

**The Relationship Between Daily PTSD Symptom Fluctuations and Substance Use: A
Systematic Literature Review**

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PSB3E-BT15: Bachelor Thesis

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June 30, 2024

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Abstract

Posttraumatic stress disorder (PTSD) and substance use disorder (SUD) are highly comorbid. The occurrence of both disorders in an individual is associated with increased symptom severity, increased violence, poorer treatment outcomes, and additional adverse effects. At this point in time self-medication hypothesis (SMH) seems to be most promising in explaining the relationship. The SMH proposes that individuals use substances to alleviate PTSD symptoms. This systematic literature review, which is to my knowledge the first to include only EMA studies, aimed to synthesize current literature on the topic. EMA studies can help to gain deeper understanding of the relationship between substance use and daily fluctuations in PTSD symptoms. In total the search of the database identified 14 studies that met the inclusion criteria. Findings for alcohol point in the direction that SMH is valuable in explaining the relationship. However, findings for other substances were less clear. These outcomes highlight the importance of further research on the topic, especially considering other substances than alcohol. Furthermore, future research should consider the role of specific PTSD symptom clusters, different populations, as well as moderating factors that could influence the relationship. Findings from this literature can be useful for designing interventions especially mobile health interventions that reach the individual at highly vulnerable moments.

Keywords: Posttraumatic Stress Disorder (PTSD), Psychological Trauma, Substance Use, Self-Medication Hypothesis (SMH), Ecological Momentary Assessment (EMA)

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Introduction

Exposure to a traumatic event, observing or hearing about such an event can lead to the development of Posttraumatic Stress Disorder (PTSD) (American Psychiatric Association, 2013). Examples for traumatic situations are war, accidents, violence, or rape. Symptoms of PTSD are intrusive thoughts about the traumatic situation, avoidance of stimuli that remind the individual of the event, changes in mood and cognition, and heightened reactivity or arousal (American Psychiatric Association, 2013).

PTSD and problematic substance use often occur together across different populations (McCauley et al., 2012). The study by McCauley et al. (2012) reports that between 34.4% of people with PTSD in Australia and up to 46.4% in the US show Substance abuse disorder (SUD). The link between the two disorders seems to be even stronger when considering individuals in treatment (McCauley et al., 2012). Studies on the relationship between PTSD Alcohol use Disorder (AUD) show that the comorbidity brings about many negative outcomes. Individuals tend to have more severe symptoms in both disorders (Najavits et al. 1998), heightened chance for negative health outcomes, elevated probability of suicide attempts, increased violence (Driessen et al. 2008; Tate, Norman, McQuaid, & Brown, 2007, as cited in Gaher et al. 2014), and score lower on Quality of life (Evren et al., 2011). Regarding treatment outcomes individuals with both diagnoses tend to use inpatient treatment services more (Brown et al. 1999), utilize psychotropic medication more (Blanco et al., 2013), and have less chance of successful treatment (Read et al., 2004), as well as earlier relapse after treatment (Evren et al., 2011).

Given the high comorbidity and adverse outcomes mentioned above it is important to find out the mechanisms underlying the relationship. Given the high comorbidity and adverse

outcomes mentioned above it is important to find out the mechanisms underlying the relationship. Several hypotheses have been brought forth to explain the connection between the two. For example, shared liability, susceptibility model (Rappaport et al., 2021), and mutual maintenance (Hruska et al., 2017). However, at the state of current research the self-medication hypothesis (SMH) seems to be most fitting (Hruska & Delahanty, 2013).

The SMH proposes that addiction does not come from the hunt for pleasure, or self-destructive motives. It is rather closely tied to the emotional suffering of an individual (Khantzian, 1999). It is important to note that the SMH is not specific to PTSD but rather tries to explain the link between different psychological conditions and substance use (Kaysen et al., 2014). The SMH puts forth two important aspects: first, the substance is used with the goal to alleviate distress; second, psychopharmacological specificity, which means that the substance is not chosen randomly but rather because it is most helpful in reducing the presenting symptoms (Khantzian, 2003).

Previous research proposes that different substances can be instrumentally chosen to achieve desired emotional state. As alcohol is a depressant it could be especially helpful to deal with symptoms of hyperarousal and emotional numbing (Possemato et al., 2015). In contrast, opiates are also commonly used to manage intense emotions, and cocaine can alleviate symptoms of low mood and flattened affect (Khantzian, 2003). Looking at this process through the lens of learning-theory, substances can alleviate PTSD in the short term (e.g. negative reinforcement), and that makes individuals turn to substances more and consume an increased amount which can lead to SUD (Schumm & Chard, 2012). The consumption of a substance can also be seen as avoidance behavior, in the sense that it helps to stop thinking about the trauma (Schumm & Chard, 2012). This is problematic as the exposure to distressing situations and memories is understood as a crucial part of recovery in individuals with PTSD according to the cognitive-behavioral view (Schumm & Chard, 2012).

