercept was specified in each model. Random slopes were also tested in these models and those that were able to be estimated with substantial variance were included in the final models.

Exploratory Analyses

Exploratory analyses were then conducted using a similar approach with two additional sleep variables. The first, Total Sleep Time, is the number of minutes of that participant was asleep in bed. This was used as additional objective approximation of sleep. This variable gives a more accurate view of how long a participant slept but does not provide any information regarding the quality of the sleep or how much of an opportunity that a participant has to sleep. This was scaled by 60 to give the time in bed by hours. The second variable was a subjective measure of how rested a participant felt. They were asked to rate on a 7-point scale how rested they felt in the morning assessments, with higher scores being indicative of feeling more rested.

Similar to the main analyses, these models were performed in two stages. First, residuals were estimated for Total Sleep Time and subjective sleep. The models included elapsed time in the study, day of the week indicators, a dummy-coded variable for if the participants were in the

intervention or not, and an interaction term for intervention by elapsed time in study. This removed temporal trend and day of the week effects. Potential curvilinear effects were assessed using a squared elapsed time variable and an interaction with this variable and intervention. Each model included random intercepts and random slopes for time variables. In the second stage, six models were estimated where PTSD symptoms, emotion dysregulation, and alcohol consumption were the outcomes. Lagged residuals of these were also used as predictors in the model and the sleep residuals were included in the model. Random intercepts were specified in each model. Random slopes were examined and included if there was substantial variance. Time, day of the week, intervention, an interaction between intervention and time, gender, and sex were included in these models.

Results

Protocol Compliance

While 63 participants were recruited, 59 participants actually completed the study. There were a possible 882 recording person days (63 x 14 days) in the analysis sample. Participants completed 684 days (78%) of the possible days with sleep data. During the two week recording period, participants completed four or more random assessments on 86.8% of the recording days.There are discrepancies in the number of days with data because participants were asked to both complete questionnaires and wear the actigraphy watch. The data suggests that participants may not have worn the watch on all recording days, lending itself to less sleep data than experience sampling data. On average, participants wore the actigrapy watch for 12.2 days during the two-week recording period. Participants were also completing questionnaires on the MetricWire application during this time.

Descriptive Statistics

Descriptive statistics for Level 1 and Level 2 variables can be found in Table 2. There are discrepancies is N for some of these variables in Level 1 if participants did not answer those questions during the baseline questionnaire. Level 2 variables are during the two week recording period, and capture the full N of 59 participants. Correlations for these variables can be found in Table 3. Intraclass Correlation Coefficients (ICC) can be found in Table 4. Of the participants, 13.6% (*n*=8) or participants endorsed using a CPAP or BiPAP machine and 25.42% (*n*=15) engaged in shiftwork. This might lend itself to sleep disturbances not related to PTSD symptoms or limit the number of assessments completed based on when they might be sleeping for their shift work. The majority of the participants identified as White (84.75%, *n*=50) and non-Hispanic (91.53%, *n*=54). In regard to military branch, the majority identified being in the Army (49.15%, *n*=29), followed by the Air Force (13.56%, *n*=8), Marines (10.17%, *n*=6), and the Navy (6.78%, *n*=4). None of the participants served in the Coast Guard and 42.37% (*n*=25) served as a National Guard member. Participants averaged two to three deployments during the course of their military career.

PTSD Symptoms

In this sample, PTSD symptom severity was generally below the suggested cut-point of 33 (Weathers et al., 2013), with 25.42% above this cut-point (*M*=20.37 *SD*=18.81). This suggests that many participants would not be experiencing clinically significant symptoms during the duration of this study. This was echoed in the daily assessments with participants endorsing experiencing less than one symptom per each assessment (*M*=0.70 *SD*=1.50). The ICC was 0.73, suggesting 27% of the variance is at the within-person level. PTSD symptoms were significantly positively correlated with trauma-related sleep disturbances, general sleep disturbances, alcohol consumption, and emotion regulation at the between-person level. PTSD symptoms were

significantly negatively correlated with emotion regulation, and subjective sleep, and significantly positively correlated with alcohol consumption and sleep efficiency at the within-person level.

Sleep Disturbances

Scores for baseline sleep disturbance ranged from 6-20 (*M*=12.64 *SD*=3.63) indicating that every participant in this study is considered a "poor sleeper," since they are above the cut-off of 5 (Buysse et al., 1989). Participants were also asked to complete the PSQI-A, where sleep disturbances are specific to PTSD. Scores ranged from 0-15 ((*M*=4 *SD*=3.66) with 57.63% scoring below the cut-off of 4, suggesting that these sleep disturbances are not indicative of PTSD but rather other disordered sleep. For experience sampling measures, sleep efficiency scores ranged from 37.2 – 100.8 (*M*=82.93 *SD*=11.56). The sleep efficiency score is a calculated score from actigraphy measures, created from total sleep time divided by time in bed. Since this is calculated based on an algorithm, it is possible that some efficiency scores could be over 100% (*n*=6). The sleep efficiency score is calculated by time asleep divided by time in bed, then multipled by 100. If the actigraphy watch believes the person to be asleep, but out of bed (which might happen as a function of activity levels, potentially from a partner moving in bed) then the score might be over 100%. This would be a discrepancy of a few minutes. A score of 80% or higher is considered a normal sleep efficiency (Desjardins, Lapierre, Hudon, & Desgagne, 2019), suggesting that on average recorded sleep nights were considered in the normal range. Participants slept on average 6.5 hours (*M*=6.44 *SD*=1.84) and rated their sleep as generally neither good nor bad (*M*=2.89 *SD*=1.76). ICCs for sleep variables were 0.53 for sleep efficiency, 0.30 for total sleep time, and 0.52 for subjective sleep. Trauma-related sleep was significantly positively correlated with general sleep disturbances, PTSD symptoms, and emotion regulation

and significantly negatively associated with alcohol consumption at the between-person level. General sleep disturbances were only significantly positively correlated with PTSD symptoms, alcohol consumption, and emotion regulation at the between-person level. At the within-person level, sleep efficiency was significantly positively correlated with PTSD symptoms and total sleep time and significantly negatively correlated with subjective sleep and emotion regulation. Subjective sleep at the within-person level was significantly positively correlated with emotion regulation and significantly negatively associated with sleep efficiency, PTSD symptoms, and alcohol consumption. Total sleep time at the within-person level was significantly associated positively with sleep efficiency and negatively with emotion regulation.

Alcohol Consumption

At baseline, 75.44% of participants endorsed drinking within the past month. The average number of drinks during a typical week was 8.27 (*SD*=11.81), with alcohol consumption ranging from 0-64 drinks in a week. During the assessment period of the first two weeks, drinks were calculated throughout the day. The participants averaged 1.82 (*SD*=3.48) drinks per day, with the number of drinks ranging from 0-28. The ICC was 0.53, suggesting 47% of the variance is at the within-person level. Alcohol consumption was significantly positively correlated with general sleep disturbance and PTSD symptoms at the between-person level and with PTSD symptoms at the within-person level. Alcohol consumption was significantly negatively associated with trauma-related sleep disturbances at the between-person level and with subjective sleep disturbances at the within-person level.

Emotion Regulation

Regarding the full DERS score, participants experienced some difficulty in regulating their emotions (*M*=80.42 *SD*=23.16). There is not a specific cut-point for this questionnaire, but research suggests that scores averaging between 80-127 (Hallion, Steinman, Tolin, & Diefenbach, 2018) are within the clinical range. For strategies to regulate emotions, higher scores suggest difficulty with these strategies. Participants endorsed some difficulty with emotion regulation strategies (*M*=15.27, *SD*=6.63). During the assessment period, participants endorsed more difficulties in regulating their emotions (*M*=26.08 *SD*=4.76). The ICC was 0.76, suggesting 24% of the variance is at the within-person level. Emotion regulation is significantly positively correlated with trauma-related sleep disturbance, general sleep disturbance, and PTSD symptoms at the between-person level. At the within-person level, emotion regulation is significantly positively correlated subjective sleep and alcohol consumption and significantly negatively correlated with sleep efficiency, total sleep time, and PTSD symptoms.

Multilevel Models

Alcohol Consumption

The alcohol consumption variable was a count variable. A negative binomial regression model was used for this variable with an added exposure variable of the number of assessments for each day. To address the possible autoregressive effect, a 1-day lagged residual for alcohol consumption was included. The model also included 1-day lagged residual scores of PTSD symptoms and emotion regulation were included in the model. Sleep Efficiency scores were already lagged by one day and the residual scores were used in the model. Additionally, elapsed time in the study, a squared time term, day of the week, and interactions between intervention and time variables were included at Level 1. At level 2, intervention, gender, and age were included in the model. The model included a random intercept. The results of this model are

presented in Table 4. Surprisingly, PTSD symptoms, sleep efficiency, and emotion regulation were not significantly associated with alcohol consumption on the next day. Instead, alcohol consumption the previous day and day of the week were significantly associated with alcohol consumption.

Emotion Regulation

The emotion regulation model used average daily scores for participants' ability to modulate or regulate their emotions throughout the day. This model included 1-day lagged residual scores for emotion regulation to address autoregressive effects. This model also included 1-day lagged residual scores for PTSD symptoms and alcohol consumption as predictors. Sleep efficiency residuals were again included. Additionally, elapsed time in the study, a squared time term, day of the week, and interactions between intervention and time variables were included at Level 1. At Level 2, intervention, gender, and age were included in the model. The model included a random intercept and random slopes for time, time squared, and emotion regulation. The results for this model are presented in Table 5. Only PTSD symptoms were significantly associated with an increase in difficulties regulating emotions the next day. Auto-regressive effects of emotion regulation, sleep efficiency, alcohol consumption, time variables, day of the week, intervention, age and gender were not significantly associated with emotion regulation.

PTSD Symptoms

An average of PTSD symptoms endorsed throughout a day, starting at morning assessment, and ending with the last random assessment completed during the assessment period, was the next model tested. This model included a 1-day lagged residual score for PTSD symptoms to address the autoregressive effect. There were also 1-day lagged residual scores for

alcohol consumption and emotion regulation included as predictors. Sleep efficiency residuals were included but did not need to be time-lagged since they already were calculated as sleep from the previous day. Additionally, elapsed time in the study, a squared time term, day of the week, and interactions between intervention and time variables were included at Level 1. At Level 2, intervention, gender, and age were included in the model. The model included a random intercept and random slopes for time and the squared time term. The results for this model are presented in Table 6. The only significant associations were PTSD symptoms from the previous day and age, suggesting higher levels of PTSD symptoms the previous day predicted a decrease in PTSD symptoms on the following day and that older participants experienced higher levels of PTSD symptoms. Alcohol consumption, difficulties regulating emotions throughout the day, and sleep efficiency were not significantly associated with PTSD symptoms during the day.

