Association Between Posttraumatic Stress Disorder Symptoms and Risky Behaviors:

An Ecological Momentary Assessment Study

by

Amanda Lane

Thesis submitted to the Faculty of the
Clinical Psychology Graduate Program
Uniformed Services University of the Health Sciences
In partial fulfillment of the requirements for the degree of
Doctor of Philosophy 2022

Distribution Statement

Distribution A: Public Release.

The views presented here are those of the author and are not to be construed as official or reflecting the views of the Uniformed Services University of the Health Sciences, the Department of Defense or the U.S. Government.

December 16, 2020

APPROVAL SHEET

Title of Masters Thesis: Association Between Posttraumatic Stress Disorder Symptoms and Risky Behaviors: An Ecological Momentary Assessment Study

Name of Candidate: Amanda Lane, Master of Science in **Clinical Psychology**

Date 12/11/20

THESIS AND ABSTRACT APPROVED:

[redacted] DATE: 12/10/20

Andrew J. Waters
DEPARTMENT OF PROGRAM NAME
Thesis Advisor

[redacted] 11/02/20

Jing Wang
DEPARTMENT OF PSYCHIATRY
Committee Member

[redacted] 12/11/20

David Riggs
DEPARTMENT OF PROGRAM NAME
Committee Member

The author hereby certifies that the use of any copyrighted material in the thesis manuscript entitled:

"Association Between Posttraumatic Stress Disorder Symptoms and Risky Behaviors: An Ecological Momentary Assessment Study"

is appropriately acknowledged and, beyond brief excerpts, is with the permission of the copyright owner.

Amanda Lane
MEDICAL AND CLINICAL PSYCHOLOGY PROGRAM
Uniformed Services University
Date 12/16/2020

ACKNOWLEDGMENTS

This thesis would not be complete without expressing my deepest appreciation to my research advisor, Dr. Andrew Waters, who has helped me throughout this entire process. He has consistently gone above and beyond my expectations of not only a faculty member, but an advisor. He cares for each of his students and shows this through his efforts in ensuring our success academically. I would also like to acknowledge my committee members, Drs. Riggs and Wang, for their time and effort in preparing this thesis.

COPYRIGHT STATEMENT

The author hereby certifies that the use of any copyrighted material in the thesis manuscript entitled: Association Between Posttraumatic Stress Disorder Symptoms and Risky Behaviors: An Ecological Momentary Assessment Study is appropriately acknowledged and, beyond brief excerpts, is with the permission of the copyright owner.

_____

Amanda Lane

DISCLAIMER

The views presented here are those of the author and are not to be construed as official or reflecting the views of the Uniformed Services University of the Health Sciences, the Department of Defense, or the U.S. Government.

ABSTRACT

Individuals diagnosed with posttraumatic stress disorder (PTSD) are at risk for impulsive behaviors. Forty-three male post-9/11-era veterans, who reported PTSD symptoms and a high-risk sexual event in the past 28 days at baseline, completed three assessments daily on a mobile device for 28 days. At each assessment, participants completed assessments of PTSD symptoms, alcohol consumption and sexual behaviors. Using generalized estimating equations, and separating between- and within-subject associations, there was evidence that when participants reported more PTSD symptoms than their subject-specific average they reported more drinking in the past two hours, and more risky sexual behaviors since the previous assessment. PTSD symptoms were not significantly associated with risky behaviors reported at the subsequent assessment, and risky behaviors were not significantly associated with PTSD symptoms reported at the subsequent assessment. In sum, PTSD symptoms were significantly associated with risky behaviors assessed contemporaneously or near-contemporaneously, but not prospectively.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Approximately 13% (over 250,000) of the 1.9 million veterans returning from Operations Enduring Freedom, Iraqi Freedom, and New Dawn (OEF/OIF/OND) have screened positive for posttraumatic stress disorder (Dursa, Reinhard, Barth, & Schneiderman, 2014). Individuals diagnosed with PTSD are at-risk for a wide range of impulsive behaviors, including substance misuse (Brady, Back, & Coffey, 2004; Jakupcak et al., 2010; Kessler, Sonnega, Bromet, Hughes, & Nelson, 1995; Ouimette, Read, & Brown, 2005) and risky sexual behavior (Strom et al., 2012). The current study examines the pattern of associations between PTSD symptoms and risky behaviors, including alcohol use and risky sexual behavior, using real-time assessment.

The organization of the introduction will be as follows. First, there will be a broad overview of the relationship between PTSD and risky behaviors. Second, the literature on the association between PTSD and alcohol misuse will be reviewed. Third, the literature on the association between PTSD and risky sexual behavior will be reviewed. Finally, the use of ecological momentary assessment as a method for examining the relationship between PTSD and risky behavior will be described.

PTSD AND GENERAL RISKY BEHAVIOR

PTSD severity is positively associated with risky behaviors (Strom et al., 2012). To capture this, a new symptom criterion, *reckless and self-destructive behaviors* (E2), was added to PTSD's diagnostic criteria in the *DSM-5* (American Psychiatric Association, 2013). Endorsement of the E2 criterion has been associated with higher PTSD severity (Contractor, Weiss, Dranger, Ruggero, & Armour, 2017). More specifically, participants who endorsed E2 "at a clinical level reported significantly

greater severity of intrusion, avoidance, anhedonia, negative affect, dysphoric arousal, and anxious arousal symptoms compared to participants who did not endorse E2 at a clinical level" (Contractor et al., 2017, p. 218). Several theoretical explanations for the association between PTSD severity and risky behaviors have been proposed and studied. A more in-depth exploration of these theoretical explanations will be discussed in the following sections.

PTSD AND ALCOHOL MISUSE

For more than 40 years, research has shown that individuals with PTSD are more likely to use alcohol and experience alcohol use disorder (AUD) than those who do not have PTSD; this significant co-occurrence extends to the military and veteran populations (Smith & Cottler, 2018). High rates of alcohol misuse have been observed among OEF/OIF/OND veterans, particularly among those who have sought out healthcare within the Veterans Affairs (Calhoun, Elter, Jones, Kudler, & Straits-Troster, 2008; Erbes, Westermayer, Engdahl, & Johnson, 2007; McDevitt-Murphy et al., 2010; Seal et al., 2011). Seal and colleagues (2011) completed the first study examining prevalence of alcohol use and drug use disorder diagnoses among OEF/OIF veterans. Among those OEF/OIF veterans, who were new users of the VA healthcare system between 2001 and 2009, 9.9% of the overall sample received an AUD diagnosis. However, for those with a PTSD diagnosis, about 25% had an AUD diagnosis. Moreover, approximately 67% of those with an AUD diagnosis had a diagnosis of PTSD (Seal et al., 2011).

Research related to individuals with these co-occurring disorders has been ongoing since the 1980s and theoretical formulations are nearly as old, starting with Khantzian's self-medication hypothesis (Khantzian, 1985).

Khantzian (1985; 1997) proposed the self-medication hypothesis to explain why there is a high co-occurrence between psychiatric disorders, such as PTSD, and substance use. The self-medication theory posits that drugs and alcohol are taken to relieve the psychological suffering or distress brought about by symptoms of a psychiatric disorder (Khantzian, 1997; Lane, Waters, & Black, 2019). Subsequent research has shown support for the self-medication hypothesis for individuals diagnosed with PTSD and alcohol use disorder (Lane et al., 2019). Taken in low to moderate doses, alcohol could reduce the emotional numbing and feelings of detachment experienced by individuals with PTSD. In higher doses, alcohol could lessen the intensity of PTSD-related emotions (emotional flooding) (Khantzian, 1997; Lane et al., 2019). As stated by Lane, Waters, and Black (2019), "this hypothesis maintains that it is not the psychiatric disorder itself that leads to alcohol use, but rather the *distress* caused by symptoms of that disorder – particularly negative alterations in emotions and thoughts regarding the trauma" (p. 2).

As concluded in a recent narrative review of by Lane et al. (2019), "several studies reported that PTSD symptoms predicted subsequent alcohol use/problems when controlling for prior drinking" (Simpson, Stappenbeck, Luterek, Lehavot, & Kaysen, 2014; Gaher et al., 2014; Possemato et al. 2015) (p. 9). Fewer EMA studies examined the relationship between specific PTSD symptom clusters and alcohol-related variables. Of those studies, hypervigilance (Simpson, Stappenbeck, Varra, Moore, & Kaysen, 2012) and intrusive symptoms (Kaysen et al., 2014; Simpson et al., 2012) correlated more strongly with later alcohol craving.

Less research has focused on the impact of alcohol use on psychiatric symptomatology, but the mutual maintenance model provides a theoretical basis for

interpreting the data. This model "is an alternative explanation of the functional relationship between PTSD symptoms and alcohol use" (Lane et al., 2019, p. 2). Like the self-medication hypothesis, the mutual maintenance model proposes that PTSD symptoms lead to alcohol use. However, the mutual maintenance model differs in its proposal that alcohol use in turn exacerbates or maintains PTSD symptom severity (Possemato et al., 2015; Kaysen et al., 2014; McFarlane et al., 2009; Lane et al., 2019). Expanding off of this idea, Blume, Schmaling, and Marlatt (2000) "argued that both biological and behavioral processes provoke a 'rebound effect,' where substance use may produce or increase psychiatric symptoms" (Tomlinson, Tate, Anderson, McCarthy, & Brown, 2006, p. 463). Biologically, substance abuse may degenerate neuronal processes, thereby causing a neurochemical imbalance over time (Blume, Schmaling, & Marlatt, 2000). Behaviorally, alcohol may alleviate symptoms initially, and intermittently thereafter. Such an intermittent reinforcement schedule perpetuates alcohol use and is difficult to extinguish (Blume, Schmaling, & Marlatt, 2000).

Some studies have provided support for the mutual maintenance model. Cohn, Hagman, Moore, Mitchell, and Ehlke (2014) reported that previous night's drinking predicted an increase in PTSD symptoms the following day, but this finding was only significant for individuals with AUD. Additionally, Simons and colleagues (2018) found that increases in alcohol dependence syndrome symptoms predicted an increase in next-day post-traumatic stress symptoms.

Unlike the self-medication hypothesis and the mutual maintenance model, social-cognitive theory incorporates environmental factors as well as the interaction between the individual and environment (Alexander & Ward, 2018; Bandura, 1989; Lane et al.,

2019). According to the social-cognitive theory, alcohol consumption is a learned response to stressors (both acute and chronic), as well as a person's interpretation of stressors (Bandura, 1986). This theory also emphasizes the importance of cognitions, such as self-efficacy, that act as moderator variables. In particular, self-efficacy should moderate the association between stressors and behaviors (Bandura, 1989). The interpretation of affective and environmental cues in addition to an individual's ability to cope with stressors largely influences alcohol use (Possemato et al., 2015). Note, however, that measures of self-efficacy were not assessed in the current study, and so predictions from social-cognitive theory could not be tested.

PTSD AND RISKY SEXUAL BEHAVIOR

Throughout research and clinical applications, risky sexual behavior and sexual risk taking has been defined and measured in a wide variety of ways. In their study on sexual risk taking among college students, Turchik and Garske (2009) defined sexual risk taking as "behaviors that could lead to unintended pregnancies or sexually transmitted infections (STIs)" (p. 937). They also considered other sexual behaviors, such as "socializing with the intent of having sex and engaging in sexual behavior, but not sex, with someone the person does not know very well" (Turchik & Garske, 2009, p. 937). While Weiss, Walsh, DiLillo, Messman-Moore, and Gratz (2019) did not include the second part of Turchik's and Garske's (2009) definition, they did consider behaviors, such as using substances prior to or during sexual activity, having multiple sexual partners, inconsistent condom use, and not engaging in safe sex communication. Meanwhile, the U.S. Preventative Services Task Force (2016) defines risk in relation to STIs. Persons at increased risk are those "who have more than one sex partner, a new sex

partner, or a sex partner with concurrent partners, and those who are not in mutually monogamous relationships and have inconsistent condom use" (Lee et al., 2016, p. 909). That risk increases when there is history of or a current STI, engaging in sexual activity with a person who has an STI, and exchanging sex for drugs or money (Lee et al., 2016).

Less research has examined the relationship between PTSD and risky sexual behavior than has examined the relationship between PTSD and alcohol use. Studies have reported that PTSD symptoms were significantly associated with risky sexual behavior among men who reported having sex with men (Reisner, Mimiaga, Safren, & Mayer, 2009), and among patients in residential SUD treatment (Weiss, Tull, Borne, and Gratz, 2013). Similar trends have been found among OEF/OIF veterans. Adler, Britt, Castro, McGurk, and Bliese (2011) found that, among their sample of 647 OEF/OIF veterans, 13% indicated they had risked receiving a sexually transmitted disease (STD) in the past three months. Those veterans who reported PTSD symptomatology were 1.57 times more likely to endorse risking the likelihood of receiving a STD than veterans who did not report PTSD symptoms (Adler, Britt, Castro, McGurk, & Bliese, 2011). In another study that recruited veterans from multiple war eras, Strom and colleagues (2012) found that OEF/OIF veterans were significantly more likely to endorse items relating to risky sexual behavior than other war-era veterans. Findings supported the hypothesis that PTSD symptoms were significantly associated with risky sexual behavior among veterans (Strom et al., 2012). When comparing veterans with and without PTSD and mild traumatic brain injury (mTBI), James, Strom, and Leskela (2014) found that veterans with PTSD, regardless of whether they had a mTBI or not, tended to engage in more risky sexual behaviors than controls and those with a mTBI only.

More recently, research has begun to focus on veterans' use of digital social media platforms to find sexual partners. The use of digital social media platforms to find sexual partners is associated with high rates of casual sex as well as STDs. Turban and colleagues (2017) were among the first researchers to investigate this among veterans; they found an association between use of digital social media platforms to find sexual partners and PTSD.

Theories, such as the self-medication hypothesis, may be limited to substance use and may not capture all the factors present in other risky behaviors, such as risky sexual behaviors. One factor that has been examined frequently is emotion dysregulation.

As defined by Gratz and Roemer (2004), and refined by Weiss, Tull, Viana, Anestis, and Gratz (2012), emotion dysregulation is a multi-faceted construct involving: "(a) a lack of awareness, understanding, and acceptance of emotions; (b) the inability to control behaviors when experiencing emotional distress; (c) lack of access to adaptive strategies for modulating the duration and/or intensity of aversive emotional experiences; and (d) an unwillingness to experience emotional distress as part of pursuing meaningful activities in life" (p. 454).

Research supports the relevance of emotion dysregulation to PTSD (e.g., McDermott, Tull, Gratz, Daughters, & Lejuez, 2009; Tull, Barrett, McMillan, & Roemer, 2007; Weiss, Tull, Anestis, & Gratz, 2013; Weiss, Tull, Viana, Anestis, & Gratz, 2012). Both overall emotion dysregulation and most of its specific dimensions, as defined above, are heightened among individuals with (versus without) PTSD (e.g., Tull et al., 2007; Weiss et al., 2012). More recently, research supports the mediating role of several dimensions of emotion dysregulation – nonacceptance of negative emotions, difficulties

controlling impulsive behaviors when distressed, and difficulties engaging in goal-directed behaviors when distressed (Weiss, Walsh, DiLillo, Messman-Moore, & Gratz, 2019).

Nonacceptance of negative emotions may increase distress as well as efforts to avoid those emotions, thereby increasing the likelihood of engaging in maladaptive emotion regulation strategies (e.g., Chapman, Gratz, & Brown, 2006; Gratz & Tull, 2010), such as risky sexual behavior (Batten, Follette, & Aban, 2002). Meanwhile, difficulties controlling impulsive behaviors when distressed has been associated with risky behaviors (Weiss et al., 2015a, b, c) and risky sexual behavior, specifically in the form of sexual partners (Weiss et al., 2019; Artime & Peterson, 2012; Tull, Weiss, Adams, & Gratz, 2012). Finally, difficulties engaging in goal-directed behaviors (i.e., difficulty focusing and completing tasks) when distressed "may interfere with the implementation of adaptive strategies for regulating distress and/or effective interpersonal behaviors, such as setting limits, saying no, or initiating uncomfortable conversations" (Weiss et al., 2019, p. 982).

Several theories have highlighted the importance of emotion dysregulation to engagement in risky sexual behavior among individuals with PTSD. Crepaz and Marks (2001) hypothesized that risky sexual behavior may function to alleviate or distract attention away from negative emotions. Likewise, Briere and Elliott (1994) theorized that the short-term pleasure associated with engaging in sexual behaviors may counter, or distract, attention away from negative affective states. Overall, the short-term benefits of a behavior may provide more of an incentive than the long-term consequences (immediate versus delayed reinforcer).

ECOLOGICAL MOMENTARY ASSESSMENT

Research on the relationship between PTSD symptoms and risky behaviors has typically relied on self-report measures that ask participants to answer questions about the past week, month, or several months. In many of the studies, participants' PTSD symptoms and risky behaviors were only assessed once, meaning that the studies were limited in examining between-subject associations. That is, they addressed the question "Do individuals who report generally higher levels of PTSD symptoms report generally more risky behaviors?"

One limitation with this approach is that PTSD symptomatology and risky behaviors fluctuate and so getting an accurate assessment that accounts for this fluctuation with conventional self-report measures (administered in the laboratory) is difficult (Lane et al., 2019). Ecological momentary assessment (EMA) is an assessment method that can better capture the changing relationship between PTSD symptoms and behaviors because symptoms and behaviors are measured "right now" or over short periods of time (e.g., past two hours) (Shiffman, Stone, & Hufford, 2008). EMA also allows for the collection of large pools of data for each individual, which can also permit single-subject analyses.

In a narrative review, Lane et al. (2019) described EMA as follows. EMA is a collection of "methods using repeated collection of real-time data on subjects' behavior and experience in their natural environments" (p. 3). "Ecological" refers to collection of data as participants go about their daily lives (Shiffman, Stone, & Hufford, 2008). "Momentary" captures the idea that the method seeks to assess an individual's current state, or recent state (e.g., the past couple of hours), as opposed to recollection over

longer periods of time (Shiffman et al., 2008). Researchers schedule assessments based on variables of interest and the purpose of study, as well as hypotheses about frequency of behavior and rates of fluctuation.

SEPARATION OF BETWEEN-SUBJECT AND WITHIN-SUBJECT ASSOCIATIONS

EMA data are multilevel data with subjects at level 2 and assessments at level 1 (Preacher, Zyphur, & Zhang, 2010). EMA allows researchers to separate between-subject associations (e.g., Do individuals who report generally higher levels of PTSD symptomatology report generally higher levels of risky behaviors?) and within-subject associations (e.g., When an individual reports a higher level of PTSD symptomatology than their person-specific average, do they report higher levels of risky behavior?) (Preacher et al., 2010). This is important because between- and within-subject associations are not always the same. The literature has demonstrated that it is possible to have a within-subjects association but not a between-subjects association (and vice versa). Indeed, it is even possible to have significant associations with opposite signs.

The assumption that these effects are equal has been referred to as the "ecological fallacy" (Robinson, 1950). A depiction of voting trends in the United States presents a useful illustration of this principle (Gelman, Shor, Bafumi, & Park, 2007). In this example, states are at level 2 and individuals are at level 1. When looking across states (level 2), on average, wealthier states tend to vote for Democrat presidential candidates while less wealthy states tend to vote for Republican presidential candidates. However, within states, the probability of an individual voting for a Democrat increases when individual income decreases whereas the probability of an individual voting for a Republican increases as individual income increases (Gelman et al., 2007). This is an

example of when there is a positive between-state association (wealthier states more likely to vote for a Democrat) but a negative within-subjects association (within states, wealthier individuals less likely to vote for a Democrat).

In the above example, states are level 2 and subjects are level 1. In the current study, subjects are level 2 and assessments are level 1. There are examples where different signs have been observed for between- and within-subject associations when subjects are level 2 and assessments are level 1. Exercise and its association with heart attack risk is an example (Mittleman et al., 1993). Individuals who generally exercise more have a lower risk of heart attacks. However, when individuals exercise, their risk of heart attack increases. Again, this example underscores the importance of separating between- and within-subject associations.

EMA USE AMONG PTSD AND RISKY BEHAVIOR RESEARCH

In addition to permitting separation of between- and within-subject associations, EMA also allows researchers to examine temporal relationships and to test prospective associations (e.g., When individuals report higher levels of PTSD than usual, do they report more drinking during the subsequent time period?). As noted later, prospective associations can be tested for both between- and within-subject associations. Therefore, this method of data collection allows for more precise testing of theories, such as the self-medication hypothesis and the mutual maintenance model.

Lane et al. (2019) completed a narrative review of EMA studies examining the association between PTSD symptoms and drinking. They concluded that participants were generally compliant with EMA procedures. The majority of the studies supported the self-medication hypothesis while there was less support for the mutual maintenance

model. In sum, more research is needed to examine the bidirectional relationships between PTSD symptoms and alcohol use.

Only one study has investigated the relationship between PTSD symptoms and risky sexual behaviors using EMA methodology. Results demonstrated feasibility of utilizing an EMA protocol in veterans, and evidence was found for an association between PTSD symptoms and risky sexual behavior (Black et al., 2016). More detailed information is provided in the following section.

PRELIMINARY STUDIES

Black and colleagues began their series of EMA studies by first assessing PTSD symptoms and high-risk sexual behavior among nine male veterans who were recruited between April and August of 2014. Original results from Black et al. (2016) found specific PTSD symptoms, such as PTSD-related negative affect (Cohen's $dz = 1.04$, a large effect size), to precede high-risk sexual events. No other specific PTSD symptoms, nor total score, differed significantly by high-risk sexual event occurrence. While PTSD symptom instability was positively associated with having multiple sexual partners in the 28-day EMA period, it was unrelated to number of risk events (Black et al., 2016).

Black and colleagues continued data collection with a different sample to test their hypotheses that trait impulsivity would moderate the association between PTSD symptoms and alcohol use. Male veterans were recruited between March 2015 and January 2017, and 28 veterans were included in Black et al.'s (2018) analyses. Black et al. (2018) reported that acute increases (from the previous assessment) in PTSD symptoms were associated with higher levels of drinking at the same timepoint in 28 veterans male post-9/11-era veterans who met the required minimum score of 24/80 on

the PCL-5 (PTSD Checklist) and who reported at least one binge drinking event in the past 28 days. In addition, as Black and colleagues' (2018) hypothesized, the association between increases in PTSD symptoms and alcohol use was significantly moderated by trait impulsivity such that it was stronger in individuals with higher trait impulsivity. The current study extends the analysis of Black et al. (2018) by: 1) Examining associations between PTSD symptoms and risky sexual behaviors (as well as alcohol use), 2) Examining both between- and within-subject associations, using the typical approach to decomposition, and 3) Examining prospective associations between PTSD symptoms and risky behaviors, and vice versa.

In sum, Black and colleagues completed two separate studies, both of which provide the foundation for the current study. While Black et al. (2018) did not include analyses of risky sexual behavior, that information was collected in addition to PTSD symptomatology and alcohol use, thereby allowing for all variables to be considered in future research.

CHAPTER 2: SPECIFIC AIMS

STUDY RATIONALE

Overall, there is evidence that PTSD and risky behaviors, such as harmful alcohol use, frequently co-occur. EMA has been used to examine the association between PTSD symptoms and risky behaviors, specifically alcohol use. EMA is a particularly useful methodology in that both between- and within-subject associations can be tested, and the temporality of associations can be examined. To our knowledge, no study has combined daily PTSD measures with assessment of both alcohol use and risky sexual behaviors among military veterans. A better understanding of the contemporaneous and prospective associations between PTSD and risky behaviors may lead to better treatments for this population.

The current study extended the analysis of Black et al. (2018) by examining how PTSD symptomatology and risky behaviors, specifically alcohol use and risky sexual behaviors, were related to each other among a military veteran sample. The first Specific Aim examined "contemporaneous" associations. Here, the term contemporaneous is used to mean "over the same period" (for alcohol use) or "over an overlapping time period" (for risky sex). For example, for the within-subject analysis, Specific Aim 1 examined whether participants reported more alcohol use over the past 2 hours when they reported more PTSD symptoms than usual over the past 2 hours. Specific Aim 1 also examined whether participants reported more risky sex since the previous assessment when they reported more PTSD symptoms than usual over the past 2 hours.

Specific Aims 2 and 3 examined whether PTSD symptoms were associated with later engagement in risky behaviors and vice versa (see Figure 1). Therefore, these analyses are referred to as "prospective" (as opposed to "contemporaneous").

STUDY AIMS

Specific Aim 1: To examine whether PTSD symptoms are cross-sectionally associated with risky behaviors.

Hypothesis 1.1: Individuals who generally report higher levels of PTSD symptoms will report more drinking during the 4-week study. This hypothesis examines a between-subjects association.

Hypothesis 1.2: When individuals report higher levels of PTSD than their average, they will report more drinking during the same period. This hypothesis examines a within-subjects association.

Hypothesis 1.3: Individuals who generally report higher levels of PTSD symptoms will report more risky sexual behavior during the 4-week study. This hypothesis examines a between-subjects association.

Hypothesis 1.4: When individuals report higher levels of PTSD than their average, they will report more risky sexual behavior during the same period. This hypothesis examines a within-subjects association.

Specific Aim 2: To examine whether PTSD symptoms are prospectively associated with risky behaviors.

Hypothesis 2.1: Individuals who report higher levels of PTSD symptoms during the first 2 weeks will report more drinking during the second 2 weeks. This hypothesis examines a between-subjects prospective association.

Hypothesis 2.2: When individuals report higher levels of PTSD than their average, they will report more drinking during the subsequent time period. This hypothesis examines a within-subjects prospective association.

Hypothesis 2.3: Individuals who report higher levels of PTSD symptoms during the first 2 weeks will report more risky sexual behavior during the second 2 weeks. This hypothesis examines a between-subjects prospective association.

Hypothesis 2.4: When individuals report higher levels of PTSD than their average, they will report more risky sexual behavior during the subsequent time period. This hypothesis examines a within-subjects prospective association.

Specific Aim 3: To examine whether risky behaviors are prospectively associated with PTSD symptoms.

Hypothesis 3.1: Individuals who report higher levels of drinking during the first 2 weeks will report more PTSD symptoms during the second 2 weeks. This hypothesis examines a between-subjects prospective association.

Hypothesis 3.2: When individuals report higher levels of drinking than their average, they will report higher levels of PTSD symptoms during the subsequent time period. This hypothesis examines a within-subjects prospective association.

Hypothesis 3.3: Individuals who report higher levels of risky sexual behavior during the first 2 weeks will report more PTSD symptoms during the second 2 weeks. This hypothesis examines a between-subjects prospective association.

Hypothesis 3.4: When individuals report higher levels of risky sexual behavior than their average, they will report higher levels of PTSD symptoms during the subsequent time period. This hypothesis examines a within-subjects prospective association.

CHAPTER 3: METHODS

This study is a secondary data analysis of data collected in a 4-week prospective observational study that used mobile devices to assess each participant's PTSD symptoms, drinking, and risky sexual behavior multiple times a day using EMA. The parent study was conducted by researchers at two Department of Veterans Affairs Medical Center campuses in Connecticut between March 2015 and January 2017 (supported by NIH R21 DA039038, PI Black). The study was approved by the West Haven VA and Yale University institutional review boards (IRBs). The investigators agreed to share the data. The data were fully deidentified. The parent study is described below.

Sampling and Enrollment

The parent study recruited male veterans through convenience sampling between March 2015 and January 2017 from two Department of Veterans Affairs Medical Center campuses in Connecticut. As reported in Black et al. (2018), study inclusion criteria were as follows: 1) Military service after 9/11; 2) Self-reported experience of a military-related traumatic event; 3) Ability to reliably receive text messages and complete a web-based assessment every day for 28 days; 4) Score of 24 or more (out of 80) on the PTSD Checklist for the Diagnostic and Statistical Manual (DSM) – 5th edition (PCL-5) (Weathers et al., 2013). As stated in Black et al. (2018) this last criterion was based on National Center for PTSD guidelines "recommending use of cut-point scores lower than the suggested threshold of 33/80 when a more sensitive screening measure is desired" (p. 525).