Exploratory Analyses

Two sleep variables, Total Sleep Time and Subjective Sleep, were introduced into the models to substitute for Sleep Efficiency. For Total Sleep Time, participants slept for approximately 6.5 hours on average (*M*=386.56, *SD*=110.6, Range 125-895). This is below the recommended 7 or more hours of sleep recommended for optimal health (Watson, Badr, Belenky, Bliwise, Buxton, Buysse, …& Tasali, 2015). However, 6.5 hours of sleep is still considered to be a safe amount of sleep and unlikely to drastically impact health conditions (Spurgeon, 2002). For the following models, Total Sleep Time was scaled by 60 to put the variable in terms of hours asleep rather than minutes asleep. For Subjective Sleep, participants were asked how rested they felt on a 7 point scale, with higher scores indicating feeling more rested. In general, participants indicated feeling that they were below the midpoint for feeling rested (*M*=2.96, *SD*=1.79). Previous research suggests that it is common for participant to

perceive their sleep differently than what objective measures show, or a sleep state misperception (Hsiao, Tsai, Wu, Yang, Lane, Lee, … & Wu, 2018).

Alcohol Consumption. Table 7 and Table 10 present the results for the models using a Total Sleep Time variable in hours and Subjective Sleep Variable, respectively. In both models, the alcohol consumption variable was a count variable. Negative binomial regression models were used for this variable with an added exposure variable of the number of assessments for each day. To address the possible autoregressive effect, a 1-day lagged residual for alcohol consumption was included. The models also included 1-day lagged residual scores of PTSD symptoms and emotion regulation. Both total sleep time and subjective sleep variable scores were already lagged by one day and the residual scores were used in the models. Additionally, elapsed time in the study, a squared time term, interactions between intervention and time variables, and day of the week were included at Level 1. At level 2, intervention, gender, and age were included in the models. In both models, there was a random intercept. A random slope for time was included in the subjective sleep model. For the both models, there were similar results to the original sleep variable. Only alcohol consumption the previous day and day of the week were significant.

Emotion Regulation. Table 8 and Table 11 present the results for the models using a Total Sleep Time variable and Subjective Sleep Variable, respectively. The emotion regulation models used average daily scores for participants' ability to modulate or regulate their emotions throughout the day. These models included 1-day lagged residual scores for emotion regulation to address autoregressive effects. These models also included 1-day lagged residual scores for PTSD symptoms and alcohol consumption as predictors. Total sleep time and subjective sleep were added to their respective models. Additionally, elapsed time in the study, a squared time

term, interactions between intervention and time variables, and day of the week were included at Level 1. At Level 2, intervention, gender, and age were included in the model. The models included a random intercept and random slopes for time and time squared. In the total sleep time model, the 1-day lagged residual for emotion regulation also had a random slope. In the subjective sleep model, the 1-day lagged residual for PTSD symptoms also had a random slope. In the Total Sleep Time model, only PTSD symptoms had a significant association with emotion regulation the following day, indicating that those with higher PTSD symptoms one day would have more difficulty regulating their emotions the next day. In the subjective sleep model, no variables were significantly associated with emotion regulation.

PTSD Symptoms. Table 9 and Table 12 present the results for the models using a Total Sleep Time variable and Subjective Sleep Variable, respectively. An average of PTSD symptoms endorsed throughout a day was used for these models. These models included a 1-day lagged residual score for PTSD symptoms to address the autoregressive effects. There were also 1-day lagged residual scores for alcohol consumption and emotion regulation included as predictors. Residuals for total sleep time and subjective sleep were included in their respective models. Additionally, elapsed time in the study, a squared time term, interactions between intervention and time variables, and day of the week were included at Level 1. At Level 2, intervention, gender, and age were included in the model. The models included a random intercept and random slopes for time and the squared time term. In the total sleep time model, there was a significant autoregressive effect where PTSD symptoms the previous day were associated with a decrease in PTSD symptoms the following day. Age was also significantly associated with older participants experiencing a larger amount of PTSD symptoms. These results were echoed in the subjective sleep model, with PTSD symptoms on the previous day being significantly associated

with a decrease in PTSD symptoms the following day and older age being significantly associated with an increase in PTSD symptoms.

Discussion

This study sought to elucidate the temporal associations between sleep disturbances, PTSD symptoms, difficulty regulating emotion, and alcohol consumption in a veteran of the post-9/11 Afghanistan and Iraq conflicts population. Previous research has demonstrated associations between these variables. Oftentimes, these studies are cross-directional and unable to demonstrate a temporal sequence (Fairholme et al., 2013; Surette et al., 2020). Further complications include the bidirectional nature of relationships between many of these variables (Conroy & Arnedt, 2014; Harvey, Murray, Chandler, & Soehner 2011; Kahn, Sheppes, & Sadeh 2013). This study hypothesized that disturbed sleep would be associated with more difficulty regulating emotion and higher endorsement of daytime PTSD symptoms, which would lead to increased alcohol consumption.

In order to address the temporal associations, three models were created with alcohol consumption, difficulties regulating emotion, and PTSD symptoms as outcomes in each of these models. This was analyzed using a two-stage model. In the first stage, residual scores were estimated for sleep variables (including sleep efficiency, total sleep time in hours, and a subjective measure of how rested a participant felt), alcohol consumption, PTSD symptoms, and emotion regulation, reflecting deviations from a person's expected score on a given day with a person-mean of zero. Residual scores from the previous day and sleep efficiency were identified as predictors in the three models where alcohol consumption, difficulty in emotion regulation, and PTSD symptoms were outcomes. These models were examined together, to further understand if there was a specific sequence of these outcomes. When these models are examined

together, the data suggests that PTSD symptoms was significantly associated with difficulty regulating emotions the following day. Sleep efficiency was not associated with any of the outcomes in the models. This is not consistent with previous studies that suggest that sleep disturbances are significantly associated with PTSD symptoms, alcohol consumption, and difficulties in emotion regulation (Fairholme et al., 2013; Surette et al., 2020).

However, there were some interesting findings related to sleep. Participants generally identified themselves as poor sleepers, however actigraphy data suggests that participants slept decently. Additionally, participants did not endorse trauma-related sleep disturbances. This suggests that participants believe they are sleeping poorly for other reasons unrelated to trauma. It is possible that participants identified sleep disturbances that were more somatic or related to other health-concerns that they may have. At the within-person level, sleep efficiency was negatively correlated with emotion dysregulation, suggesting that as sleep efficiency increased, emotion dysregulation decreased. Interestingly, for subjective sleep, this was negatively associated with PTSD symptoms and sleep efficiency. Taken together, this might suggest that the experience of sleep is more important in experiencing PTSD symptoms rather than the actualy objective sleep parameters. Instead, objective sleep parameters may be more important in emotion dysregulation. It would be beneficial to have more symptomatic participants to see if these associations hold when participants have more disturbed sleep or higher levels of PTSD symptoms.

Additional analyses were conducted to see if other commonly used objective approximations for sleep (total sleep time) would yield similar results and if this would change if a subjective measure of sleep was used instead. Additional approximations of sleep yielded similar results, however in the models with subjective sleep there were no significant

associations in regard to emotion regulation, whereas before PTSD symptoms were significantly associated with more difficulty regulating emotion the following day when objective sleep measures (sleep efficiency and total sleep time) were included in the model. The results for each outcome, PTSD symptoms, alcohol consumption, and emotion regulation, as well as for age and gender, will be discussed in turn.

Alcohol Consumption

In each of the alcohol consumption models, only the alcohol use from the day before and the day of the week were significantly associated with alcohol consumption. With days of the week, participants were less likely to drink on days during the traditional work week. What is surprising is that PTSD symptoms, difficulties regulating emotion, and sleep disturbances were not significantly associated with alcohol use the following day. Research supports the idea that veterans may self-medicate, utilizing more alcohol following increased PTSD symptoms (Leeies, Pagura, Sareen, & Bolton, 2010). There are several possibilities for why this study did not show significant associations between PTSD symptoms, sleep disturbances, or emotion regulation and alcohol consumption the following day. One possibility is that this sample endorsed less than one PTSD symptom a day and slept fairly well, suggesting that they were not a heavily symptomatic sample and therefore didn't engage in self-medication. Another possibility is that this sample did not drink heavily. Veterans in this sample averaged under 2 drinks per day. The U.S. Department of Health and Human Services (2020) describes drinking in moderation as under 2 drinks per day for men and 1 drink per day for women. It is possible that in a sample that is experiencing more symptoms or drinking heavily, results would be more similar to previous research.

Emotion Regulation

For emotion regulation, in the models with objective measures of sleep (sleep efficiency and total sleep time), PTSD symptoms the previous day were associated with more difficulty regulating emotions. This is in keeping with research that suggests that those with PTSD need to spend more effort regulating their emotions or that they have difficulty modulating these emotions (Seligowski et al., 2015). However, sleep has been identified as being important in one's ability regulate their emotions, with restricted sleep negatively impacting a person's ability to modulate their emotions (Yoo et al., 2007). Since this sample generally slept close to the recommended amount (Watson et al., 2015), it is possible that sleep was not restricted enough to see significant associations on the ability to regulate emotions.

PTSD Symptoms

In each of the PTSD models, only PTSD symptoms from the day before and age were significant associated with PTSD symptoms the following day. This is surprising since sleep disturbances are a common complaint for veterans (Lew et al., 2010) and included in PTSD diagnostic criteria (APA, 2013). Additionally, alcohol use is highly comorbid with PTSD in veteran populations (Bowe & Rosenheck, 2015; Ralevski, et al. 2014). However, none of this was found in the current study. Instead, PTSD symptoms were associated with less PTSD symptoms the following day. This is not only counterintuitive but not in keeping with the literature (Simons et al., 2018). It is possible that it is because of such a non-symptomatic sample. Veterans in this sample endorsed less than one symptom a day and many fell below a cut-off of clinical significance during the baseline questionnaire. It is also possible that this particular sample had strong coping skills, in that if they experienced symptoms the previous day, they were able to cope with these symptoms and decrease the experience of PTSD symptoms the following day.

Age and Gender

Gender was not significant in any of the models. In the current study, women only accounted for approximately 11% of the sample. While this is consistent with the general veteran population (National Center for Veteran Analysis and Statistics, 2017), there may not have been enough data to fully explore sex differences. Age, however, was significantly associated with PTSD symptoms in each PTSD model, suggesting that older veterans in this sample who endorsed PTSD symptoms endorsed higher rates of PTSD symptoms than their younger counterparts. The research is mixed in this area, suggesting that older populations are exposed to more traumatic events but that younger to middle-aged adults have higher prevalence rates (Reynolds et al., 2016). In general, this sample did not endorse many symptoms throughout the day and many were below the clinical cut-off for PTSD at baseline. Additionally, with no significant associations to alcohol consumption or emotion regulation, it is possible that a larger population would be needed with a larger span of ages to see how impact of age on these outcomes.