The study also focused on high-risk sexual behavior, and so the inclusion criteria included "reporting a high-risk sexual event in the past 28 days." One participant dropped out after baseline and before EMA data collection. There were no inclusion criteria related to alcohol or drug use.

Participants

A total of 44 male veterans provided written informed consent and completed the baseline assessment. The majority of the participants (39 out of 43) had a preliminary diagnosis of PTSD, based on PCL-5 scores. Characteristics of the sample are detailed in Table 1.

Procedure

Study procedures are illustrated in Figure 2. Participants completed an initial telephone screening and were invited to an in-person visit (Lab Visit 1; Baseline) based on the inclusion/exclusion criteria. During the baseline appointment, a detailed description of the study was provided. Written informed consent was obtained (for eligible participants). Participants were then trained on EMA procedures.

Following Lab Visit 1, eligible participants used a mobile device (their own device) to complete assessments throughout the next 28 days. As reported in Black et al. (2018), participants received automated text messages on their smart phones three times/day for 28 days. Each text message was presented at a random time within three intervals (7:00am–12:00pm, 12:01–5:00 pm, 5:01–10:00 pm). The text message alerted participants to complete a linked, web-based assessment, generated using Research Electronic Data Capture survey software (Harris et al., 2009). Each assessment, which

were date- and time-stamped, assessed PTSD symptom severity, number of alcoholic drinks, substance use, and number of sexual events in the past two hours.

At Lab Visit 2 (28 Day Follow-Up), participants completed an author-constructed questionnaire assessing perceptions of the study. They were then debriefed and given an opportunity to ask questions.

Participants were compensated for their time. They received $2.50 for each completed assessment "within the same calendar day of the text prompt, and an additional $0.50 for each assessment completed within 15 minutes of the text (allowing for 5 minute delivery time), with an additional $1.00 for every day that all three assessments were completed within 15 minutes of the respective text prompts" (p. 527).

Measures

Baseline Assessment of PTSD

Each participant was given the PTSD Checklist for DSM-5 (PCL-5; Weathers et al., 2013), a 20-item questionnaire assessing PTSD symptoms in the past month based on DSM-5 diagnostic criteria, at both Lab Visits' 1 and 2. Participants rated on a scale of 0 (not at all) to 4 (extremely) the extent to which they were experienced each symptom. The total score on the PCL-5 is a sum of all items ranging from 0-80. A minimum score of 24 was required for inclusion into this study; this cut point is lower than the National Center for PTSD's guidelines of 33 "in order to enroll a more inclusive sample of veterans experiencing PTSD symptoms" (Black et al., 2018, p. 526). This measure was given along with the Lifetime Events Checklist for DSM-5 (LEC-5; Weathers et al., 2013) at Lab Visit 1.

Baseline Assessment of Alcohol Use

A calendar-based assessment collecting retrospective information about smoking, alcohol, and substance use (marijuana, cocaine, opiates, and "other" drugs) in the 28 days preceding Lab Visits' 1 and 2.

Demographics

The demographics questionnaire included items on age, race/ethnicity, gender, marital status, period of last deployment, date decommissioned, psychiatric history, history of TBI, as well as questions from the legal history section of the Addiction Severity Index (McLellan et al., 1992) and from the Sexual History Questionnaire (including HIV status and sexual orientation).

EMA Assessments

EMA assessments were scheduled 3 times/day for 28 days (see Figure 3 for items used).

PCL-5 Adapted for EMA

This newest version of the widely used PCL is a 20-item questionnaire based on the DSM-5 PTSD criteria. Psychometrics are not yet available, but the earlier-version PCL had high internal consistency ($\alpha = 0.94$) and 1-week retest reliability ($r = 0.88$). The PCL-5 has been adapted for EMA by inquiring about the past 2 hours (rather than the past month). DSM criteria-based items showed sensitivity to momentary fluctuation in an EMA study with veterans who smoked (Dedert et al., 2012). To be consistent with the approach of Black et al. (2018), PCL total scores were only computed if participants responded to all 20 items (using this method, data from 65 out of 2,719 assessments were missing PCL total scores). When the term "PCL ratings" is used throughout the manuscript, it refers to level of PTSD symptomology.

Alcohol Use

A single item was used to assess the number of alcoholic drinks consumed in the past two hours ("In the past 2 hours, how many alcoholic drinks (equivalent to a 12 oz beer, 5 oz glass of wine, or 1-1/2 oz of hard liquor) have you had?"; 0-13 scale, where 13 = 13 or more drinks in the past 2 hours). When the term "alcohol use" is used throughout the manuscript, it refers to number of alcoholic drinks.

Sexual Event Item

An item asked whether a sexual event occurred since the last questionnaire ("Since your last completed questionnaire, did you have any sexual contact with another person?"). Follow-up questions asked about the number and types of sexual contact, partner, substance use, condom use, moods and PTSD symptoms occurring immediately prior to the sexual event.

Risky Sexual Event

For this study, a risky sexual event was defined as any event with a non-main partner that occurred 1) without a condom/latex protection (regardless of other conditions) or 2) in exchange for money/drugs or 3) while under the influence of drugs or alcohol regardless of condom use. For every sexual event, three items were administered to evaluate whether a risky sexual event occurred (see Figure 3 for list of items).

DATA ANALYSIS

Of the 44 subjects who started the EMA study, 43 provided at least 1 EMA assessment. The analytic sample included up to 2719 assessments from 43 subjects (Figure 4). All subjects (N=43) provided data to all analyses. The minimum number of assessments for an individual subject was 6. One subject provided 7 assessments, and all

other subjects contributed 16 or more assessments. Sample sizes varied across analyses due to missing data.

Given that the item assessing drinking enquired about drinking in the past two hours, assessments that occurred within 2 hours of previous assessment were removed from analyses involving drinking to avoid counting the same drink/s twice. For risky sexual behavior, all available assessments were included because the measure assessed risky sexual behavior since the last assessment (rather than in the past two hours).

Analyses used Generalized Estimating Equations (GEE) using PROC GENMOD in SAS. GEEs (Liang & Zeger, 1986) can be used to analyze intensive longitudinal data in that they consider the correlated nature of the data and allow for different numbers of assessments for each subject. Atkins et al. (2013) also note that GEEs are a class of statistical models that are appropriate for longitudinal and clustered data. GEE was preferred over generalized linear mixed models (GLMMs) because the latter models often failed to converge, especially when specifying random coefficients for level 1 predictor variables, and treating coefficients as fixed rather than random could potentially yield invalid *p* values for level 1 predictors (e.g., Barr, Levy, Scheepers, & Tily, 2013). A negative binomial distribution was assumed for count data. For analysis of risky sexual behavior, the log of the inter-assessment interval was used in an offset statement to allow for different "exposures" (i.e., the extent of time during which risky sex could occur) for each assessment. As is typical for analysis of longitudinal data, all analyses assumed first order autocorrelation of residuals.

For the primary analyses, separate univariate models were conducted for each dependent variable. Analyses separated out between- and within- associations as

described below, a procedure which is valid for GEEs (McNeish, 2019), including longitudinal data (Donald Hedeker, email communication, 03/12/20). Covariates included Day in study (continuous), as recommended by Bolger and Laurenceau (2013), Type of Day (binary: Weekend vs. Weekday), and Time of Day (binary: Nighttime vs. Daytime). To be consistent with the analysis of Black et al. (2018), for the variable Type of Day, Friday, Saturday and Sunday were coded as 1 (for Weekend), and all other days as 0 (for Weekday). For the variable Time of Day, times between 7.00 PM and 5.00 AM were coded as 1 (for Nighttime), and all other times coded as 0 (for Daytime). Effect sizes included the regression coefficient and the Rate Ratio (the exponentiated regression coefficient). All tests used $\alpha = .05$ and were 2-tailed.

For Specific Aim 1, *Mean* PCL-5 (a subject-specific average across all EMA assessments) and *Deviation* PCL-5 scores (deviation scores between each score and the subject-specific mean) were entered concurrently into a GEE. A significant coefficient for *Mean* PCL-5 would indicate a between-subject association, i.e., that participants who report generally higher *Mean* PCL-5 scores report higher drinking or risky sexual behavior. A significant coefficient for *Deviation* PCL-5 would indicate a within-subject association, i.e., that when a participant reports a higher PCL-5 score than his or her average during EMA they report more drinking or sexual behavior during the same time period. Example syntax used is shown in the Appendix.

A similar approach was taken for Specific Aims 2 and 3, except that *Deviation* scores were lagged to permit examination of prospective associations.

For each Specific Aim separately, a false discovery rate (FDR) procedure was implemented to help identify findings ("discoveries") that are likely to be more robust.

The two-stage linear step-up procedure developed by Benjamini, Krieger, and Yekutieli (2006) was computed on *p* values derived from analyses using GraphPad Prism Version 8.1.1 for Windows (GraphPad Software, San Diego, California USA, www.graphpad.com), which is the "recommended" approach in GraphPad Prism Version 8.1.1. According to the logic of FDR correction, when using *Q* (False Discovery Rate) = .05, in the long run 95% of the "discoveries" identified by this procedure will be "true positives" with the remaining 5% "false positives".

Supplementary Analyses

A number of additional analyses were conducted, which should be considered exploratory.

In the primary analyses described above, alcohol use was coded as a count variable (0-13). In an additional analysis, a new variable was generated, Risky Drinking, which was defined as 3 or more drinks in the past two hours (0=fewer than 2 drinks in the past two hours, 1=3+ drinks in the past two hours). This variable can capture periods of rapid drinking, which may differentiate risky vs non-risky (one or two drinks) drinking. A GEE was conducted with Risky Sex coded as a binary variable.

There were few assessments on which participants reported more than one risky sex episode since the previous assessment (Table 2). To examine the robustness of results under different coding, Risky Sex was coded as a binary variable (0=no risky sex since last assessment, 1=one or more risky sex episodes since last assessment), and a GEE was conducted with Risky Sex coded a binary variable.

To examine if associations were specific to risky sex, analyses were also conducted with the following three additional bonary variables: Any Sex (0=no Sex since

last assessment, 1=one or more sex events, whether risky or non-risky, since the last assessment); Non-Risky Sex (0=no Sex since last assessment, 1=one or more Non-Risky Sex events since the last assessment, with assessments involving Risky Sex excluded from analyses); and Risky Sex (0=no Sex since last assessment, 1=one or more Risky Sex events since the last assessment, with assessments involving Non-Risky Sex excluded from analyses).

Power

Field (2017) notes that computing power analysis for multilevel models is not straightforward. Field (2017) referenced methods described in Twisk (2006), which use "traditional" methods (i.e., methods used on single-level data) using an adjusted sample size that accounts for the correlated nature of the data. This was the approach taken here to derive estimates of power for GEE, which should be similar to power estimates for the fixed effects of LMMs.

A priori power analyses were conducted using G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007) (α= .05, 2-tailed test). Power estimates account for the fact that repeated observations from the same person will be correlated, indexed by the intraclass correlation coefficient (*ICC*). To compute the "effective sample size", the total number of study assessments is divided by the VIF (Variance Inflation Factor). (VIF = 1+((average number of observations per person) -1)**ICC*), where *ICC* is the intraclass correlation coefficient for the dependent variable. For Specific Aim 1, assuming 44 participants, ~3500 assessments (initial estimate of number of assessments), and *ICC* = .5, the "effective sample size" is 86.4, and the study has power = .81 to detect a correlation, *rho* = .30 (i.e., a medium effect size), between *Mean* PCL-5 scores and outcome variables

(between-subject association). If the *ICC* = .1 (i.e., the repeated measures EMA data are weakly correlated), then the effective sample size and power are greater. For within-subject associations, the study has .80 power to detect a mean correlation *rho* (between *Deviation* PCL-5 scores and the outcome) = 0.1, assuming the *SD* (of the correlations between *Deviation* scores and the outcome) is 0.23 (within-subject association). Power should be similar for Aims 2 and 3.

Additionally, an a priori simulation study was conducted by Black using multilevel logistic regression modeling (which would be expected to produce estimates of fixed effects similar to GEE with a binary outcome) to determine whether the sample size was adequate for estimation of unbiased parameter estimates (Anne Black, email communication, 09/21/18). The simulation showed relatively unbiased and accurate parameter estimates for samples of 50 observations (assessments) nested within 30 clusters (subjects), and *ICC* = .38. The relative bias of fixed effects was no greater than 5%, and 7% for variance components, with 95% confidence intervals covering fixed-effect and variance parameters at least 93% and 89% of the time, respectively (indicating unbiased standard error estimation), even when the prevalence of the outcome was only 10%. (The prevalence of risky behaviors can be expected to be relatively low). Stated simply, according to this simulation, the sample size used in the current study (i.e.., 43 level 2 units, each with a mean of over 50 level 1 assessments) is sufficient for accurate estimation of parameter estimates, at least for a binary outcome with the parameters tested in the simulation. However, it should be noted that, with respect to the current study, one limitation of the simulation conducted by Black was that it used multilevel logistic regression (rather than GEE).

CHAPTER 4: RESULTS

Subjects were on average 32.42 years old (*SD* = 6.74) and predominantly White or African American. At the initial laboratory visit, subjects reported that they consumed on average of around 40 drinks in the past 28 days (Table 1). The mean score on the PCL-5 was 48.88 (*SD* = 11.68).

EMA Descriptive Statistics

During EMA, subjects completed 2719 assessments across 28 days. Compliance was defined as the proportion of random assessments that were completed, and by this measure the mean compliance was 73%. The *Mean* number of assessments with alcohol use data was 53.77 (SD = 22.87, *Range* 5 - 83). The *Mean* number of assessments with risky sex data was 62.95 (SD = 24.53, *Range* 6 - 90). The average duration between assessments occurring on the same day was 4.14 hours (*SD* = 3.14).

Table 2 shows summary statistics for EMA variables used in the current study. As can be seen, on average subjects reported consuming at least one drink in the past two hours on 10.90% of assessments, and at least one risky sexual event on 1.92% of assessments. The mean PCL-5 rating was 28.11 (*SD* = 20.31).