Strengths and Limitations

Utilizing lagged effects and temporal ordering is a strength of this study. Lagged residuals were used to test within-person time-dependent effects (Simons et al, 2018) rather than observed scores. While this provides a powerful test of lagged associations, it is not sufficient to infer causality. Additionally, different tests were used based on the outcome data. Using a count variable and a negative binomial distribution when modeling alcohol consumption accounted for non-normality within the sample.

There were several limitations to this study. The sample of this study was small and mainly composed of white, male veterans from the Midwest. This limits generalizability to other

areas of the country, female veterans, and veterans who identify as persons of color. Participants generally reported limited experience of PTSD symptoms during the study. It is possible that this sample has a avariety of supports and coping strategies leaving them less likely to experience these symptoms. Additionally, while the sample reported levels of subjective sleep disturbance that would identify them as "poor sleepers," objective approximations of sleep, the use of actigraphy, showed that generally the sample was comprised of participants getting "normal" sleep. Having a larger, more heterogenous sample could've helped to identify further associations between sleep and other outcome variables.

While participants were recorded for approximately 14 days during the course of this study, a small sample size and the complexity of these models may mean that there was not sufficient power to detect some of these associations. Additionally, there may be some overlap in constructs. For example, alterations in cognition and mood and avoidance symptoms could be considered strategies to modulate or regulate emotions. These are highly correlated in this sample and could suggest that the data is identifying examining aspects of the same construct. In the current conceptualization of PTSD, sleep disturbance symptoms are present in both intrusive symptoms and arousal symptoms. It is possible that without multiple ways to study these constructs and a smaller sample to start with, associations are being missed or diminished.

The use of actigraphy as a sleep measure could also be considered both a strength and a limitation. PSG is seen as the gold standard in sleep research but is both costly and invasive (Rundo & Downey 3rd, 2019). Having additional sleep data would be beneficial to understand the sleep habits of the sample. One possible way would be to use actigraphy in addition to heart-rate variability for an approximation of sleep. Originally, it was planned to use an Oura ring, which provides this information (Altini & Kinnunen, 2021), in addition to the Readiband.

Unfortunately, at the time of this study, there was no research mode that would allow researchers to see this data without also having it available to the participant. With this development, heart-rate variability and actigraphy data could be collected without the use of uncomfortable measures, such as ECG leads.

A significant limitation to this study is the emergence of Covid-19. Shortly after beginning to enroll participants, the university stopped allowing for in-person data collection. Data collection methods had to be adjusted to include tele-appointments to consent, screen, and enroll participants. Participants were also sent devices in the mail. These challenges may have impacted the data that was collected. There were not enough participants enrolled prior to this change to be able to compare the two groups.

Clinical Implications

In this sample, participants rated their sleep at baseline to be more problematic than what was found during recording days. During the recording days, subjective sleep was measured by a single question of how rested a participant might feel, which does not necessarily give a well-rounded view into how a participant feels that they slept. However, what this study might suggest is a possibility for a simple and cost-effective sleep intervention that could benefit veterans who are coming in with a primary concern of sleep problems by using the Readiband. The Readiband has functions beyond showing researchers approximate sleep parameters, and can provide wearers with the SAFTE^{TM} (Sleep, Activity, Fatigue, and Task Effectiveness) Fatigue Model where it gives the wearer a score on how fatigued they might be feeling. This coupled with information about sleeping habits could provide individuals with feedback to improve their sleep. While it might not impact somatic and mental health symptoms it could improve the

number of sleep hours a person in a high risk field can get and their subjective experience of sleep (Adler, Gunia, Bliese, Kim, & LoPResti, 2017).

Another possible clinical implication is that studies like this might be used for educational purposes for high risk populations. Specifically, even though participants in this study did not endorse high amounts of PTSD symptoms at baseline or on a daily basis, these symptoms still were highly associated with difficulty modulating emotion the following day. This might suggest that even those who are mildly symptomatic or that do not meet a diagnostic threshold can still see impairments in their life. Normalizing these changes from pre-military functioning may help veterans seek mental health care (Spelman, Hunt, Seal, & Burgo-Black, 2012). Additionally, understanding the risks that are associated with chronic subthreshold symptoms, such as a greater likelihood for being diagnosed with a psychiatric comorbidity or experiencing poorer health outcomes (Mota et al., 2016), might encourage more veterans to engage with mental health care.

Summary and Future Research

The current study used experience sampling and actigraphy to investigate the relationships and temporal associations between sleep, difficulties with emotion regulation, PTSD symptoms, and alcohol consumption. Surprisingly, sleep disturbances were not associated with difficulty regulating emotion, PTSD symptoms, or alcohol consumption. This might be due to having a sample of primarily "normal" sleepers but it is also possible that subjective experience of sleep is more highly associated with PTSD symptoms, difficulty regulating emotions, and alcohol consumption. The subjective measure of sleep used in the exploratory analysis was only a single question and may not have fully explored the subjective experience of sleep in these participants. PTSD symptoms the day before were significantly associated with

difficulty in regulating emotion the following day. This is in keeping with literature that describes emotion regulation as being hampered or less effective in those with significant PTSD symptoms (Shepherd & Wild, 2014).

There are several avenues for future research. One possibility is to use multiple types of assessment to explore sleep in the veteran population. Research suggests that sleep detection methods should be combined for a more complete picture of an individual's sleep (Ibanez, Silva, & Cauli, 2018). This could include daily subjective assessments of sleep quality, sleep diaries, and actigraphy. These various methods would provide multiple data points regarding sleep and allow for further exploring how objective approximations of sleep and subjective experiences of sleep might interact with PTSD symptoms, difficulties in emotion regulation, and alcohol consumption. In this sample, there was a disconnect between the baseline perception of participants' sleep and the objective approximation of their sleep. This misperception of sleep state is common in the literature (Hsiao et al., 2018; Lemola, Ledermann, & Friedman, 2013). Having more information in future studies would provide a more robust understanding of this populations' sleep habits and perceptions.

Another direction for future research is to expand upon this current study, recruiting a more diverse population, utilizing more of the capabilities of the current technology, and having a longer recording period. This study had a small sample size that was primarily white and male. Oversampling of female veterans and veterans who identify as people of color in a future study could provide more information on how these associations may play out in subgroups of this veteran population. Additionally, it might be beneficial to utilize different capabilities of the technology used in this study. For example, the Readiband offers a "Readiness Score" or a score that tells the participant (or researcher) how impaired they may be due to their sleep. It would be

necessary for participants to wear the actigraphy band without interruption, since the algorithm requires 3 days of information before being able to supply a score (Russell et al., 2016). This would be beneficial in approximating a level of impairment due to fatigue in this population. Recent research also suggests that longer recording periods, over two months if possible, might be necessary to provide a more complete picture of sleep patterns (Oskarsdottir, Islind, August, Arnardottir, Patou, & Maier, 2022). The current study provided up to 28 days of recording but a longer period could provide further insight into the fluctuations of sleep habits and other symptoms over time.

Finally, future research may be able to further identify clinical treatments that help veterans with PTSD symptoms, emotion regulation strategies, alcohol use, and sleep disturbances. There are several gold-standard treatments identified to treat these various difficulties (e.g., Cognitive Processing Therapy, Prolonged Exposure, Cognitive Behavioral Therapies). Research has shown that there is a case for distinctive PTSD profiles or subtypes (Dalenberg, Glaser, & Alhassoon, 2012; Lanius et al., 2010). It is possible that with further study, treatment profiles might emerge, helping veteran populations to get involved with treatments specifically focused on their constellation of symptoms. This might include a mixture of cognitive processing, skill-building, sleep hygiene, and/or behavioral strategies.

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Table 1

Descriptive Statistics

Variable	*N*	*M(SD)*	Range	Skew	Kurtosis
Level 1					
PTSD Symptoms	781	0.70(1.50)	0 – 12	3.15	2.24
Sleep Efficiency	684	82.93(11.56)	37.2 – 100.8	-1.15	4.12
Total Sleep Time (in hours)	684	6.44(1.84)	2.08 – 14.92	0.29	4.00
Subjective Sleep	604	2.89(1.76)	0 - 6	0.13	1.99
Alcohol Consumption	787	1.82(3.48)	0 – 28	3.06	15.5
Emotion Regulation	777	26.08(4.76)	7 – 35	-0.29	2.74
Level 2					
Gender	59	--	52 (M), 7 (F)	--	--
Age	59	39.27 (8.11)	23 - 59	0.31	2.52
PTSD Symptoms	59	20.37 (18.81)	0 - 76	1.01	3.44
Sleep Disturbance	59	12.64 (3.63)	5 - 20	-0.14	2.38
Trauma-Related Sleep	59	4 (3.66)	0 – 15	0.93	3.18
Alcohol Consumption	57	8.27 (11.81)	0 – 64	2.66	11.26
Emotion Regulation	59	80.42 (23.16)	37 – 146	0.78	3.51
Strategies	59	15.27(6.63)	8 - 35	1.23	3.86

Table 2

Correlation Matrix

Variable	*1.*	*2.*	*3.*	*4.*	*5.*	*6.*	*7.*	*8.*	*9.*
1. Gender	1.00								
2. Age	.01	1.00							
3. Trauma-Related Sleep	-.09	-.04	1.00						
4. Subjective Sleep	-.01	.02	.41***	1.00	-0.06	-0.08*	-0.11**	-0.07*	0.31***
5. Total Sleep Time					1.00	0.72***	-0.06	0.01	-0.11**
6. Sleep Efficiency						1.00	0.08*	0.01	-0.17***
7. PTSD Symptoms	.09	.14	.71***	.45***			1.00	0.08*	-0.24***
8. Alcohol Consumption	.11	.11	-.16***	.35**			.27*	1.00	0.13***
9. Emotion Regulation	-.07	-.08	.45***	.47***			.62***	.20	1.00

Note. $N = 59$. Level 1 observations range from 741 to 868. Between-person correlations are below the diagonal and within-person correlations are above the diagonal. Gender is coded 0 = male and 1 = female. *$p < 0.05$, ** $p < 0.01$, ***$p < 0.001$

Table 3

Intraclass Correlation Tables

Variable	ICC	SE	95% CI
PTSD Symptoms	0.73	0.04	0.65, 0.80
Emotion Regulation	0.76	0.03	0.69, 0.82
Alcohol Consumption	0.53	0.05	0.43, 0.63
Sleep Efficiency	0.53	0.05	0.43, 0.63
Total Sleep Time	0.30	0.05	0.22, 0.41
Subjective Sleep	0.52	0.05	0.42, 0.62

Note. Intraclass Correlations were calculated by estimating an empty model without predictors, then comparing this variance of the continuous variables to total variance. For the count variable, days were recoded to either 0 = no drinking or 1 = drinks for that day. The method was then the same as the other continuous variables.