SPECIFIC AIM 1: CONTEMPORANEOUS ASSOCIATION BETWEEN PTSD SYMPTOMS AND RISKY BEHAVIORS

Hypothesis 1.1 stated that subjects who generally report higher levels of PTSD symptoms will report more drinking during the 4-week study.

Table 3 indicates that the association between *Mean* PCL scores and Alcohol Use across all assessments was not significant. There was no evidence that subjects who report generally higher PCL scores report generally greater Alcohol Use (Figure 5).

Hypothesis 1.2 stated that when subjects report higher levels of PTSD than their average, they will report more drinking during the same period.

Table 3 indicates that there was a significant positive association between PCL *Deviation* score (deviation score between the observed PCL rating and the subject-specific average) and Alcohol Use. As subjects report greater PCL scores than their subject-specific average, they report more drinking in the same time period (past two hours) (Figure 5). For every 10-point increase in *Deviation* PCL score, the predicted Number of Drinks increases 1.30 times (i.e., increases by 30%), when controlling for Day, Time of Day, and Type of Day.

Hypothesis 1.3 stated that subjects who generally report higher levels of PTSD symptoms will report more risky sexual behavior during the 4-week study.

Table 4 indicates that the association between *Mean* PCL Ratings and Risky Sex was not significant. There was no evidence that subjects who report generally greater PCL scores report generally greater risky sexual behavior (Figure 6).

Hypothesis 1.4 stated that when subjects report higher levels of PTSD than their average, they will report more Risky Sexual Behavior during the same period.

Table 4 indicates that the association between PCL *Deviation* score and Risky Sex was significant. When subjects report greater PCL scores than their subject-specific average, they report more risky sexual behavior since the last assessment. (Figure 6). For every 10-point increase in *Deviation* PCL score, the predicted rate of episodes of Risky Sex increases 1.33 times (i.e., increases by 33%), when controlling for Day, Time of Day, and Type of Day.

When using the methods of Benjamini et al. (2006), the four *p* values relating to Specific Aim 1 yielded two "discoveries", i.e., the association between *Deviation* PCL and Alcohol Use, and the association between *Deviation* PCL and Risky Sex.

SPECIFIC AIM 2

Hypothesis 2.1 stated that subjects who generally report higher levels of PTSD symptoms during the first two weeks of the study will report more drinking during the second two weeks.

Table 3 indicates that the association between *Mean* PCL ratings across the first two weeks of the study and Alcohol Use across the second two weeks was not significant. There was no evidence that individuals who reported generally higher PCL ratings in the first two weeks of the study reported generally more Alcohol Use in the second two weeks.

Hypothesis 2.2 stated that when subjects report higher levels of PTSD than their average, they will report more drinking during the subsequent time period.

Table 3 indicates that the association between the PCL *Lagged Deviation* score and Alcohol Use reported at the subsequent assessment was not significant. There was no evidence that when individuals reported greater PCL scores than their subject-specific average, they reported more Alcohol Use before the subsequent assessment.

Hypothesis 2.3 stated that subjects who generally report higher levels of PTSD symptoms during the first two weeks of the study will report more risky sexual behavior during the second two weeks.

Table 4 indicates that the association between *Mean* PCL ratings across the first two weeks of the study and Risky Sex across the second two weeks was not significant.

There was no evidence that individuals who reported generally higher PCL ratings in the first two weeks of the study reported generally more Risky Sex in the second two weeks.

Hypothesis 2.4 stated that when subjects report higher levels of PTSD than their average, they will report more risky sexual behavior during the subsequent time period.

Table 4 indicates that the association between the PCL *Lagged Deviation* score and Risky Sex reported at the subsequent assessment was not significant. There was no evidence that when individuals reported greater PCL scores than their subject-specific average, they reported more Risky Sex before the subsequent assessment.

When using the methods of Benjamini et al. (2006), the four *p* values relating to Specific Aim 2 yielded no "discoveries".

Analyses were also conducted for Hypotheses 2.1 and 2.3 when controlling for the lagged *Mean* score of the dependent variable. Results did not change if the lagged *Mean* score was included in analyses. Similarly, analyses were also conducted for Hypotheses 2.2 and 2.4 when controlling for the lagged *Deviation* score of the dependent variable. Results did not change if the lagged *Deviation* score was included in analyses.

SPECIFIC AIM 3

Hypothesis 3.1 stated that subjects who generally report higher levels of drinking during the first two weeks of the study will report more PTSD symptoms during the second two weeks.

Table 3 indicates that the association between *Mean* Alcohol Use score across the first two weeks of the study and PCL ratings across the second two weeks was not significant. There was no evidence that individuals who reported generally higher

Alcohol Use in the first two weeks of the study reported generally higher PCL ratings in the second two weeks.

Hypothesis 3.2 stated that when subjects report higher levels of drinking than their average, they will report higher levels of PTSD symptoms during the subsequent time period.

Table 3 indicates that the association between the Alcohol Use *Lagged Deviation* score and PCL ratings reported at the subsequent assessment was not significant. There was no evidence that when individuals reported greater Alcohol Use than their subject-specific average, they reported higher PCL ratings before the subsequent assessment.

Hypothesis 3.3 stated that subjects who generally report higher levels of risky sexual behavior during the first two weeks will report more PTSD symptoms during the second two weeks.

Table 4 indicates that the association between *Mean* Risky Sex across the first two weeks of the study and PC ratings across the second two weeks was not significant. There was no evidence that individuals who reported generally more Risky Sex in the first two weeks of the study reported generally higher PCL ratings in the second two weeks.

Hypothesis 3.4 stated that when subjects report higher levels of risky sexual behavior than their average, they will report higher levels of PTSD symptoms during the subsequent time period.

Table 4 indicates that the association between the Risky Sex *Lagged Deviation* score and PCL ratings reported at the subsequent assessment was not significant. There

was no evidence that when individuals reported more Risky Sex than their subject-specific average, they reported higher PCL ratings at the subsequent assessment.

When using the methods of Benjamini et al. (2006), the four *p* values relating to Specific Aim 3 yielded no "discoveries".

As with Specific Aim 2, analyses were also conducted for Hypotheses 3.1 and 3.3 when controlling for the lagged *Mean* score of the dependent variable. Results did not change if the lagged *Mean* score was included in analyses. Similarly, analyses were also conducted for Hypotheses 3.2 and 3.4 when controlling for the lagged *Deviation* score of the dependent variable. Results did not change if the lagged *Deviation* score was included in analyses.

Supplementary Analyses

A number of additional analyses were conducted, which should be considered exploratory.

Association between PCL Ratings and Risky Drinking

Using GEE with a binary outcome variable, there was no association between *Mean* PCL ratings and Risky Drinking, but there was a significant association between *Deviation* PCL ratings and Risky Drinking (p=.02). For every 10-point increase in *Deviation* PCL score, the odds of Risky Drinking increases 1.2 times (i.e., increases by 20%), when controlling for Day, Time of Day, and Type of Day. Therefore, results were similar to those reported for Hypotheses 1.1 and 1.2.

Association between PCL Ratings and Risky and Non-Risky Sexual Behavior

When Risky Sex is coded as a binary variable then results are similar to treating Risky Sex as a count variable (Binary Variable: *PE*=0.025, *SE*=0.01, *p*=.01, *OR*=1.29 for 10-unit change in *Deviation* PCL) (#1 in Table 5).

If Any Sex is the dependent variable), then *Deviation* PCL is significant (*PE*=0.015, *SE*=0.006, *p*=.01, *OR*=1.16 for 10-unit change in *Deviation* PCL) (#2 in Table 5).

If Non-Risky Sex is the dependent variable, the association between *Deviation* PCL and Non-Risky Sex is not significant (*PE*=0.012, *SE*=0.008, *p*=.10, *OR*=1.13 for 10-unit change in *Deviation* PCL) (#3 in Table 5).

If Risky Sex is the dependent variable, the association between *Deviation* PCL and Risky Sex is significant (*PE*=0.027, *SE*=0.01, *p*=.01, *OR*=1.30 for 10-unit change in *Deviation* PCL) (#4 in Table 5).

The above set of results are all summarized in Table 5. They indicate that the association between *Deviation* PCL and Risky Sex may be stronger than the association between *Deviation* PCL and Non-Risky Sex, but further research would be required to confirm this, and results should be treated with caution pending replication.

CHAPTER 5: DISCUSSION

The current study examined contemporaneous and prospective associations between PTSD symptoms and alcohol use/risky sexual behaviors in military veterans. The main results of this study were as follows. First, regarding Specific Aim 1, there was a significant positive association between PTSD symptoms and both drinking and risky sexual behaviors during the same (or overlapping) time period. Second, regarding Specific Aim 2, there was no evidence that PTSD symptoms were associated with drinking or risky sexual behaviors reported at the next assessment. And third, regarding Specific Aim 3, there was no evidence that drinking or risky sexual behaviors were associated with PTSD symptoms reported at the next assessment. The results from each Specific Aim are discussed in further detail below.

Contemporaneous Association between PTSD Symptoms and Risky Behaviors

When evaluating Specific Aim 1, contrary to hypotheses, there was no evidence that individuals who reported generally higher PCL ratings reported generally more drinking or risky sexual behavior (i.e., no significant between-subjects association). However, consistent with hypotheses, when individuals reported higher levels of PTSD symptoms than their subject-specific average they reported more drinking over the same time period and more risky sexual behavior since the last assessment (i.e., significant within-subjects association).

When interpreting the absence of a significant between-subjects association, one should consider the following points. The relatively small sample size at level 2 coupled with a number of individuals who did not report any drinking or risky sexual behaviors may have reduced power to detect a true effect. Moreover, regarding alcohol use, data

from EMA studies reveal that a between-subject association may be stronger between PTSD symptoms and alcohol-related problems (which were not assessed in the current study) than between PTSD symptoms and alcohol use (Gaher et al., 2014). Additionally, individuals with more severe PTSD symptoms may experience negative alcohol-related experiences regardless of the amount of alcohol consumed (Wilson et al., 2017).

Regarding the significant contemporaneous within-subject association, it is not possible to determine whether PTSD symptoms prompt drinking/risky sexual behavior, or vice versa. Both causal pathways are still possible. Therefore, the current data are not sufficient to distinguish between theoretical models described earlier. Our findings are consistent with interpretation of data from other EMA studies examining this association (Possemato et al., 2015). Possemato and colleagues (2015) concluded that PTSD symptoms may have increased first, and participants drank within the time block to manage their symptoms, but their data cannot exclude the possibility that drinking occurred first.

The analyses treated alcohol use and risky sexual behavior as separate dependent variables. Future research can also use a multivariate approach, treating alcohol use and risky sexual behavior as two (correlated) dependent variables, potentially increasing power of some analyses.

Finally, regarding the within-subject association between PTSD symptoms and risky sexual behavior, one may wonder whether this finding generalizes to non-risky sexual behavior. Results of preliminary analyses reported in the supplementary analysis section suggested that the within-subject association between PTSD symptoms and risky sex may be more robust than the within-subject association between PTSD symptoms and

non-risky sex, although further research is required to examine this question more comprehensively.

Prospective Association between PTSD Symptoms and Risky Behaviors

Based on the large amount of research supporting the self-medication hypothesis, it was hypothesized that PTSD symptoms would be associated with drinking reported at the next assessment. And given the evidence supporting the role of emotion dysregulation, it was hypothesized that PTSD symptoms would be associated with risky sexual behaviors. However, the results provided no evidence that PTSD symptoms were prospectively associated with either drinking or risky sexual behaviors, either at the between-subjects or the within-subjects level, whether controlling or not for the lagged value of the dependent variable.

These results appear to contrast with a statement from Lane et al. (2019) noted earlier that "several studies reported that PTSD symptoms predicted subsequent alcohol use/problems when controlling for prior drinking" (p. 9). However, these results should not be over-interpreted to indicate the absence of a prospective association. Generally, it is more difficult to find prospective associations using EMA data, in part because any causal relationship between PTSD symptoms and risky behaviors may occur very quickly. For example, if an individual experiences a flashback, they may initiate drinking in the timescale of minutes, rather than hours. If causal processes play out over the timescale of minutes, this may make it more difficult to detect prospective associations over a longer timescale.

To illustrate this idea, Kwako and colleagues (2014) studied how a stress induction influenced alcohol craving over time in a laboratory study. They reported that

alcohol craving peaked at the 5- and 15-minute timepoints following exposure to a stress script among individuals with comorbid alcohol dependence and PTSD. Although the dependent variable was alcohol craving (rather than alcohol use), it suggests that causal processes linking induction of stress to reports of alcohol craving may occur quickly. EMA researchers have also suggested a rapid relationship between PTSD symptoms and alcohol use (Possemato et al., 2015; Simpson et al., 2012), and Possemato and colleagues (2015) recommended assessing participants hourly to provide a more sensitive test of the relationship between alcohol use and PTSD symptoms.

Prospective Association between Risky Behaviors and PTSD Symptoms

Based on the literature supporting the mutual maintenance model, it was hypothesized that drinking and risky sexual behaviors would be associated with PTSD symptoms reported at the next assessment. Again, the results provided no evidence that risky behaviors were prospectively associated with PTSD symptoms, either at the between-subjects or within-subjects level.

As just noted, the causal relationship between PTSD symptoms and risky behaviors may occur very quickly, which may make it less likely to detect an association at the next assessment, a few hours later. In contrast, the causal relationship between risky behaviors and PTSD symptoms may occur over a longer duration of time. The average time between assessments occurring on the same day in this study was approximately four hours. This may not be a sufficient amount of time to capture the relationship between PTSD symptoms and subsequent risky behaviors.

For example, Cohn and colleagues (2014) found that previous nights' alcohol use predicted increases in PTSD symptoms the next day, although this association was only

significant for individuals with an existing alcohol use disorder. Consistent with the mutual maintenance model and the rebound effect, while alcohol use may provide reprieve in the short-term, taken in heavier quantities, PTSD symptoms may worsen once the alcohol wears off (Cohn, Hagman, Moore, Mitchell, & Ehlke, 2014; Tomlinson et al., 2006). Nonetheless, Cohn et al.'s (2014) study provides proof of concept that alcohol use may increase subsequent PTSD symptoms at least in some participants.

Alcohol may relieve PTSD symptoms for a short time because it promotes dopamine release in the brain (Boileau et al., 2003), but, as just noted, it can leave individuals feeling even worse later on. As an example, disordered sleep, a common symptom of PTSD, may prompt an individual to drink alcohol before bed. While alcohol has sedating qualities and reduces the time to fall asleep, it is also associated with an increase in awakenings and "respiratory disturbances during the night" (Vandrey, Babson, Herrmann, & Bonn-Miller, 2014, p. 239; Mitler, Dawson, Henriksen, Sobers, & Bloom, 1988). Chronic use of alcohol is also associated with an increase in sleep latency and a reduction in total sleep time (Clark et al., 1998; Drummond, Gillin, Smith, & DeModena, 1998; Landolt & Gillin, 2001; Yules, Lippman, & Freedman, 1967). This lack of quality sleep can then impact a person's emotionality and ability to function the following day.

LIMITATIONS

Like any study, this one had several limitations. Most importantly, the sample size was small (particularly for level 2, subjects), which, as already noted, reduces the power of the study for between-subject analyses. For example, if the true effect size for a between-subject association were small or small-to-moderate, the study would be severely underpowered. Another limitation also relating to the sample is that it was

comprised of all males. Therefore, these findings are limited to individuals who identify as male. In addition, the majority of the participants had a preliminary diagnosis of PTSD based on PCL-5 scores, and so results will generalize to this population.

There were also limitations regarding assessments. Alcohol craving and alcohol-related problems were not assessed, and previous EMA research has suggested these assessments are useful (Lane et al., 2019). As noted in the introduction, social-cognitive theory has been used to provide a theoretical basis for examining associations, but the study did not include measures to adequately test the social-cognitive theory.

There was also limited variability in risky behaviors: 22 participants did not report any risky sexual behaviors and 13 participants did not report any drinking during the study. This limited variability presumably makes detecting within-subject associations more difficult. Studies of sexual behavior have typically relied on self-reports despite its validity being questioned. Sexual behavior is often kept private and risky sexual behavior is often perceived negatively, thus impacting the rate at which it is reported (LaBrie & Earleywine, 2000). It is also possible that participants were engaged in other forms of treatment throughout their time in this study as study criteria did not limit them from doing so, and this treatment may have reduced alcohol use and risky sexual behavior. However, no data were collected on treatment engagement, and so there are no data for or against this possibility.

There were also potential limitations with analysis and interpretation. As with all EMA studies, the presence of missing data can potentially lead to biased parameter estimates, depending on the reasons why data are missing and the methods of analysis used. Although GEEs have a number of advantages over GLMMs, to include more

straightforward interpretation of fixed effects, they also have limitations (see Atkins, Baldwin, Zheng, Gallop, & Neighbors, 2013). For example, GEEs make stronger assumptions about missing data than GLMMs (Atkins et al., 2013). In addition, the author is not aware of a method of implementing first order autocorrelation of residuals with unequal intervals with GEEs (this is easy to implement with GLMMs). Finally, as noted in Lane et al. (2019), the inclusion of lagged dependent variables in prospective analyses can potentially yield biased parameter estimates for focal predictor variables ("Nickell's bias"). Results from prospective analyses with lagged dependent variables should be interpreted with caution, although the magnitude of the parameter estimates are likely to biased downwards (Lane et al., 2019).

Finally, as with all EMA studies, the data are correlational. Therefore, one cannot conclude that elevations in PTSD symptoms cause risky behaviors (or vice versa). It is possible that a third (level 1) variable causes both PTSD symptoms and risky behaviors creating a "spurious relationship."

STRENGTHS

This study had several strengths. The most important strength to this study was the novelty of the methodology used and population examined. To our knowledge, this was the first naturalistic study exploring the relationship between PTSD and risky sexual behaviors among military veterans. EMA research in this area of study has several advantages over cross-sectional research, including acquisition of more ecologically valid data and the assessment of environmental/behavioral variables. Additionally, EMA reduces retrospection bias because subjects fill out the self-report measures for the recent past (e.g., past two hours).

FUTURE DIRECTIONS

Based on the above considerations, there are many directions future research could go. Future research could examine variables that mediate or moderate the relationship between PTSD symptoms and risky behaviors. For example, regarding mediation, as noted in the introduction, distress and emotion dysregulation (e.g., Weiss et al., 2019) are possible candidate variables.

Moreover, this study's conceptual model and analyses treat alcohol consumption and risky sexual behavior as two separate dependent variables. As noted earlier, future research can consider the use of multivariate analyses in which both dependent variables are included in a single model. In addition, and particularly pertinent to the current point, one can hypothesize a causal relationship between alcohol use and risky sexual behavior. With this hypothesized model, one can examine whether there is evidence for within-subject mediation (i.e., When participants report more PTSD symptoms than usual, do they report more alcohol consumption? And is increased alcohol consumption in turn related to risky sexual behavior?). Future research can evaluate the causal relationship between alcohol consumption and risky sexual behavior.

In addition, as noted above, future studies can examine moderators of the association between PTSD symptoms and risky behaviors such as self-efficacy (e.g., Possemato et al., 2015), distress tolerance (e.g., Marshall-Berenz, Vujanovic, & MacPherson, 2011) or impulsivity. Preliminary research supports a larger association between PTSD symptoms and alcohol use for individuals who reported higher trait impulsiveness (Black et al., 2018). However, future research can examine the moderating role of state impulsivity measures. Wilson and colleagues (2017) also reported evidence for the moderating effect of both overall PTSD severity and daily PTSD symptoms on the

association between alcohol use and alcohol-related problems. As PTSD severity increased, the association between number of drinks consumed and alcohol-related problems weakened. This finding underscores the importance of assessments of alcohol-related problems (as well as alcohol use).

Given that different causal relationships may play out over different timescales, future research can also examine prospective associations at longer time intervals. For example, one can examine whether risky behaviors influence PTSD symptoms not at the subsequent assessment but at the assessment following that. Future research can also examine the role of different PTSD symptom clusters (rather than just the total score).

Future research can also examine predictors of missingness of data. Although Black et al. (2018) examined subject-level predictors of missingness (compliance), they did not examine level 1 predictors. For example, it would be useful to treat missingness (0=Not Missing, 1=Missing) as a dependent variable and examine this dependent variable in a multilevel analysis. Intuitively one would expect missingness to be related to risky behaviors, but little research has examined this (Lane et al., 2019).

Continuing to understand the mechanisms of the relationship between PTSD symptoms and risky behaviors from different theoretical perspectives is also essential. For example, incorporating and testing newer theories, such as the behavioral economic model of addiction (e.g., Luciano, Acuff, McDevitt-Murphy, & Murphy, 2020), may help advance this field of research. Future research could also use EMA research to examine the role of sleep in these associations, and sleep quality can be assessed using EMA with the use of assessments taken in the morning upon awakening (e.g., Shiffman et al., 2006).

CONCLUSION

In this 28-day EMA study, PTSD symptoms were contemporaneously associated with both alcohol use and risky sexual behavior. Contrary to study hypotheses, there was no evidence that PTSD symptoms were associated with alcohol use or risky sexual behavior at the following assessment. Similarly, there was no evidence that risky behaviors were associated with PTSD symptoms at the following assessment. Future research should seek to understand the time course of causal relationships, if any, between PTSD symptoms and risky behaviors, as well as mediators and moderators of this association.

Table 1. Baseline Data (Lab Visit 1)

Measure ↓	***Mean* or *n***	***SD* or %**	***Min***	***Max***
Age	32.42	6.74	22	51
Race/Ethnicity				
American Indian or Alaskan Native	1	2.3%		
Asian or Pacific Islander	1	2.3%		
Black, not of Hispanic origin	14	32.6%		
Hispanic, regardless of race	6	26.1%		
White, not of Hispanic origin	21	48.8%		
Marital Status				
Single/Never Married	19	44.2%		
Married (once)	4	9.3%		
Remarried	1	2.3%		
Widowed	1	2.3%		
Separated	4	9.3%		
Divorced	14	32.6%		
Education (Years)	14.49	1.40	12	17
Lifetime months' active military service	75.02	64.85	10	309
Alcohol Use				
Baseline past 28-day number drinks	40.34	46.081	0	221
Mental health				
Baseline PCL	48.88	11.68	26	74
Preliminary diagnosis of PTSD	39	90.7%		
Lifetime psychiatric hospitalization	19	44.19%		
Current medication for mental health condition	21	48.8%		
Traumatic brain injury	12	27.9%		

Note: Data pertain to 43 individuals with baseline data and at least 1 EMA assessment

Table 2. EMA Data

Measure ↓	***Total N***	***Mean***	***SD***	***N***	**%**
Assessments					
Mean completed assessments during study (with alcohol use data)	2312	53.77	22.87		
Mean interval between assessments on same day (hours)	1696	4.14	3.14		
Alcohol Consumption					
Percent EMA recording any alcohol use in the past 2 h	2312			252	10.90%
Percent EMA recording 3+ alcohol drinks in the past 2 h	2312			120	5.2%
Mean Alcohol Use (13-point scale)	2312	0.38	1.48		
Sexual Behavior					
Percent EMA recording *any* sexual behavior since the last assessment	2707			245	9.05%
Percent EMA recording no risky sexual behavior since the last assessment	2707			2855	98.08%
Percent EMA recording 1 risky sexual behavior episode since the last assessment	2707			43	1.59%
Percent EMA recording 2 risky sexual behavior episodes since the last assessment	2707			7	0.26%
Percent EMA recording 3 risky sexual behavior episodes since the last assessment	2707			2	0.07%
PCL					
Mean momentary PCL-5	2654	28.11	20.31		

Note: Data derived from up to 2707 EMA assessments from 43 individuals with baseline data and at least 1 EMA assessment. ***Total N*** = Total number of assessments.

Table 3. Results of GEEs for Associations between PCL & Alcohol Use

DV →			**Number of Drinks**					**PCL**			
IV↓	Component ↓	H↓	*PE*	*SE*	*z*	*p*	*RR*	*PE*	*SE*	*Z*	*p*
PCL	*Mean*	1.1	0.0053	0.0120	0.44	0.6587	1.01	.	.	.	.
	Deviation	1.2	**0.0266**	**0.0102**	**2.60**	**0.0094**	**1.03**	.	.	.	.
Lagged PCL	*Lagged Mean*	2.1	-0.0009	0.0177	-0.05	0.9579	1.00	.	.	.	.
	Lagged Deviation	2.2	-0.0037	0.0115	-0.32	0.7468	1.00	.	.	.	.
Lagged Alcohol Use	*Lagged Mean*	3.1	.	.	.	.	.	6.7473	4.7486	1.42	0.1553
	Lagged Deviation	3.2	.	.	.	.	.	0.0501	0.1598	0.31	0.7537

Table Note: Data are results for GEEs. H = Hypothesis. . = Not Applicable. *PE* = Parameter Estimate, *SE* = Standard Error, *RR* = Rate Ratio (exponentiated parameter estimate), DV = Dependent Variable, IV = Independent Variable. Lagged *Mean* analyses examine if Mean values of the predictor variable in the first 14 days are associated with the DV in the second 14 days.

Table 4. Results of GEEs for Associations between PCL & Risky Sexual Behavior

DV →			**Number of Episodes of Risky Sex**					**PCL**			
IV↓	Component ↓	H↓	*PE*	*SE*	*z*	*p*	*RR*	*PE*	*SE*	*z*	*p*
PCL	*Mean*	1.3	-0.0081	0.0087	0.0089	-0.93	0.99	.	.	.	.
	Deviation	1.4	**0.0289**	**0.0132**	**2.20**	**0.0281**	**1.03**	.	.	.	.
Lagged PCL	*Lagged Mean*	2.3	-0.0169	0.0114	-1.48	0.1387	0.98	.	.	.	.
	Lagged Deviation	2.4	-0.0195	0.0196	-0.99	0.3211	0.98	.	.	.	.
Lagged Risky Sex	*Lagged Mean*	3.3	.	.	.	.	.	-10.866	48.4324	-0.22	0.8225
	Lagged Deviation	3.4	.	.	.	.	.	1.1964	1.1456	1.04	0.2963

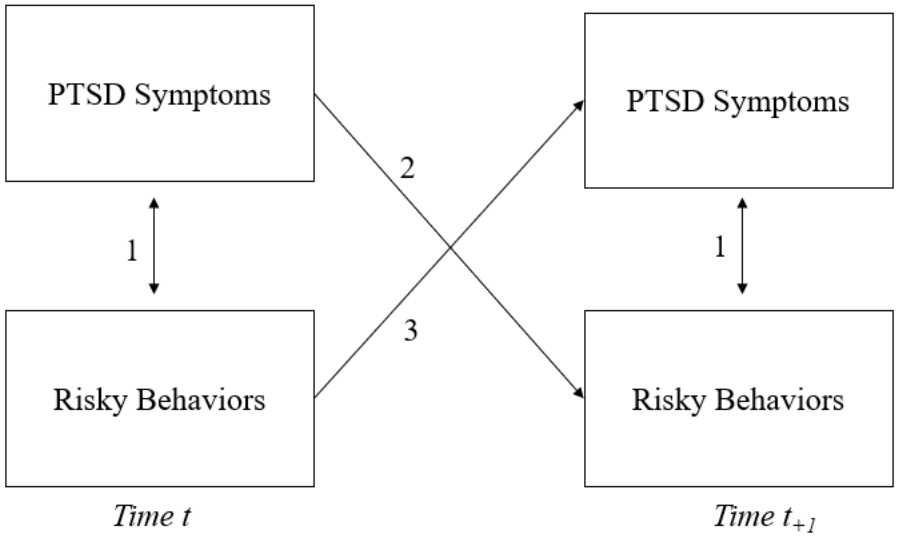
Table Note: Data are results for GEEs. H = Hypothesis. . = Not Applicable. *PE* = Parameter Estimate, *SE* = Standard Error, *RR* = Rate Ratio (exponentiated parameter estimate), DV = Dependent Variable, IV = Independent Variable. Lagged *Mean* analyses examine if Mean values of the predictor variable in the first 14 days are associated with the DV in the second 14 days.