Table 4

Alcohol Consumption

Variable	*b*	*SE*	*p*	95%CI	IRR
Level 1					
Drink resid *t* -1	0.05	0.02	.004	0.01, 0.08	1.05
PTSD symptoms resid *t* -1	0.07	0.08	.390	-0.08, 0.22	1.07
Sleep Efficiency resid	0.08	0.08	.283	-0.07, 0.23	1.08
Emotion Regulation resid *t* -1	0.02	0.03	.504	-0.04, 0.08	1.02
Time	0.48	0.56	.384	-0.60, 1.57	1.62
Time^2	-0.40	0.27	.143	-0.93, 0.13	0.67
Intervention*Time	-0.66	0.75	.377	-2.12, 0.80	0.52
Intervention* Time^2	0.51	0.36	.160	-0.20, 1.22	1.67
Day of week covariates					
Monday	-0.20	0.17	.227	-0.53, 0.13	0.82
Tuesday	-0.57	0.18	.001	-0.91, -0.22	0.57
Wednesday	-0.17	0.16	.287	-0.49, 0.15	0.84
Thursday	-0.25	0.17	.134	-0.58, 0.08	0.78
Friday	0.08	0.18	.662	-0.27, 0.42	1.08
Saturday	0.10	0.16	.543	-0.21, 0.40	1.10
Level 2					
Gender	-0.64	0.87	.458	-2.34, 1.06	0.53
Age	0.02	0.04	.596	-0.05, 0.09	1.02
Intervention	-0.58	0.68	.932	-1.39, 1.27	0.94
Intercept	-1.80	0.94	.057	-3.65, 0.05	0.17

Note. *N* = 514 (52 participants), Log likelihood = -739.09043. Time is elapsed days since starting the study. Resid = residual, *t* -1 is a one-day lag. Gender is coded 0 = female, 1 = male. Intervention is coded 0 = no, 1= yes. Day of the week effects represent the day's effect compared to Sunday.

Table 5

Emotion Regulation Difficulties

Variable	*b*	*SE*	*p*	95%CI
Level 1				
Drink resid *t* -1	0.02	0.03	.660	-0.05, 0.08
PTSD symptoms resid *t* -1	0.33	0.11	.003	0.11, 0.54
Sleep Efficiency resid	0.00	0.11	.983	-0.21, 0.21
Emotion Regulation resid *t* -1	-0.05	0.07	.466	-0.18, 0.08
Time	-0.03	1.11	.980	-2.20, 2.14
Time^2	-0.07	0.54	.898	-1.12, 0.98
Intervention*Time	0.76	1.54	.620	-2.25, 3.77
Intervention* Time^2	-0.06	0.74	.934	-1.51, 1.39
Day of week covariates				
Monday	0.18	0.25	.490	-0.32, 0.67
Tuesday	0.33	0.26	.199	-0.17, 0.84
Wednesday	0.19	0.26	.469	-0.32, 0.70
Thursday	0.11	0.26	.674	-0.39, 0.61
Friday	0.17	0.27	.517	-0.35, 0.69
Saturday	0.42	0.25	.096	-0.07, 0.91
Level 2				
Gender	1.90	1.67	.256	-1.38, 5.18
Age	0.04	0.07	.551	-0.10, 0.18
Intervention	-0.11	1.30	.931	-2.65, 2.43
Intercept	24.29	1.83	<.001	20.69, 27.88
Random Variances and Covariances				
Time	13.21	6.63		4.94, 35.35
Time^2	3.74	1.68		1.55, 9.01
Emotion Regulation (ER) resid *t* -1	0.08	0.04		0.03, 0.21
Intercept	18.26	4.65		11.09, 30.06
(Time, Time^2)	-6.61	3.31		-13.10, -0.12
(Time, ER resid t-1)	0.38	0.41		-0.42, 1.18
(Time, Intercept)	-1.06	3.94		-8.79, 6.67
(Time^2, ER resid t-1)	-0.27	0.21		-0.68, 0.14
(Time^2, Intercept)	0.06	1.96		-3.78, 3.91
(ER resid t-1, Intercept)	0.67	0.37		-0.04, 1.39

Note. *N* = 511 (51 participants), Log likelihood = -1092.2528. Time is elapsed days since starting the study. Resid = residual, *t* -1 is a one-day lag. Gender is coded 0 = female, 1 = male. Intervention is coded 0 = no, 1= yes. Day of the week effects represent the day's effect compared to Sunday.

Table 6

PTSD Symptoms

Variable	*b*	*SE*	*p*	95%CI
Level 1				
Drink resid *t* -1	0.02	0.02	.168	-0.01, 0.05
PTSD symptoms resid *t* -1	-0.30	0.04	<.001	-0.39, -0.21
Sleep Efficiency	-0.04	0.04	.411	-0.12, 0.05
Emotion Regulation resid *t* -1	-0.00	0.02	.945	-0.04\, 0.04
Time	-0.61	0.58	.293	-1.74, 0.53
Time^2	0.13	0.27	.620	-0.39, 0.65
Intervention*Time	0.06	0.81	.940	-1.52, 1.64
Intervention* Time^2	0.10	0.37	.790	-0.63, 0.83
Day of week covariates				
Monday	-0.04	0.11	.682	-0.25, 0.17
Tuesday	0.05	0.11	.660	-0.16, 026
Wednesday	0.06	0.11	.565	-0.15, 0.28
Thursday	0.06	0.11	.552	-0.15, 0.28
Friday	0.11	0.11	.332	-0.11, 0.33
Saturday	0.02	0.11	.874	-0.19, 0.23
Level 2				
Gender	0.03	0.43	.943	-0.81, 0.87
Age	0.06	0.02	.001	0.03, 0.10
Intervention	-0.56	0.62	.371	-1.77, 0.66
Intercept	1.25	0.60	.036	008, 2.43
Random Variances and Covariances				
Time	5.27	1.99		2.51, 11.04
Time^2	1.13	0.39		0.57, 2.23
Intercept	4.16	1.09		2.49, 6.94
(Time, Time^2)	-2.41	0.88		-4.14, -0.68
(Time, Intercept)	-3.93	1.36		-6.60, -1.27
(Time^2, Intercept)	1.68	0.60		0.51, 2.85

Note. N = 508 (51 participants), Log likelihood = -611.72951. Time is elapsed days since starting the study. Resid = residual, *t* -1 is a one-day lag. Gender is coded 0 = female, 1 = male. Intervention is coded 0 = no, 1= yes. Day of the week effects represent the day's effect compared to Sunday.

Table 7

Alcohol Consumption Using Total Sleep Time in Model

Variable	*b*	*SE*	*p*	95%CI	IRR
Level 1					
Drink resid *t* -1	0.05	0.02	.004	0.01, 0.08	1.05
PTSD symptoms resid *t* -1	0.06	0.08	.420	-0.09, 0.21	1.06
Total Sleep Time resid	-0.01	0.04	.764	-0.08, 0.06	0.99
Emotion Regulation resid *t* -1	0.02	0.03	.525	-0.04, 0.08	1.02
Time	0.46	0.56	.403	-0.62, 1.55	1.59
Time^2	-0.39	0.27	.149	-0.92, 0.14	0.68
Intervention*Time	-0.63	0.75	.403	-2.09, 0.84	0.54
Intervention* Time^2	0.49	0.36	.174	-0.22, 1.21	1.64
Day of week covariates					
Monday	-0.19	0.17	.248	-0.52, 0.13	0.82
Tuesday	-0.57	0.18	.001	-0.92, -0.23	0.56
Wednesday	-0.17	0.16	.296	-0.49, 0.15	0.84
Thursday	-0.25	0.17	.138	-0.58, 0.08	0.78
Friday	0.08	0.18	.651	-0.27, 0.43	1.08
Saturday	0.10	0.16	.516	-0.21, 0.41	1.11
Level 2					
Gender	-0.65	0.87	.456	-2.35, 1.06	0.52
Age	0.02	0.04	.602	-0.05, 0.09	1.02
Intervention	-0.07	0.68	.913	-1.41, 1.26	0.93
Intercept	-1.78	0.95	.059	-3.64, 0.07	0.17

Note. N = 514 (52 participants), Log likelihood = -739.62369 Time is elapsed days since starting the study. Resid = residual, *t* -1 is a one-day lag. Gender is coded 0 = female, 1 = male. Intervention is coded 0 = no, 1= yes. Day of the week effects represent the day's effect compared to Sunday.

Table 8

Emotion Regulation Difficulties Using Total Sleep Time in Model

Variable	*b*	*SE*	*p*	95%CI
Level 1				
Drink resid *t* -1	0.02	0.04	.618	-0.05, 0.09
PTSD symptoms resid *t* -1	0.32	0.11	.003	0.11, 0.54
Total Sleep Time resid	-0.05	0.06	.367	-0.16, 0.06
Emotion Regulation resid *t* -1	-0.05	0.07	.444	-0.18, 0.08
Time	-0.03	1.11	.979	-2.20, 2.14
Time^2	-0.08	0.54	.888	-1.13, 0.98
Intervention*Time	0.74	1.54	.632	-2.28, 3.75
Intervention* Time^2	-0.04	0.74	.953	-1.50, 1.41
Day of week covariates				
Monday	0.18	0.25	.479	-0.32, 0.68
Tuesday	0.33	0.26	.194	-0.17, 0.84
Wednesday	0.19	0.26	.471	-0.32, 0.70
Thursday	0.11	0.26	.663	-0.39, 0.61
Friday	0.17	0.27	.528	-0.35, 0.69
Saturday	0.42	0.25	.092	-0.07, 0.91
Level 2				
Gender	1.85	1.68	.271	-1.44, 5.15
Age	0.04	0.07	.554	-0.10, 0.18
Intervention	-0.12	1.30	.929	-2.67, 2.43
Intercept	24.34	1.84	<.001	20.73, 27.95
Random Variances and Covariances				
Time	13.35	6.63		5.05, 35.33
Time^2	3.79	1.68		1.59, 9.03
Emotion Regulation (ER) resid *t* -1	0.08	0.04		0.03, 0.21
Intercept	18.24	4.63		11.09, 30.01
(Time, Time^2)	-6.70	3.31		-13.19, -0.21
(Time, ER resid t-1)	0.38	0.41		-0.41, 1.18
(Time, Intercept)	-1.04	3.94		-8.77, 6.68
(Time^2, ER resid t-1)	-0.27	0.21		-0.68, 0.13
(Time^2, Intercept)	0.06	1.96		-3.78, 3.91
(ER resid t-1, Intercept)	0.65	0.37		-0.07, 1.37

Note. N = 511 (51 participants), Log likelihood = -1091.8518. Time is elapsed days since starting the study. Resid = residual, *t* -1 is a one-day lag. Gender is coded 0 = female, 1 = male. Intervention is coded 0 = no, 1= yes. Day of the week effects represent the day's effect compared to Sunday.