Table 5. Results of Supplementary Analyses

	Primary Analyses	Supplementary Analyses			
		#1	#2	#3	#4
		Risky Sex	*Any Sex*	*Non- vs None*	*Risky vs None*
Risky Sex	Count (1-3)	1	1	.	1
Non-Risky Sex	0	0	1	1	.
No Sex	0	0	0	0	0
OR		1.29	1.16	1.13	1.30
Significant		*	*		*

Table Note: Summary of results of supplementary analyses, illustrating coding used (see text for details).

Figure 1. Conceptual Model



Note: Two time points are depicted. Single-headed arrows depict causal relationships. Double-headed arrows depict associations in which no commitment to the direction of any causal relationship is asserted. Specific Aim 1 examines contemporaneous associations between PTSD symptoms and Risky Behaviors. Specific Aim 2 examines whether PTSD symptoms prospectively predict Risky Behaviors. Specific Aim 3 examines whether Risky Behaviors prospectively predict PSTD symptoms. The model does not depict decomposition into between- and within-subject associations; this is described in the text. PTSD symptoms may be correlated over time, and the same is true for Risky Behaviors (not shown in model).

Figure 2. Flowchart

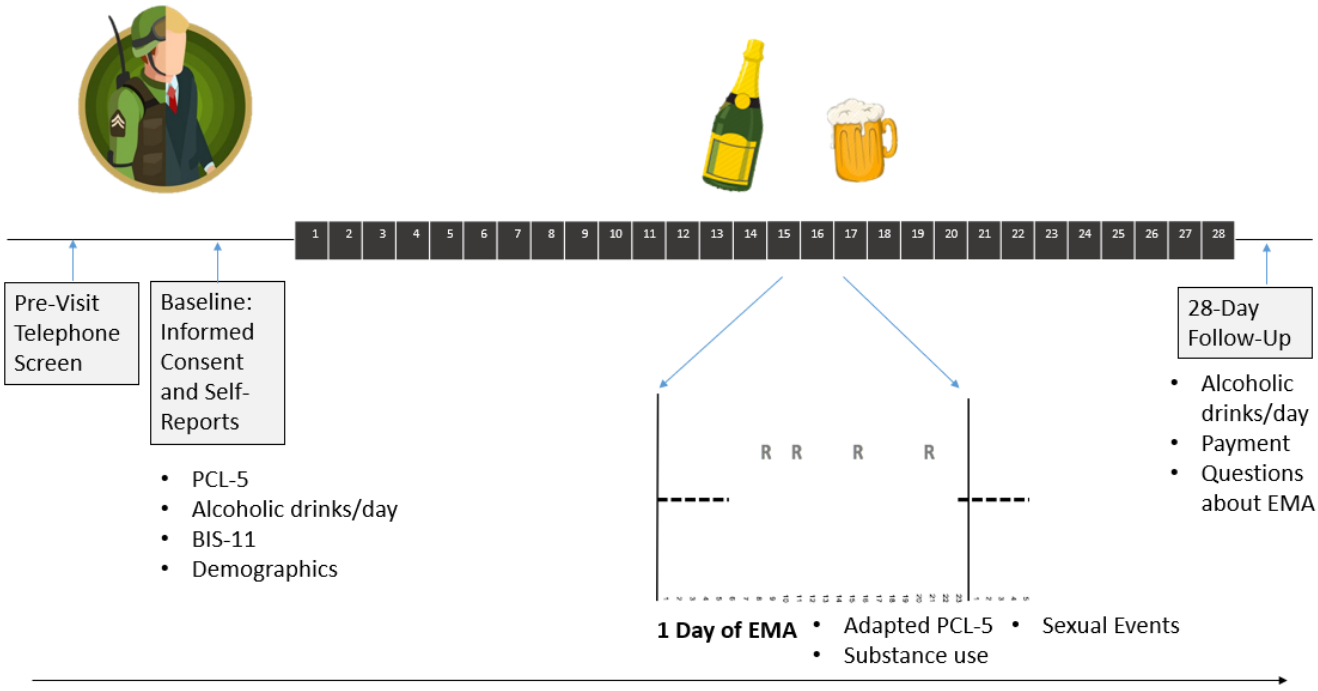


Figure 3. Sample of EMA Items

Section Header: PTSD Symptoms
In the past 2 hours, have you experienced any of the following:

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?
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?
6. Avoiding memories, thoughts, or feelings related to the stressful experience?
7. Avoiding external reminders of the stressful experience?
8. Trouble remembering important parts of the stressful experience?
9. Having strong negative beliefs about yourself, other people, or the world?
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 o from other people?
14. Trouble experiencing positive feelings?
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?

Section Header: Alcohol and Substance Use

In the past 2 hours, how many alcoholic drinks (equivalent to a 12 oz beer, 5 oz. glass of wine, or 1-1/2 oz of hard liquor) have you had?

Section Header: Sex

SINCE YOUR LAST COMPLETED QUESTIONNAIRE, did you have any sexual contact with another person?

SINCE THE LAST TIME YOU COMPLETED A QUESTIONNAIRE, how many times did you have any sexual contact with a partner?

Section Header: Sexual Event #1

1. When did the sexual contact occur (to the nearest hour)?

[selection of 1-hr increments; e.g., 1AM, 2AM, etc.]

2. When did the sexual contact occur (day)
   [today] [yesterday] [2 days ago] [3 days ago] [4 or more days ago]
3. What type(s) of sexual contact did you have (check all that apply)?
   [oral sex] [vaginal sex] [anal sex]
4. Which choice best describes your sexual partner?
   [main partner] [other partner] [new partner]
5. Did you have sex with this partner in exchange for money, drugs, or as part of a financial arrangement?
   [yes] [no]
6. Which choice describes your sexual partner?
   [male] [female]
7. Did you and/or your partner use a condom or other latex protection when you had sexual contact?
   [yes] [no]
8. Did you use alcohol or drugs before or during this sexual event?
   [yes] [no]

Figure 4. Consort Chart

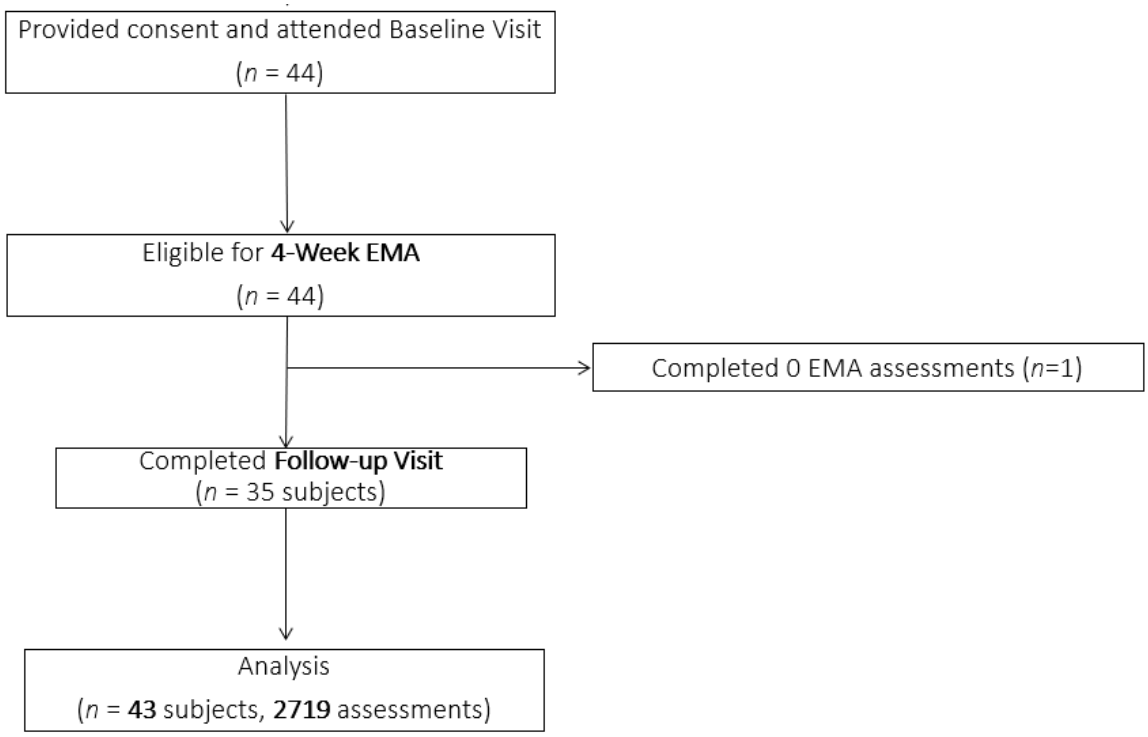


Figure 5. Specific Aim 1: Contemporaneous Associations between PTSD Symptoms and Drinking

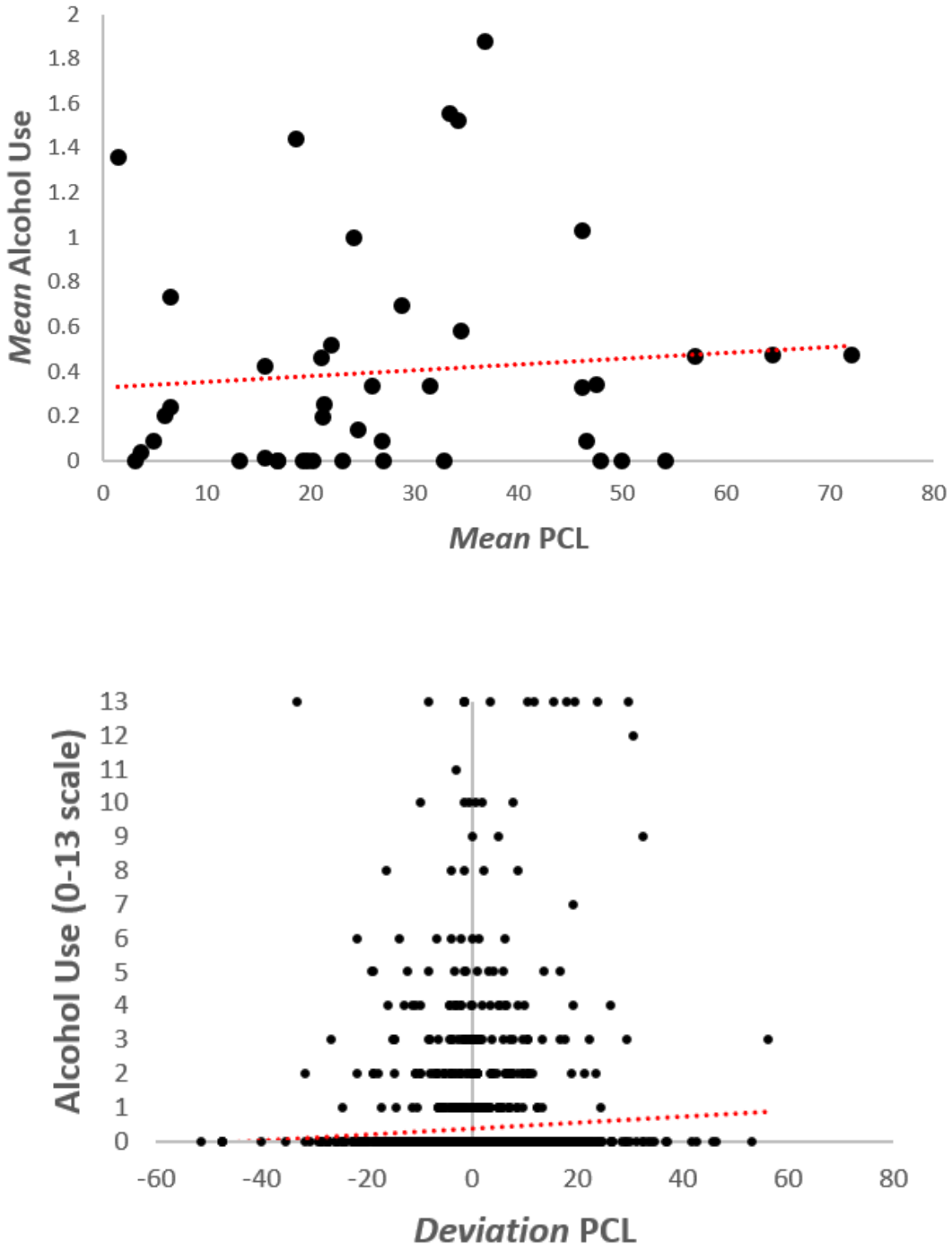
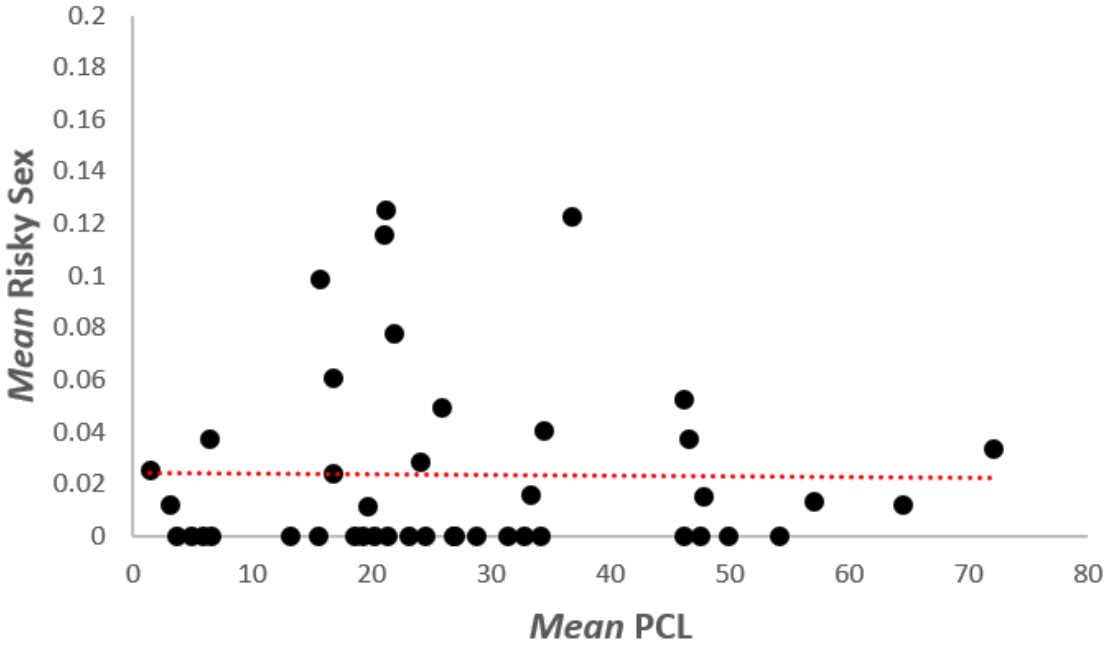
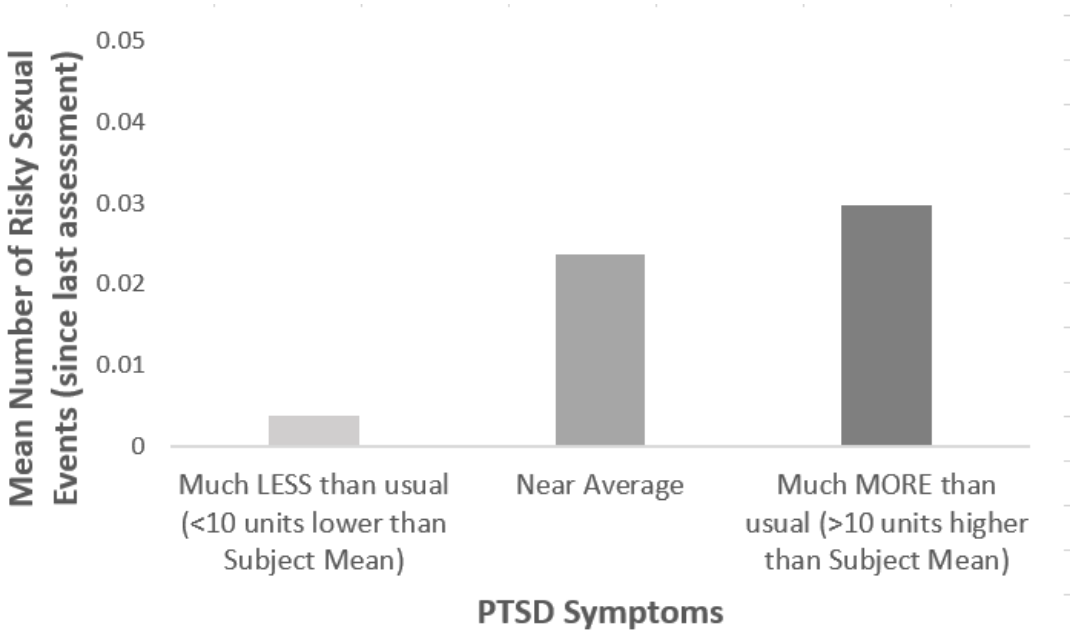