Table 9

PTSD Symptoms Using Total Sleep Time in Model

Variable	*b*	*SE*	*p*	95%CI
Level 1				
Drink resid *t* -1	0.02	0.02	.172	-0.01, 0.05
PTSD symptoms resid *t* -1	-0.30	0.04	<.001	-0.39, -0.21
Total Sleep Time resid	0.00	0.02	.864	-0.04, 0.05
Emotion Regulation resid *t* -1	-0.00	0.02	.977	-0.04, 0.04
Time	-0.60	0.57	.294	-1.72, 0.52
Time^2	0.13	0.26	.620	-0.39, 0.65
Intervention*Time	0.05	0.80	.946	-1.51, 1.62
Intervention* Time^2	0.10	0.37	.782	-0.62, 0.82
Day of week covariates				
Monday	-0.04	0.11	.688	-0.25, 0.17
Tuesday	0.05	0.11	.657	-0.16, 0.26
Wednesday	0.06	0.11	.578	-0.15, 0.27
Thursday	0.06	0.11	.576	-0.15, 0.27
Friday	0.11	0.11	.328	-0.11, 0.33
Saturday	0.02	0.11	.882	-0.19, 0.22
Level 2				
Gender	0.04	0.43	.930	-0.80, 0.88
Age	0.06	0.02	.001	0.03, 0.10
Intervention	-0.55	0.62	.373	-1.76, 0.66
Intercept	1.24	0.60	.038	0.07, 2.41
Random Variances and Covariances				
Time	5.10	1.94		2.42, 10.76
Time^2	1.10	0.39		0.55, 2.18
Intercept	4.12	1.07		2.46, 6.86
(Time, Time^2)	-2.34	0.86		-4.03, -0.65
(Time, Intercept)	-3.85	1.33		-6.46, -1.23
(Time^2, Intercept)	1.64	0.57		0.49, 2.79

Note. N = 508 (51 participants), Log likelihood = -612.04746. Time is elapsed days since starting the study. Resid = residual, *t* -1 is a one-day lag. Gender is coded 0 = female, 1 = male. Intervention is coded 0 = no, 1= yes . Day of the week effects represent the day's effect compared to Sunday.

Table 10

Alcohol Consumption Using Subjective Sleep Variable in Model

Variable	*b*	*SE*	*p*	95%CI	IRR
Level 1					
Drink resid *t* -1	0.04	0.02	.012	0.01, 0.07	1.04
PTSD symptoms resid *t* -1	0.07	0.09	.407	-0.10, 0.24	1.07
Subjective Sleep resid	-0.05	0.04	.256	-0.13, 0.03	0.95
Emotion Regulation resid *t* -1	0.03	0.03	.405	-0.04, 0.09	1.03
Time	0.27	0.69	.256	-1.09, 1.62	1.30
Time^2	-0.36	0.33	.700	-1.01, 0.28	0.69
Intervention*Time	0.02	0.88	.983	-1.70, 1.74	1.02
Intervention* Time^2	0.09	0.42	.829	-0.74, 0.92	1.10
Day of week covariates					
Monday	-0.36	0.18	.044	-0.71, -0.01	0.70
Tuesday	-0.67	0.19	<.001	-1.04, -0.31	0.51
Wednesday	-0.47	0.18	.008	-0.82, -0.12	0.63
Thursday	-0.41	0.18	.026	-0.78, -0.05	0.66
Friday	-0.20	0.19	.294	-0.56, 0.17	0.82
Saturday	0.02	0.17	.929	-0.32, 0.36	1.02
Level 2					
Gender	-0.66	0.83	.422	-2.28, 0.95	0.52
Age	-0.00	0.03	.984	-0.07, 0.07	1.00
Intervention	-0.13	0.64	.842	-1.38, 1.13	0.88
Intercept	-1.45	0.91	.112	-3.24, 0.34	0.23
Random Variances and Covariances					
Time	0.27	0.22		0.05, 1.38	
Intercept	3.01	1.25		1.33, 6.79	
(Time, Intercept)	0.33	0.44	.451	-0.53, 1.20	

Note. $N = 535$ (58 participants), Log likelihood = -805.60982. Time is elapsed days since starting the study. Resid = residual, *t* -1 is a one-day lag. Gender is coded 0 = female, 1 = male. Intervention is coded 0 = no, 1= yes. Day of the week effects represent the day's effect compared to Sunday.

Table 11

Emotion Regulation Difficulties Using Subjective Sleep Variable in Model

Variable	*b*	*SE*	*p*	95%CI
Level 1				
Drink resid *t* -1	0.54	0.32	.096	-0.01, 0.12
PTSD symptoms resid *t* -1	0.03	0.18	.868	-0.32, 0.38
Subjective Sleep resid	-0.06	0.06	.342	-0.18, 0.06
Emotion Regulation resid *t* -1	-0.09	0.05	.072	-0.18, 0.01
Time	0.67	1.16	.560	-1.59, 2.94
Time^2	-0.51	0.55	.354	-1.60, 0.57
Intervention*Time	0.32	1.53	.834	-2.53, 2.40
Intervention* Time^2	0.26	0.72	.716	-2.68, 3.32
Day of week covariates				
Monday	0.41	0.25	.102	-0.08, 0.89
Tuesday	0.30	0.25	.225	-0.19, 0.79
Wednesday	0.08	0.25	.741	-0.41, 0.57
Thursday	0.16	0.25	.535	-0.34, 0.65
Friday	0.28	0.26	.286	-0.23, 0.78
Saturday	0.36	0.25	.147	-0.13, 0.85
Level 2				
Gender	0.69	1.71	.685	-2.66, 4.04
Age	0.06	0.07	.425	-0.08, 0.19
Intervention	-0.06	1.26	.959	-2.53, 2.40
Intercept	25.13	1.86	<.001	21.49, 28.78
Random Variances and Covariances				
Time	12.15	6.46		4.29, 34.44
Time^2	2.68	1.55		0.86, 8.33
PTSD Symptoms resid *t* -1	0.34	0.23		0.09, 1.30
Intercept	16.53	4.38		9.83, 27.80
(Time, Time^2)	-4.99	3.09		-11.05, 1.08
(Time, PTSD resid t-1)	1.66	0.90		-0.10, 3.41
(Time, Intercept)	-1.35	4.03		-9.24, 6.55
(Time^2, PTSD resid t-1)	-0.68	0.41		-1.48, 0.12
(Time^2, Intercept)	-0.01	1.92		-3.78, 3.76
(PTSD resid t-1, Intercept)	-0.97	0.77		-2.49, 0.54

Note. N = 526 (57 participants), Log likelihood = -1122.5383. Time is elapsed days since starting the study. Resid = residual, *t* -1 is a one-day lag. Gender is coded 0 = female, 1 = male. Intervention is coded 0 = no, 1= yes. Day of the week effects represent the day's effect compared to Sunday.

Table 12

PTSD Symptoms Using Subjective Sleep Variable in Model

Variable	*b*	*SE*	*p*	95%CI
Level 1				
Drink resid *t* -1	0.01	0.01	.386	-0.01, 0.04
PTSD symptoms resid *t* -1	-0.34	0.04	<.001	-0.43, -0.25
Subjective Sleep resid	0.01	0.02	.648	-0.03, 0.06
Emotion Regulation resid *t* -1	-0.00	0.02	.891	-0.04, 0.04
Time	-0.52	0.62	.400	-1.74, 0.69
Time^2	0.12	0.29	.669	-0.44, 0.69
Intervention*Time	0.04	0.84	.966	-1.61, 1.68
Intervention* Time^2	0.06	0.39	.879	0.70, 0.82
Day of week covariates				
Monday	-0.01	0.10	.899	-0.21, 0.19
Tuesday	0.07	0.10	.508	-0.13, 0.27
Wednesday	0.11	0.10	.273	-0.09, 0.31
Thursday	0.10	0.10	.318	-0.10, 0.30
Friday	0.16	0.11	.126	-0.05, 0.37
Saturday	0.01	0.10	.896	-0.19, 0.21
Level 2				
Gender	-0.03	0.41	.938	-0.84, 0.77
Age	0.60	0.02	<.001	0.03, 0.09
Intervention	-0.50	0.60	.402	-1.68, 0.68
Intercept	1.18	0.59	.045	0.03, 2.33
Random Variances and Covariances				
Time	6.81	2.14		3.68, 12.61
Time^2	1.40	0.43		0.76, 2.56
Intercept	4.41	1.03		2.79, 6.98
(Time, Time^2)	-3.08	0.96		-4.96, -1.20
(Time, Intercept)	-4.82	1.39		-7.55, -2.09
(Time^2, Intercept)	2.12	0.62		0.91, 3.34

Note. N = 530 (58 participants), Log likelihood = -619.13748. Time is elapsed days since starting the study. Resid = residual, *t* -1 is a one-day lag. Gender is coded 0 = female, 1 = male. Intervention is coded 0 = no, 1= yes. Day of the week effects represent the day's effect compared to Sunday.

Figure 1

Conceptual Model

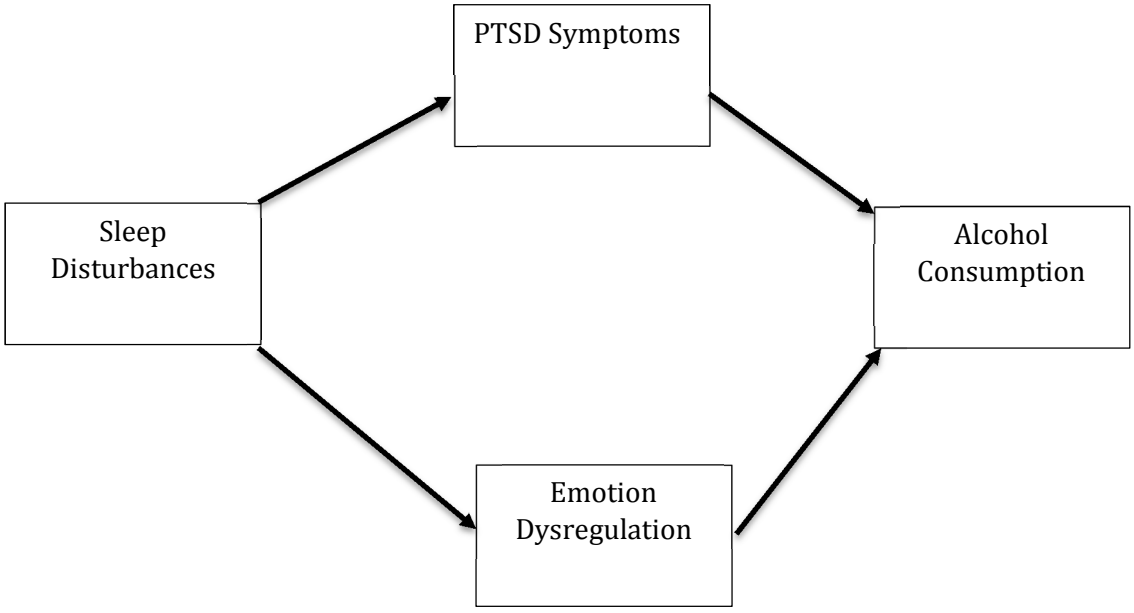


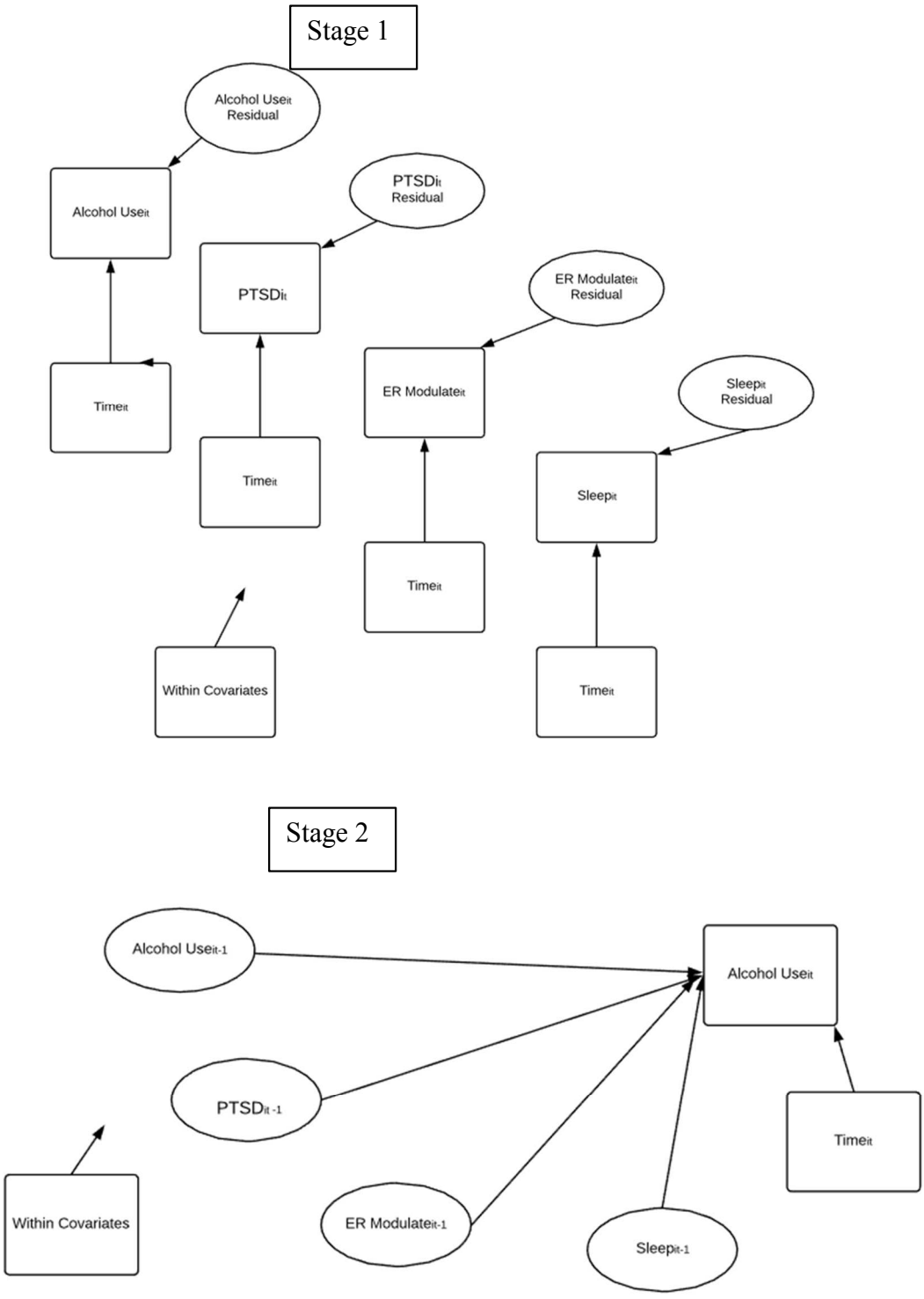
Figure 2

Parent Study Protocol

Week	1	2	3	4	5	6	7
Day	1		15			36	49
All participant visits	Baseline, Initiate burst		Return Readiband			Pick-up Readiband	Complete follow-up
All participants	Actigraphy/ESM					Actigraphy/ESM	
Intervention group only	CBT-I intervention						
Description	2 weeks of MetricWire surveys and Readiband, CBT-I intervention starts (if they are assigned to it)		3-week break from MetricWire surveys and Readiband, CBT-I intervention continues (if they are assigned to it)			2 weeks of MetricWire surveys and Readiband, CBT-I intervention done (if they are assigned to it)	

Figure 3

Example of the two-stage analytic approach at the within-person level



Appendix A

Informed Consent Form

IRB Approval effective from: 6/27/2018
IRB Approval not valid after: 6/26/2019
USD IRB

INFORMED CONSENT
The University of South Dakota

TITLE: Stress and Sleep Among Veterans

PROJECT DIRECTOR: *Raluca Simons, Ph.D.*
PHONE #: *605-677-5353*

Department: *Psychology*

WHAT IS THE PURPOSE OF THIS STUDY?

You are invited to participate in a research study about sleep, stress, and alcohol use. We are inviting you to be in the study because you are an OIF/OEF/OND veteran between the ages of 18 and 60, have difficulty sleeping, and drink alcohol at least once a week.

The purpose of this research study is to better understand sleep, stressful experiences, and alcohol use in returning veterans, and to test the effectiveness of a sleep intervention program.

HOW MANY PEOPLE WILL PARTICIPATE?

Approximately 100 OIF/OEF/OND veterans will take part in this study. Veterans who meet the criteria to be included in the study will be divided into two groups, either the intervention or the control group.

HOW LONG WILL I BE IN THIS STUDY?

Your total participation in the study will last 7 weeks. You will need to visit the South Dakota Union room 100 a total of four times. The first visit will last between 60-90 minutes. The second and third visits will take about 5 minutes. The fourth and final visit will take no more than an hour.

WHAT WILL HAPPEN DURING THIS STUDY?

Participation in this study involves the following: (a) a fifteen minute interview about current mental health symptoms; (b) completing two online surveys (baseline and follow-up) which take approximately an hour; these ask about military experiences, sleep, emotions and alcohol use; (c) wearing a watch that measures sleep for 4 weeks throughout the day/night over the course of 7 weeks; (d) answering **8** brief daily questionnaires on your cell phones. These questionnaires are very brief lasting approximately 2-minutes, at random times within 2-hour blocks from 10:00 am and 2:00 am. There will also be one brief morning and one brief evening survey. The surveys are the same every day and ask about sleep quality, alcohol use, and emotions. You will be asked to answer the questions during wake hours and can turn the phones off when you sleep or otherwise would be disturbed by it. (e) Finally, if you are assigned to the intervention group, you will also

be asked to listen to a 20-minute audio clips about sleep quality 3 times per week for the first 5 weeks of the study.

The first visit (day 1) will include informed consent, a 60-minute online survey, a 15-minute interview, and training regarding (1) functioning of the sleep watch and (2) training in completing the daily questionnaires on an application called MetricWire that will be installed on your phones. Then the watch is worn for the next 14 days, and the questionnaires on the cell phone will also be active for these 14 days as well. At the second visit (approximately around day 15), we will invite you back to return the watch. Three weeks later, at the third visit (day 36), we will invite you to pick up the watch to wear for another 14 days and we will again activate the MetricWire application that gives you the daily questionnaires on your phone. Finally, the fourth visit (day 49) will include a 60-minute online survey similar to the survey you completed at baseline, a new brief satisfaction with the research questionnaire, and return of the watch. All participants will receive $25 at the first study visit and approximately $150/week contingent on number of responses for the brief assessments completed on the MetricWire application on your cell phones. The intervention group will receive an additional $20 per week for doing the online sleep quality audio intervention over 5 weeks. You may choose to decline participation at any point during the study. If during any of the visits we find out you are at risk to harm yourself or others, we will do everything possible to keep you or that person safe, and that includes recommendation for treatment, and possibly contacting local authorities. Participants who are at risk for suicide or homicide will also be withdrawn from the study and referred to treatment.

WHAT ARE THE RISKS OF THE STUDY?

There are no risks in participating in this research beyond those experienced in everyday life. It is possible that answering certain questions about mood and military experiences may cause some discomfort. In the event that you feel you need to talk to a professional about any concerns you might have, you can obtain help at the Student Counseling Center (605-677-5777), the Psychological Services Center (605-677- 5354), or the Veterans Crisis Line at 1-800-273-8255 (press one).

WHAT ARE THE BENEFITS OF THIS STUDY?

You may not benefit personally from participating in this research project. You will, however, be helping us to better understand stressful experiences, alcohol use, and sleep habits among returning veterans. You may also learn about your sleep habits and how to improve them by completing the intervention. Members of the control group will be offered the at-home intervention at the conclusion of the study. Your participation in this research study is completely voluntary. If you decide not to be in this study, or if you stop participating at any time, you will not be penalized or lose any benefits for which you are otherwise entitled.

WILL IT COST ME ANYTHING TO BE IN THIS STUDY?

You will not have any costs for being in this research study.

WILL I BE PAID FOR PARTICIPATING?

Participants will be paid $25 at the first study visit and **up to** $150/week contingent on number of responses for the brief prompts completed on the phone application. There are 8 surveys a day and the more prompts participants respond to, the more compensation they receive. For example, a participant who responds to all 8 prompts in a day will obtain maximum payout for that day. A participant who responds to all 8 prompts every day for a week will receive maximum payout for the week.
The intervention group will receive an additional $20 per week. You may withdraw from the study at any time or not answer any questions. If you decide to withdraw, you will still be paid $25 for the first visit, and paid for your participation up to that point.

WHO IS FUNDING THE STUDY?

The Great Plains IdEA-Clinical and Translational Research Network is funding this research study. This means that USD Clinical Psychology is receiving payments from Great Plains IdEA-CTR to support the activities that are required to conduct the study. No one on the research team will receive a direct payment or an increase in salary from Great Plains IdEA-CTR for conducting this study.

ARE MY RECORDS CONFIDENTIAL?

The records of this study will be kept confidential. Only the main research personnel and the University of South Dakota Human Subject Protection Office (Institutional Review Board) representative will have access to the information collected as part of this research. In any report about this study that might be published or presented, only group data will be described, and you will not be identified.