Figure 6. Specific Aim 1: Contemporaneous Associations between PTSD Symptoms and Risky Sexual Behavior





Appendix

```
proc genmod data=lanem ;
class subject observation;
model alcuse = day weekend night pcl_S dev_pcl / link=log dist=negbin  wald type3  ;
repeated subject = subject / type = ar(1) within=observation PRINTMLE;
ESTIMATE 'pcl_S' pcl_S 1 / EXP;
ESTIMATE 'dev_pcl' dev_pcl 10 / EXP;
run;
```

Syntax used for Hypotheses 1.1 and 1.2. SAS PROC GENMOD was used to implement Generalized Estimating Equations. The analysis assumes first-order autocorrelation of residuals.

REFERENCES

Adler, A. B., Britt, T. W., Castro, C. A., McGurk, D., & Bliese, P. D. (2011). Effect of transition home from combat on risk-taking and health-related behaviors. *Journal of Traumatic Stress, 24*(4), 381-389. doi:10.1002/jts.20665

Alexander, A. C., & Ward, K. D. (2018). Understanding postdisaster substance use and psychological distress using concepts from the self-medication hypothesis and social cognitive theory. *Journal of Psychoactive Drugs, 50*(2), 177-186. doi:10.1080/02791072.2017.1397304

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders (5th ed.). Arlington, VA: American Psychiatric Publishing.

Artime, T. M., & Peterson, Z. D. (2012). The relationships among childhood maltreatment, emotion regulation, and sexual risk taking in men from urban STD clinics. *Journal of Aggression, Maltreatment and Trauma, 21,* 277–299.

Atkins, D. C., Baldwin, S. A., Zheng, C., Gallop, R. J., & Neighbors, C. (2013). A tutorial on count regression and zero-altered count models for longitudinal substance use data. *Psychology of Addictive Behaviors*, 27(1), 166.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory.* Englewood Cliffs, NJ: Prentice Hall, Inc.

Bandura, A. (1989). Human agency in social cognitive theory. *American Psychologist, 44*(9), 1175-1184. doi:10.1037/0003-066X.44.9.1175

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language, 68*(3), 255-278. doi:10.1016/j.jml.2012.11.001

Batten, S. V., Follette, V. M., & Aban, I. B. (2002). Experiential avoidance and high-risk sexual behavior in survivors of child sexual abuse. *Journal of Child Sexual Abuse, 10*(2), 101-120. doi:10.1300/J070v10n02_06

Benjamini, Y., Krieger, A. M., & Yekutieli, D. (2006). Adaptive linear step-up procedures that control the false discovery rate. *Biometrika, 93*(3), 491-507. doi:10.1093/biomet/93.3.491

Black, A. C., Cooney, N. L., Sartor, C. E., Arias, A. J., & Rosen, M. I. (2018). Impulsivity interacts with momentary PTSD symptom worsening to predict alcohol use in male veterans. *The American Journal of Drug and Alcohol Abuse*, 44(5), 524-8.

Black, A. C., Cooney, N. L., Justice, A. C., Fiellin, L. E., Pietrzak, R. H., Lazar, C. M., Rosen, M. I. (2016). Momentary assessment of PTSD symptoms and sexual risk behavior in male OEF/OIF/OND Veterans. *J Affect Disord*. 190:424–28. doi:10.1016/j.jad.2015.10.039.

Bolger, N., & Laurenceau, J. P. (2013). *Intensive longitudinal methods: An introduction to diary and experience sampling research.* Guilford, New York, NY.

Blume, A. W., Schmaling, K. B., & Marlatt, G. A. (2000). Revisiting the self-medication hypothesis from a behavioral perspective. *Cognitive and Behavioral Practice, 7*(4), 379-384. doi:10.1016/S1077-7229(00)80048-6

Boileau, I., Assaad, J., Pihl, R. O., Benkelfat, C., Leyton, M., Diksic, M., . . . Dagher, A. (2003). Alcohol promotes dopamine release in the human nucleus accumbens. *Synapse, 49*(4), 226-231. doi:10.1002/syn.10226

Brady, K. T., Back, S. E., & Coffey, S. F. (2004). Substance abuse and posttraumatic stress disorder. *Current Directions in Psychological Science, 13*(5), 206-209. doi:10.1111/j.0963-7214.2004.00309.x

Briere, J. N., & Elliott, D. M. (1994). Immediate and long-term impacts of child sexual abuse. *The Future of Children, 4*(2), 54.

Calhoun, P. S., Elter, J. R., Jones, E. R., Kudler, H., & Straits-Tröster, K. (2008). Hazardous alcohol use and receipt of risk-reduction counseling among U.S. veterans of the wars in iraq and afghanistan. *The Journal of Clinical Psychiatry, 69*(11), 1686-1693. doi:10.4088/JCP.v69n1103

Chapman, A. L., Gratz, K. L., & Brown, M. Z. (2006). Solving the puzzle of deliberate self-harm: The experiential avoidance model. *Behaviour Research and Therapy, 44*(3), 371-394. doi:10.1016/j.brat.2005.03.005

Clark, C. P., Gillin, J. C., Golshan, S., Demodena, A., Smith, T. L., Danowski, S., . . . Schuckit, M. (1998). Increased REM sleep density at admission predicts relapse by three months in primary alcoholics with a lifetime diagnosis of secondary depression. *Biological Psychiatry (1969), 43*(8), 601-607. doi:10.1016/s0006-3223(97)00457-5

Cohn, A., Hagman, B. T., Moore, K., Mitchell, J., & Ehlke, S. (2014). Does negative affect mediate the relationship between daily PTSD symptoms and daily alcohol involvement in female rape victims? evidence from 14 days of interactive voice response assessment. *Psychology of Addictive Behaviors*, 28(1), 114-126. doi:10.1037/a0035725

Contractor, A. A., Weiss, N. H., Dranger, P., Ruggero, C., & Armour, C. (2017). PTSD's risky behavior criterion: Relation with DSM-5 PTSD symptom clusters and

psychopathology. *Psychiatry Research, 252*, 215-222. doi:10.1016/j.psychres.2017.03.008

Crepaz, N., & Marks, G. (2001). Are negative affective states associated with HIV sexual risk behaviors? A meta-analytic review. *Health Psychology, 20*(4), 291-299. doi:10.1037/0278-6133.20.4.291

Dedert, E. A., Calhoun, P. S., Harper, L. A., Dutton, C. E., McClernon, F. J., & Beckham, J. C. (2012). Smoking withdrawal in smokers with and without posttraumatic stress disorder. *Nicotine & tobacco research*, *14*(3), 372-376.

Dursa, E. K., Reinhard, M. J., Barth, S. K., & Schneiderman, A. I. (2014). Prevalence of a positive screen for PTSD among OEF/OIF and OEF/OIF-Era veterans in a large Population-Based cohort. *Journal of Traumatic Stress, 27*(5), 542-549. doi:10.1002/jts.21956

Drummond, S. P., Gillin, J. C., Smith, T. L., & DeModena, A. (1998). The sleep of abstinent pure primary alcoholic patients: Natural course and relationship to relapse. *Alcoholism, Clinical and Experimental Research, 22*(8), 1796. doi:10.1097/00000374-199811000-00026

Erbes, C., Westermeyer, J., Engdahl, B., & Johnsen, E. (2007). Post-traumatic stress disorder and service utilization in a sample of service members from iraq and afghanistan. *Military Medicine, 172*(4), 359-363. doi:10.7205/MILMED.172.4.359

Faul, F., Erdfelder, E., Lang, A., & Buchner, A. (2007). GPower 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175-191. doi:10.3758/bf03193146

Field, A. (2017). *Discovering Statistics Using IBM SPSS Statistics*: SAGE Publications.

Gaher, R. M., Simons, J. S., Hahn, A. M., Hofman, N. L., Hansen, J., & Buchkoski, J. (2014). An experience sampling study of PTSD and alcohol-related problems. *Psychology of Addictive Behaviors, 28*(4), 1013-1025. doi:10.1037/a0037257

Gelman, A., Shor, B., Bafumi, J., & Park, D. (2007). Rich state, poor state, red state, blue state: What's the matter with Connecticut?. *Quarterly Journal of Political Science, 2*(4), 345-367. doi: 10.2139/ssrn.1010426

Gratz, K. L., & Roemer, L. (2004). Multidimensional assessment of emotion regulation and dysregulation: Development, factor structure, and initial validation of the difficulties in emotion regulation scale. *Journal of Psychopathology and Behavioral Assessment, 26*(1), 41-54. doi:10.1023/B:JOBA.0000007455.08539.94

Gratz, K. L., & Tull, M. T. (2010). Emotion regulation as a mechanism of change in acceptance-and mindfulness-based treatments. In R. A. Baer (Ed.), *Assessing mindfulness and acceptance: Illuminating the theory and practice of change* (pp. 105–133). Oakland, CA: New Harbinger Publications.

Harris, P. A., Taylor, R., Thielke, R., Payne, J., Gonzalez, N., Conde, J. G. (2009). Research electronic data capture (REDCap) —a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 42(2):377–81. doi:10.1016/j.jbi.2008.08.010.

Jakupcak, M., Tull, M. T., McDermott, M. J., Kaysen, D., Hunt, S., & Simpson, T. (2010). PTSD symptom clusters in relationship to alcohol misuse among iraq and afghanistan war veterans seeking post-deployment VA health care. *Addictive Behaviors, 35*(9), 840-843. doi:10.1016/j.addbeh.2010.03.023

James, L. M., Strom, T. Q., & Leskela, J. (2014). Risk-taking behaviors and impulsivity among veterans with and without PTSD and mild TBI. *Military Medicine, 179*(4), 357-363. doi:10.7205/MILMED-D-13-00241

Kaysen, D., Atkins, D. C., Simpson, T. L., Stappenbeck, C. A., Blayney, J. A., Lee, C. M., & Larimer, M. E. (2014). Proximal relationships between PTSD symptoms and drinking among female college students: Results from a daily monitoring study. *Psychology of Addictive Behaviors: Journal of the Society of Psychologists in Addictive Behaviors, 28*(1), 62-73. doi:10.1037/a0033588

Kessler, R. C., Sonnega, A., Bromet, E., Hughes, M., & Nelson, C. B. (1995). Posttraumatic stress disorder in the national comorbidity survey. *Archives of General Psychiatry, 52*(12), 1048-1060. doi:10.1001/archpsyc.1995.03950240066012

Khantzian, E. J. (1985). The self-medication hypothesis of addictive disorders: Focus on heroin and cocaine dependence. *American Journal of Psychiatry, 142*(11), 1259-1264. doi:10.1176/ajp.142.11.1259

Khantzian, E. J. (1997). The self-medication hypothesis of substance use disorders: A reconsideration and recent applications. *Harvard Review of Psychiatry*, 4(5), 231-244. doi:10.3109/10673229709030550

Kreft, I., & de Leeuw, J. (1998). *Introducing multilevel modeling*: Sage.