Confidentiality will be maintained as follows: Your name and contact information for scheduling will be stored on a password protected electronic master list separately from any questionnaire data you will be providing. Hence, your responses are only linked to an ID number and never to your name. This master list linking your name to your ID number will be destroyed at the completion of the study or your request for withdrawal from the study. Your name will not be able to be linked to any of your responses after your completion of the study or withdrawal therefrom. You will receive a copy of the consent form for your records.

A certificate of confidentiality will be obtained from NIH. This protects all the data in case of a court order, and against disclosing any sensitive and identifiable information to anyone not connected to the research.

WILL I BE COMPENSATED FOR AN INJURY?

If you require treatment because you were injured from participating in this study, the research study staff will assist you in obtaining appropriate medical treatment. You or your health plan/insurance will be billed for the cost of this treatment. There are no plans to offer any type of payment for injury. However, by signing this form, you have not given up any of your legal

rights. In the same manner, the research study staff and any involved entities have not waived their defenses or immunities allowed under law.

If you feel you have suffered a research-related injury, please contact Dr. Raluca Simons or Dr. Jeffrey Simons at 605-677-5353, the University of South Dakota Human Protection IRB office at (605) 677-6184, or the Veterans Crisis Line at 1-800-273-8255 (press one).

IS THIS STUDY VOLUNTARY?

Your participation is voluntary. You may choose not to participate or you may discontinue your participation at any time without penalty or loss of benefits to which you are otherwise entitled. Your decision whether or not to participate will not affect your current or future relations with The University of South Dakota.

If you decide to leave the study early, we may need to contact you to schedule a close-out visit and return of the watch.

WHOM MAY I CONTACT IF I HAVE QUESTIONS?

The researchers conducting this study are Raluca Simons, Ph.D., Jeffrey Simons, Ph.D., and Renata Surette, M.A. You may ask any questions you have now or in the future. If you later have questions, concerns, or complaints about the research please contact Raluca Simons, Ph.D. at Raluca.simons@usd.edu or 605-677-5353 during the day. You may also correspond with Dr. Simons (Raluca.simons@usd.edu) or the student investigator (Renata.Surette@coyotes.usd.edu) with regard to any questions that may arise in conjunction with this study.

If you need to change your appointment, please contact Renata Surette at 605-677-3950 or via email (Renata.Surette@coyotes.usd.edu).

If you have questions regarding your rights as a research subject, you may contact The University of South Dakota- Office of Human Subjects Protection at **(605) 677-6184**.

- You may also call this number about any problems, complaints, or concerns you have about this research study.
- You may also call this number if you cannot reach research staff, or you wish to talk with someone who is independent of the research team.

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Subject's Name: _____

_____ _____

Signature of Subject Date

Appendix B

Informed Consent Form With Covid-19 Changes

INFORMED CONSENT
The University of South Dakota

TITLE: Stress and Sleep Among Veterans

PROJECT DIRECTOR: *Raluca Simons, Ph.D.*
PHONE #: 605-658-3710

Department: *Psychology*

WHAT IS THE PURPOSE OF THIS STUDY?

You are invited to participate in a research study about sleep behaviors, alcohol use, and emotions. We are inviting you to be in the study because you are an OIF/OEF/OND veteran.

The purpose of this research study is to better understand emotional experiences, alcohol use, and sleep habits.

HOW MANY PEOPLE WILL PARTICIPATE?

Approximately 100 OIF/OEF/OND veterans will take part in this study.

HOW LONG WILL I BE IN THIS STUDY?

Your total participation in the study will last 7 weeks. Participation will occur virtually over Zoom (visit 1 and 3) and telephone calls (visit 2 and 4). The total participation for first visit will last between 60-90 minutes. The second and third visits will take about 5 minutes. The total participation for the fourth and final visit will take no more than an hour.

WHAT WILL HAPPEN DURING THIS STUDY?

Participation in this study involves the following: (a) a fifteen minute interview about current mental health symptoms; (b) completing two online surveys (baseline and follow-up) which take approximately an hour; these ask about military experiences, sleep, emotions and alcohol use; (c) wearing a watch that measures sleep for 4 weeks throughout the day/night over the course of 7 weeks; this watch will be mailed to you. (d) answering brief daily questionnaires on your cell phones. These surveys are very brief lasting approximately 2-minutes, at random times within 2-hour blocks from 10:00 am and 2:00 am. There will also one brief morning and one brief evening survey. The surveys are the same every day and ask about sleep quality, alcohol use, and emotions. You will be asked to answer the questions during wake hours and can turn the phones off when you sleep or otherwise would be disturbed by it. (e) If you are assigned to the intervention group, you will also be asked to read some PDFs about sleep quality 3 times per week for the first 5 weeks of the study. (f) Finally, if you agree, you will wear an additional device, a ring, that measures activity level and heart rate; this will also be mailed to you.

The first Zoom visit (day 1) will include informed consent, a 60-minute online survey, a 15-minute interview, and training regarding (1) functioning of the sleep watch and (2) training in completing the daily questionnaires on an application called MetricWire that will be installed on your phones. After the Zoom visit#1 has concluded, the research assistant will sanitize the sleep watch (Readibands), and you will be sent these items via postal mail; once you have received the equipment, you are to call the research assistant for further instruction. Then the watch you receive in the mail is worn for the next 14 days, and the questionnaires on the cell phone will also be active for these 14 days as well. You will be compensated for visit #1 via PayPal. At the visit#2 (day 15) you will be contacted via phone and told that you can take off the Readiband (and charge it) for 3 weeks, and that the phone surveys will stop for 3 weeks, as well. If you are in the intervention group, you will also be reminded to continue completing the CBT-I PDFs for the following 3 weeks. You are encouraged to ask any questions at this point. You will be compensated via PayPal based on your number of completed MetricWire surveys. Three weeks later, at the third Zoom visit (day 36), we will ask you to start wearing the watch for another 14 days and we will again activate the MetricWire application that gives you the daily questionnaires on your phone. Finally, for visit #4 (day 49 of study), you will be contacted by phone and told that your participation in the study is nearly complete. You will be instructed on how to send the Readiband back to the research lab via mail. You will also be provided with the follow-up Psychdata survey link for completion. Once the follow-up Psychdata survey AND the research equipment have been returned successfully, you will be compensated via Paypal for the final burst of the study.
All participants will receive $25 at the first study visit and approximately $150/week contingent on number of responses for the brief assessments completed on the MetricWire application on your cell phones. The intervention group will receive an additional $20 per week for doing the online sleep quality intervention over 5 weeks. You may choose to decline participation at any point during the study.

WHAT ARE THE RISKS OF THE STUDY?

There are no risks in participating in this research beyond those experienced in everyday life. It is possible that answering certain questions about mood and military experiences may cause some discomfort. In the event that you feel you need to talk to a professional about any concerns you might have, you can obtain help at the Student Counseling Center (605-658-3580), the Psychological Services Center (605-658-3720), or the Veterans Crisis Line at 1-800-273-8255 (press one).

There are also some risks to privacy and confidentiality anytime that technology, such as Zoom, is used. These risks are not expected to be more than what is expected of electronic communication in general. To protect against these risks, we will set a meeting password that only the participant and research assistant will have access to.

WHAT ARE THE BENEFITS OF THIS STUDY?

You may not benefit personally from participating in this research project. You will, however, be helping us to better understand emotional experiences, alcohol use, and sleep habits among returning veterans. You may also learn about your sleep habits and how to improve them by

completing the intervention. Members of the control group will be offered the at-home intervention at the conclusion of the study. Your participation in this research study is completely voluntary. If you decide not to be in this study, or if you stop participating at any time, you will not be penalized or lose any benefits for which you are otherwise entitled.

WILL IT COST ME ANYTHING TO BE IN THIS STUDY?

You will not have any costs for being in this research study.

WILL I BE PAID FOR PARTICIPATING?

Participants will be paid $25 at the first study Zoom visit and approximately $150/week contingent on number of responses for the brief assessments completed on the phone application. The intervention group will receive an additional $20 per week. You may withdraw from the study at any time or not answer any questions and still receive this payment.

WHO IS FUNDING THE STUDY?

The Great Plains IdEA-Clinical and Translational Research Network is funding this research study. This means that USD Clinical Psychology is receiving payments from Great Plains IdEA-CTR to support the activities that are required to conduct the study. No one on the research team will receive a direct payment or an increase in salary from Great Plains IdEA-CTR for conducting this study.

ARE MY RECORDS CONFIDENTIAL?

The records of this study will be kept confidential. However, there are some inherent risks to privacy and confidentiality anytime that technology, such as Zoom, is used. These risks are not expected to be more than what is expected of electronic communication in general. By consenting to participate in this study, you are indicating that you understand those risks. To protect against these risks, we will set a meeting password that only the participant and research assistant will have access to.

Only the main research personnel and the University of South Dakota Human Subject Protection Office (Institutional Review Board) representative will have access to the information collected as part of this research. In any report about this study that might be published or presented, only group data will be described, and you will not be identified.

Confidentiality will be maintained as follows: Your name and contact information for scheduling will be stored on a password protected electronic master list separately from any questionnaire data you will be providing. Hence, your responses are only linked to an ID number and never to your name. This master list linking your name to your ID number will be destroyed at the completion of the study or your request for withdrawal from the study. Your name will not be able to be linked to any of your responses after your completion of the study or withdrawal therefrom. You will receive a copy of the consent form for your records.

WILL I BE COMPENSATED FOR AN INJURY?

If you require treatment because you were injured from participating in this study, the research study staff will assist you in obtaining appropriate medical treatment. You or your health plan/insurance will be billed for the cost of this treatment. There are no plans to offer any type of payment for injury. However, by signing this form, you have not given up any of your legal rights. In the same manner, the research study staff and any involved entities have not waived their defenses or immunities allowed under law.

If you feel you have suffered a research-related injury, please contact Dr. Raluca Simons or Dr. Jeffrey Simons at 605-658-3710, the University of South Dakota Human Subjects Protection IRB office at (605) 658-3743, or the Veterans Crisis Line at 1-800-273-8255 (press one).

IS THIS STUDY VOLUNTARY?

Your participation is voluntary. You may choose not to participate or you may discontinue your participation at any time without penalty or loss of benefits to which you are otherwise entitled. Your decision whether or not to participate will not affect your current or future relations with The University of South Dakota.

If you decide to leave the study early, we may need to contact you to schedule a close-out visit and return of the watch.

WHOM MAY I CONTACT IF I HAVE QUESTIONS?