Kwako, L. E., Schwandt, M. L., Sells, J. R., Ramchandani, V. A., Hommer, D. W., George, D. T., . . . Heilig, M. (2015). Methods for inducing alcohol craving in individuals with co-morbid alcohol dependence and posttraumatic stress disorder: Behavioral and physiological outcomes. *Addiction Biology, 20*(4), 733-746. doi:10.1111/adb.12150

LaBrie, J. W., & Earleywine, M. (2000). Sexual risk behaviors and alcohol: Higher base rates revealed using the unmatched-count technique. *The Journal of Sex Research, 37*(4), 321-326. doi:10.1080/00224490009552054

Landolt, H. P., & Gillin, J. C. (2001). Sleep abnormalities during abstinence in alcohol-dependent patients. aetiology and management. *CNS Drugs, 15*(5), 413

Lane, A., Waters, A. J., & Black, A. C. (2019). Ecological momentary assessment studies of comorbid PTSD and alcohol use: A narrative review. *Addictive Behaviors Reports, 10*, 100205-100205. doi:10.1016/j.abrep.2019.100205

Lee, K. C., Ngo-Metzger, Q., Wolff, T., Chowdhury, J., Lefevre, M. L., & Meyers, D. S. (2016). Sexually transmitted infections: Recommendations from the U.S. preventive services task force. *American Family Physician, 94*(11), 907-915.

Liang, K. Y., & Zeger, S. L. (1986). Longitudinal data analysis using generalized linear models. *Biometrika, 73*(1), 13-22.

Linehan, M. M. (1993). *Cognitive behavioral treatment of borderline personality disorder*. New York: Guilford Press.

Luciano, M. T., Acuff, S. F., McDevitt-Murphy, M. E., & Murphy, J. G. (2020). Behavioral economics and coping-related drinking motives in trauma exposed drinkers: Implications for the self-medication hypothesis. *Experimental and Clinical Psychopharmacology, 28*(3), 265-270. doi:10.1037/pha0000318

Marshall-Berenz, E. C., Vujanovic, A. A., & MacPherson, L. (2011). Impulsivity and alcohol use coping motives in a trauma-exposed sample: The mediating role of distress tolerance. *Personality and Individual Differences, 50*(5), 588-592. doi:10.1016/j.paid.2010.11.033

McDermott, M. J., Tull, M. T., Gratz, K. L., Daughters, S. B., & Lejuez, C. W. (2009). The role of anxiety sensitivity and difficulties in emotion regulation in posttraumatic stress disorder among crack/cocaine dependent patients in residential substance abuse treatment. *Journal of Anxiety Disorders, 23*(5), 591-599. doi:10.1016/j.janxdis.2009.01.006

McDevitt-Murphy, M. E., Williams, J. L., Bracken, K. L., Fields, J. A., Monahan, C. J., & Murphy, J. G. (2010). PTSD symptoms, hazardous drinking, and health functioning among U.S.OEF and OIF veterans presenting to primary care. *Journal of Traumatic Stress, 23*(1), 108-111. doi:10.1002/jts.20482

McFarlane, A. C., Browne, D., Bryant, R. A., O'Donnell, M., Silove, D., Creamer, M., & Horsley, K. (2009). A longitudinal analysis of alcohol consumption and the risk of posttraumatic symptoms. *Journal of Affective Disorders, 118*(1), 166-172. doi:10.1016/j.jad.2009.01.017

McLellan, A. T., Kushner, H., Metzger, D., Peters, R., Smith, I., Grissom, G., . . . Argeriou, M. (1992). The fifth edition of the addiction severity index. *Journal of Substance Abuse Treatment, 9*(3), 199-213. doi:10.1016/0740-5472(92)90062-S

McNeish, D. (2019). Effect partitioning in cross-sectionally clustered data without multilevel models. *Multivariate Behavioral Research, 54*(6), 906-925. doi:10.1080/00273171.2019.1602504

Mills, K. L., Teesson, M., Ross, J., & Peters, L. (2006). Trauma, PTSD, and substance use disorders: Findings from the australian national survey of mental health and well-being. *American Journal of Psychiatry, 163*(4), 652-658. doi:10.1176/appi.ajp.163.4.652

Mitler, M. M., Dawson, A., Henriksen, S. J., Sobers, M., & Bloom, F. E. (1988). Bedtime ethanol increases resistance of upper airways and produces sleep apneas in asymptomatic snorers. *Alcoholism: Clinical and Experimental Research, 12*(6), 801-805. doi:10.1111/j.1530-0277.1988.tb01349.x

Mittleman, M. A., Maclure, M., Tofler, G. H., Sherwood, J. B., Goldberg, R. J., & Muller, J. E. (1993). Triggering of acute myocardial infarction by heavy physical exertion -- protection against triggering by regular exertion. *The New England Journal of Medicine, 329*(23), 1677-1683. doi:10.1056/nejm199312023292301

Ouimette, P., Read, J., & Brown, P. J. (2005). Consistency of retrospective reports of DSM-IV criterion A traumatic stressors among substance use disorder patients. *Journal of Traumatic Stress, 18*(1), 43-51. doi:10.1002/jts.20009

Patton, J. H., Stanford, M. S., & Barratt, E. S. (1995). Factor structure of the barratt impulsiveness scale. *Journal of Clinical Psychology, 51*(6), 768-774. doi:10.1002/1097-4679(199511)51:6<768::AID-JCLP2270510607>3.0.CO;2-1

Possemato, K., Maisto, S. A., Wade, M., Barrie, K., McKenzie, S., Lantinga, L. J., & Ouimette, P. (2015). Ecological momentary assessment of PTSD symptoms and alcohol use in combat veterans. *Psychology of Addictive Behaviors*, 29(4), 894-905. doi:10.1037/adb0000129

Preacher, K. J., Zhang, Z., & Zyphur, M. J. (2016). Multilevel structural equation models for assessing moderation within and across levels of analysis. *Psychol Methods*, 21(2), 189-205.

Preacher, K. J., Zyphur, M. J., & Zhang, Z. (2010). A general multilevel SEM framework for assessing multilevel mediation. *Psychological Methods, 15*(3), 209-233. doi:10.1037/a0020141

Reisner, S. L., Mimiaga, M. J., Safren, S. A., & Mayer, K. H. (2009). Stressful or traumatic life events, post-traumatic stress disorder (PTSD) symptoms, and HIV sexual risk taking among men who have sex with men. *AIDS Care*, 21(12), 1481-1489.

Robinson W.S. (1950). Ecological correlations and the behavior of individuals. *American Sociological Review 15, 351–*57

Seal, K. H., Cohen, G., Waldrop, A., Cohen, B. E., Maguen, S., & Ren, L. (2011). Substance use disorders in iraq and afghanistan veterans in VA healthcare, 2001–2010: Implications for screening, diagnosis and treatment. *Drug and Alcohol Dependence, 116*(1), 93-101. doi:10.1016/j.drugalcdep.2010.11.027

Shiffman, S., Patten, C., Gwaltney, C., Paty, J., Gnys, M., Kassel, J., . . . Balabanis, M. (2006). Natural history of nicotine withdrawal. *Addiction*, 101(12), 1822-1832. doi:10.1111/j.1360-0443.2006.01635.x

Shiffman, S., Stone, A. A., & Hufford, M. R. (2008). Ecological momentary assessment. *Annual Review of Clinical Psychology, 4*(1), 1-32. doi:10.1146/annurev.clinpsy.3.022806.091415

Simpson, T. L., Stappenbeck, C. A., Luterek, J. A., Lehavot, K., & Kaysen, D. L. (2014). Drinking motives moderate daily relationships between PTSD symptoms and alcohol use. *Journal of Abnormal Psychology, 123*(1), 237-247. 10.1037/a0035193

Simpson, T. L., Stappenbeck, C. A., Varra, A. A., Moore, S. A., & Kaysen, D. (2012). Symptoms of posttraumatic stress predict craving among alcohol treatment seekers: Results of a daily monitoring study. *Psychology of Addictive Behaviors, 26*(4), 724-733. doi:10.1037/a0027169

Smith, N. D. L., & Cottler, L. B. (2018). The epidemiology of post-traumatic stress disorder and alcohol use disorder. *Alcohol Research*, 39(2), 113-120.

Stone, A. A., & Shiffman, S. (1994). Ecological momentary assessment (EMA) in behavioral medicine. *Annals of Behavioral Medicine, 16*(3), 199-202.

Strom, T. Q., Leskela, J., James, L. M., Thuras, P. D., Voller, E., Weigel, R., . . . Holz, K. B. (2012). An exploratory examination of risk-taking behavior and PTSD symptom severity in a veteran sample. *Military Medicine, 177*(4), 390-396. doi:10.7205/MILMED-D-11-00133

Tomko, R. L., Solhan, M. B., Carpenter, R. W., Brown, W. C., Jahng, S., Wood, P. K., Trull, T. J. (2014). Measuring impulsivity in daily life: the momentary impulsivity scale. *Psychological Assessment, 26*(2), 339-349. doi: 10.1037/a0035083

Tomlinson, K. L., Tate, S. R., Anderson, K. G., McCarthy, D. M., & Brown, S. A. (2006). An examination of self-medication and rebound effects: Psychiatric symptomatology before and after alcohol or drug relapse. *Addictive Behaviors, 31*(3), 461-474. doi:10.1016/j.addbeh.2005.05.028

Tull, M. T., Barrett, H. M., McMillan, E. S., & Roemer, L. (2007). A preliminary investigation of the relationship between emotion regulation difficulties and posttraumatic stress symptoms. *Behavior Therapy, 38*(3), 303-313. doi:10.1016/j.beth.2006.10.001

Tull, M. T., Weiss, N. H., Adams, C. E., & Gratz, K. L. (2012). The contribution of emotion regulation difficulties to risky sexual behavior within a sample of patients in residential substance abuse treatment. *Addictive Behaviors, 37*(10), 1084-1092. doi:10.1016/j.addbeh.2012.05.001

Turban, J. L., Potenza, M. N., Hoff, R. A., Martino, S., & Kraus, S. W. (2017). Psychiatric disorders, suicidal ideation, and sexually transmitted infections among post-deployment veterans who utilize digital social media for sexual partner seeking. *Addictive Behaviors, 66*, 96-100. doi:10.1016/j.addbeh.2016.11.015

Turchik, J. A., & Garske, J. P. (2009). Measurement of sexual risk taking among college students. *Archives of Sexual Behavior, 38*(6), 936-948. doi:10.1007/s10508-008-9388-z

Twisk, J. W. (2006). *Applied multilevel analysis: A practical guide for medical researchers*. Cambridge: Cambridge University Press. doi:10.1017/CBO9780511610806

Vandrey, R., Babson, K. A., Herrmann, E. S., & Bonn-Miller, M. O. (2014). Interactions between disordered sleep, post-traumatic stress disorder, and substance use disorders. *International Review of Psychiatry*, 26(2), 237-247. doi:10.3109/09540261.2014.901300

Weathers, F.W., Blake, D. D., Schnurr, P. P., Kaloupek, D. G., Marx, B. P., & Keane, T. M. (2013). *The life events checklist for dsm-5 (LEC-5).* http://www.ptsd.va.gov/professional/assessment/te-measures/life_events_checklist.asp

Weathers, F. W., Litz, B. T., Keane, T. M., Palmieri, P. A., Marx, B. P., & Schnurr, P. P. (2013). *The ptsd checklist for dsm-5 (PCL-5).* http://www.ptsd.va.gov/professional/assessment/adult-sr/ptsd-checklist.asp.

Weiss, N. H., Tull, M. T., Anestis, M. D., & Gratz, K. L. (2013). The relative and unique contributions of emotion dysregulation and impulsivity to posttraumatic stress disorder among substance dependent inpatients. *Drug and Alcohol Dependence, 128*(1), 45-51. doi:10.1016/j.drugalcdep.2012.07.017

Weiss, N. H., Tull, M. T., Borne, M. E. R., & Gratz, K. L. (2013). Posttraumatic stress disorder symptom severity and HIV-risk behaviors among substance-dependent inpatients. AIDS Care - *Psychological and Socio-Medical Aspects of AIDS/HIV*, 25(10), 1219-1226.

Weiss, N. H., Tull, M. T., Davis, L. T., Searcy, J., Williams, I., & Gratz, K. L. (2015a). A preliminary experimental investigation of emotion dysregulation and impulsivity in risky behaviours. *Behaviour Change, 32,* 127–142.

Weiss, N. H., Tull, M. T., Sullivan, T. P., Dixon-Gordon, K. L., & Gratz, K. L. (2015b). Posttraumatic stress disorder symptoms and risky behaviors among trauma-exposed inpatients with substance dependence: The influence of negative and positive urgency. *Drug and Alcohol Dependence, 155*, 147-153. doi:10.1016/j.drugalcdep.2015.07.679

Weiss, N. H., Tull, M. T., Viana, A. G., Anestis, M. D., & Gratz, K. L. (2012). Impulsive behaviors as an emotion regulation strategy: Examining associations between PTSD, emotion dysregulation, and impulsive behaviors among substance dependent inpatients. *Journal of Anxiety Disorders, 26*(3), 453-458. doi:10.1016/j.janxdis.2012.01.007

Weiss, N. H., Walsh, K., DiLillo, D. D., Messman-Moore, T. L., & Gratz, K. L. (2019). A longitudinal examination of posttraumatic stress disorder symptoms and risky sexual behavior: Evaluating emotion dysregulation dimensions as mediators. *Archives of Sexual Behavior, 48*(3), 975-986. doi:10.1007/s10508-019-1392-y

Weiss, N. H., Williams, D. C., & Connolly, K. M. (2015c). A preliminary examination of negative affect, emotion dysregulation, and risky behaviors among military veterans in residential substance abuse treatment. *Military Behavioral Health, 3*(4), 212-218. doi:10.1080/21635781.2015.1038405

Wilson, S. M., Krenek, M., Dennis, P. A., Yard, S. S., Browne, K. C., & Simpson, T. L. (2017). Daily associations between PTSD, drinking, and self-appraised alcohol-related problems. *Psychology of Addictive Behaviors, 31*(1), 27-35. doi:10.1037/adb0000238

Yules, R. B., Lippman, M. E., & Freedman, D. X. (1967). Alcohol administration prior to sleep: The effect on EEG sleep stages. *Archives of General Psychiatry, 16*(1), 94-97. doi:10.1001/archpsyc.1967.01730190096012