The researchers conducting this study are Raluca Simons, Ph.D., Jeffrey Simons, Ph.D., and Renata Surette, M.A. You may ask any questions you have now or in the future. If you later have questions, concerns, or complaints about the research please contact Raluca Simons, Ph.D. at Raluca.simons@usd.edu during the day. You may also correspond with the student investigator (Sydney.stamatovich@coyotes.usd.edu) with regard to any questions that may arise in conjunction with this study.

If you need to change your appointment, please contact Sydney Stamatovich at 574-206-5412 or via email (Sydney.stamatovich@coyotes.usd.edu).

If you have questions regarding your rights as a research subject, you may contact The University of South Dakota- Office of Human Subjects Protection at (605) 658-3743.

- You may also call this number about any problems, complaints, or concerns you have about this research study.
- You may also call this number if you cannot reach research staff, or you wish to talk with someone who is independent of the research team.

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form. Your signature here also indicates that you understand those risks and that you consent to using Zoom as part of your participation in this study:

Subject's Name: _____

_____ _____

Signature of Subject Date

Appendix C

The Pittsburgh Sleep Quality Index (PSQI)

Instructions: The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions. During the past month,

1. When have you usually gone to bed? _____
2. How long (in minutes) has it taken you to fall asleep each night? _____
3. When have you usually gotten up in the morning? _____
4. How many hours of actual sleep do you get at night? (This may be different than the number of hours you spend in bed) _____

5. During the past month, how often have you had trouble sleeping because…	Not during the past month (0)	Less than once a week (1)	Once or twice a week (2)	Three or more times a week (3)
a. Cannot get to sleep within 30 minutes.				
b. Wake up in the middle of the night or early morning				
c. Have to get up to use the bathroom				
d. Cannot breathe comfortable				
e. Cough or snore loudly				
f. Feel too cold				
g. Feel too hot				
h. Have bad dreams				
i. Have pain				
j. Other reason(s), please describe, including how often you have had trouble sleeping because of this reason(s):				
6. During the past month, how often have you taken medicine (prescribed or 'over the counter') to help you sleep?				
7. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?				
8. During the past month, how much of a problem has it been for you to keep up enthusiasm to get things done?				
	Very good (0)	Fairly good (1)	Fairly bad (2)	Very bad (3)
9. During the past month, how would you rate your sleep quality overall?				

Appendix D

Pittsburgh Sleep Quality Index Addendum for PTSD

Instructions: Please answer the following additional questions regarding your sleep in the past month. Include any observations from your bedpartner/roommate.

1. During the past month, how often have you had trouble sleeping because you…

	Not during the past month	**Less than once a week**	**Once of twice a week**	**Three of more times a week**
a) Feel hot flashes.				
b) Feel general nervousness.				
c) Had memories or nightmares of a traum experience.				
d) Had severe anxiety or panic, not related to traumatic memories.				
e) Had bad dreams, not related to traumatic memories.				
f) Had episodes of terror or screaming during sleep without fully awakening.				
g) Had episodes of "acting out" your dreams, such as kicking, punching, running, or screaming.				

2. If you had memories or nightmares of traumatic experience during sleep (question 1-c above) …

	None	**Very little**	**Moderate**	**Severe**
a) How much anxiety did you feel during the memories/nightmares?				
b) How much anger did you feel during the memories/nightmares?				
	Early in the night	**Middle of the night**	**Late night, near morning**	**No particular time**
c) What time of night did most memories/nightmares occur?				

Appendix E

Posttraumatic Stress Disorder Checklist – DSM-5

Instructions: Below is a list of problems that people sometimes have in response to a very stressful experience. Keeping your worst event in mind, please read each problem carefully and then select a response to indicate how much you have been bothered by that problem in the past month.

	Not at all (1)	**A little bit (2)**	**Moderately (3)**	**Quite a bit (4)**	**Extremely (5)**
1. Repeated, disturbing, and unwanted memories of the stressful experience?					
2. Repeated, disturbing dreams of the stressful experience?					
3. Suddenly feeling or acting as if the stressful experience were actually happening again (as if you were actually back there reliving it)?					
4. Feeling very upset when something reminded you of the stressful experience?					
5. Having strong physical reactions when something reminded you of the stressful experience (for example, heart pounding, trouble breathing, sweating)?					
6. Avoiding memories, thoughts, or feelings related to the stressful experience?					
7. Avoiding external reminders of the stressful experience (for example, people, places, conversations, activities, objects, or situations)?					
8. Trouble remembering important parts of the stressful experience?					
9. Having strong negative beliefs about yourself, other people, or the world (for example, having thoughts such as: I am bad, there is something seriously wrong with me, no one can be trusted, the world is completely dangerous)?					

10. Blaming yourself or someone else for the stressful experience or what happened after it?					
11. Having strong negative feelings such as fear, horror, anger, guilt, or shame?					
12. Loss of interest in activities that you used to enjoy?					
13. Feeling distant or cut off from other people?					
14. Trouble experiencing positive feelings (for example, being unable to feel happiness or have loving feelings for people close to you)?					
15. Irritable behavior, angry outbursts, or acting aggressively?					
16. Taking too many risks or doing things that could cause you harm?					
17. Being "superalert" or watchful or on guard?					
18. Feeling jumpy or easily startled?					
19. Having difficulty concentrating?					
20. Trouble falling or staying asleep?					

Appendix F

Daily Drinking Questionnaire – Modified

For each day of the week, fill in both the number of drinks consumed and the number of hours you typically drink. Please be sure to fill out the information regarding your height and weight.

For the past ***30 days***, please fill in a number for each day indicating the ***typical number of drinks*** you usually consume on that day, and the ***typical number of hours*** you usually drink on that day.

	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
Number of drink							
Number of hours							

Please enter your height _____

Please enter your weight _____

Appendix G

Difficulties in Emotion Regulation Scale

Instructions: Please indicate how often the following statements apply to you.

	Almost never	**Sometimes**	**About half the time**	**Most of the time**	**Almost always**
1) I am clear about my feelings.					
2) I pay attention to how I feel.					
3) I experience my emotions as overwhelming and out of control.					
4) I have no idea how I am feeling.					
5) I have difficulty making sense out of my feelings.					
6) I am attentive to my feelings.					
7) I know exactly how I am feeling.					
8) I care about what I am feeling.					
9) I am confused about how I feel.					
10) When I'm upset, I acknowledge my emotions.					
11) When I'm upset, I become angry with myself for feeling that way.					
12) When I'm upset, I become embarrassed for feeling that way.					

13) When I'm upset, I have difficulty getting work done.					
14) When I'm upset, I become out of control.					
15) When I'm upset, I believe that I will remain that way for a long time.					
16) When I'm upset, I believe that I will end up feeling very depressed.					
17) When I'm upset, I believe that my feelings are valid and important.					
18) When I'm upset, I have difficulty focusing on other things.					
19) When I'm upset, I feel out of control.					
20) When I'm upset, I can still get things done.					
21) When I'm upset, I feel ashamed at myself for feeling that way.					
22) When I'm upset, I know that I can find a way to eventually feel better.					
23) When I'm upset, I feel I am weak.					
24) When I'm upset, I feel like I can remain in control of my behaviors.					
25) When I'm upset, I feel guilty for feeling that way.					
26) When I'm upset, I have difficulty concentrating.					

27) When I'm upset, I have difficulty controlling my behaviors.					
28) When I'm upset, I believe there is nothing I can do to make myself feel better.					
29) When I'm upset, I become irritated at myself for feeling that way.					
30) When I'm upset, I start to feel very bad about myself.					
31) When I'm upset, I believe that wallowing in it is all I can do.					
32) When I'm upset, I lose control over my behavior.					
33) When I'm upset, I have difficulty thinking about anything else.					
34) When I'm upset, I take time to figure out what I'm really feeling.					
35) When I'm upset, it takes me a long time to feel better.					
36) When I'm upset, my emotions feeling overwhelming.					

Appendix H

ESM - PTSD Symptoms

These items will be transformed to be appropriate for presentation on the phone screen.

Participants will be instructed to answer items in respect to their stressful military experience, but this will not be repeated in each questionnaire in order to decrease potential reactivity.

Instructions: Have any of the following occurred in the past 30 minutes? (Check all that apply)

- ❑ Disturbing memories, thoughts, or images of the stressful experience?
- ❑ Suddenly acting or feeling as if the stressful experience were happening again (as if you were reliving it)?
- ❑ Feeling very upset when something reminded you of the stressful experience?
- ❑ Having physical reactions (e.g., heart pounding, trouble breathing, sweating) when something reminded you of the stressful experience?
- ❑ Avoiding thinking about or talking about the stressful experience or avoiding having feelings related to it?
- ❑ Avoiding activities or situations because they reminded you of the stressful experience?
- ❑ Trouble remembering important parts of the stressful experience?
- ❑ Thinking about yourself, others, or the world in a negative way (e.g., I'm a bad person, no one can be trusted, the world is a dangerous place)?
- ❑ Blaming yourself about the stressful experience?
- ❑ Feeling scared, angry, or guilty?
- ❑ Loss of interest in activities that you used to enjoy?
- ❑ Feeling distant or cut off from other people?
- ❑ Feeling emotionally numb or being unable to have loving feelings for those close to you?
- ❑ Acting recklessly or in a way that is not good for you?
- ❑ Feeling irritable or having angry outbursts?
- ❑ Having difficulty concentrating?

- ❑ Being “super alert” or watchful or on guard?
- ❑ Feeling jumpy or easily startled

Appendix I

ESM – Alcohol Consumption

In vivo random prompts:

1. How many standard alcoholic drinks have you consumed in the past 30 minutes?
0 drinks
1 drink
2 drinks
3 drinks
4 drinks
5 drinks
6 drinks
7 drinks
8 drinks
9 drinks
10 or more drinks

2. How intoxicated are you right now?

1	2	3	4	5	6	7
Not at all						Extremely

Morning Assessment:
3. How many standard drinks did you consume last night? _____ over how many hours? _____

4. How intoxicated did you get last night?

1	2	3	4	5	6	7
Not at all						

Evening Assessment:
5. How many standard drinks did you consume today (since waking)? _____ over how many hours? _____

6. How intoxicated did you get today (since waking)?

1	2	3	4	5	6	7
Not at all						

Appendix J

ESM- Emotion Regulation

Please read the following statements and indicate how much it applies to your emotions in the past 30 minutes.

1. I am having difficulty controlling my behaviors.

1	2	3	4	5
Not at all				Completely

2. My emotions feel out of control.

1	2	3	4	5
Not at all				Completely

3. I believe that I will continue feeling this way for a long time.

1	2	3	4	5
Not at all				Completely

4. I feel out of control.

1	2	3	4	5
Not at all				Completely

5. I believe that I am going to end up feeling very depressed.

1	2	3	4	5
Not at all				Completely

6. My emotions feel overwhelming.

1	2	3	4	5
Not at all				Completely

7. I am having difficulty doing the things I need to do right now.

1	2	3	4	5
Not at all				Completely