There is considerable evidence that supports the SMH. First, 21.4% of people reported using drugs and/or alcohol in an attempt to alleviate PTSD symptoms (Leeies et al., 2010; Mills et al., 2006). Furthermore, individuals with PTSD are more likely to use substances in reaction to negative interpersonal emotions (Ouimette et al., 2007). Second, a longitudinal study spanning 12 years provides evidence that PTSD symptoms in adolescence have a significant effect on alcohol as well as drug use in adulthood. For every additional PTSD symptom there was around 10% increase in risk for substance use (Haller & Chassin, 2014). Third, studies support that PTSD increases the risk for substance use but substance use does not seem to alter the risk for experiencing a trauma (Brady et al., 2000; Chilcoat & Breslau, 1998). Lastly, laboratory studies show that individuals with comorbid PTSD and AUD show increased salivary response, distress, and craving for alcohol when presented with trauma cues. That suggests that drinking to relieve traumatic memories can lead to conditioned alcohol craving when being presented with a trauma cue (Coffey et al., 2010). However, until now little is known if the relationship between substance use and PTSD is restricted to specific symptom clusters, or if it pertains to the overall severity of PTSD symptoms. Previous research on the PTSD cluster specificity in regard to substance use is mixed (Avant et al., 2011; Somohano et al., 2019). Additionally, different symptom clusters predict craving for different drug of choice. For example, hyperarousal and avoidance symptoms predict a significant proportion of alcohol and stimulant craving respectively. No specific PTSD symptom cluster could be linked to marijuana or opiate cravings (Somohano et al., 2019). Furthermore, prior literature also suggests that avoidance symptoms predominantly drive the association with substance use in individuals with PTSD (Avant et al., 2011). Lastly, research suggests that the type of trauma matters in the sense that interpersonal trauma (especially sexual abuse) puts individuals at higher risk for substance use (Ullman et al., 2013).

The vast majority of studies concerning PTSD and substance use are cross sectional or longitudinal. That means measurements are taken at single points in time, or at infrequent intervals. Shortcomings of these designs compared to EMA are susceptibility to recall bias, inability to assess temporal relation between PTSD and substance use, as well as lower ecological validity (Wang & Cheng, 2020). In order to better understand the relationship between PTSD symptoms and substance use, Ecological Momentary Assessment (EMA) is useful as it can provide a more nuanced understanding. In EMA studies participants report on their symptoms and experiences one or several times a day (Hruska et al., 2017). This is important because PTSD symptom severity and substance use vary from day to day (Biggs et al., 2019; Johnson et al., 2002). EMA is also crucial for understanding within-person associations between PTSD symptoms and substance use (Hruska et al., 2017). Furthermore, as EMA assesses behavior at a given moment it is useful in reducing biased recall (Myin-Germeys et al., 2009, as cited in Rappaport et al., 2021). This is important regarding symptom severity as well as amount of substance use. EMA can also shed light on the question of time order, and check if PTSD symptoms precede substance use (e.g. SMH) (Rappaport et al., 2021).

The aim of this systematic review is to integrate results of studies that measure PTSD symptoms as well as substance use daily and set the outcome in relation to SMH. This is of importance, as the prevalence of PTSD in combination with substance abuse is high and causes many adversities for the individuals. Findings of the review can help to better understand the complex relationship between PTSD symptoms and substance use. Due to only including EMA studies the nuanced dynamics between PTSD and substance abuse can be assessed, and within-person variations can be studied. The collected information can help to decide whether SMH is a suitable model to understand the relationship between PTSD symptoms and substance use in different populations and for several substances. Furthermore,

the findings can inform directions for research and help design more beneficial and time sensitive interventions.

Methods

The present study is part of a larger project titled Stress in Action (Weverling, 2023). This project is a collaboration between multiple universities, focussed on reviewing research on daily measures of stress dynamics with the overarching goal of creating a more stress-resilient population. The present study was designed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) statement (Page et al., 2021). The study was also pre-registered (<https://osf.io/24auc>).

2.1 Eligibility criteria

To be included in the overall study, the articles needed to meet a set of eligibility criteria. Firstly, only studies involving human participants are considered eligible for inclusion. However, studies incorporating animals as intervention agents, such as those investigating the impact of canine companionship on daily mental distress among humans, are also included, given the focus on human participants. Additionally, single-participant case studies (N=1) are excluded from consideration.

Secondly, empirical studies are simply included for inclusion, while non-empirical sources such as dissertations, reviews, comments, opinion articles, books (chapters), and similar publications are excluded. Nevertheless, protocols detailing the methodologies of empirical studies are included to optimise selection of relevant articles.

Thirdly, selected studies must incorporate daily measures that are recorded at least once a day for several consecutive days (≥ 2 days in a row). These measures could be subjective self-reports, reported by others, or objective measures of physiology or activity. However, studies reporting daily treatments without accompanying measures, Intensive Care Diaries (ICD) documenting the status and treatments of unconscious patients in intensive care

units, or daily measures unrelated to human experiences, such as emotional word searches or crime reports, were excluded. These criteria serve to ensure the selection of studies that directly contribute to understanding daily measures of stress and mental well-being in human populations while excluding irrelevant sources.

2.2 Search strategy and information sources

The search was conducted in Web of Science with Core Collection and MEDLINE searched and PsycINFO (through EBSCOhost) on December 15th, 2023. For these electronic databases, the search string was developed on three core components: a) stress concept (context); AND b) mental health outcome; AND c) the design of the study (daily measurements). The search was conducted in the title or abstract. The first component “stress concept” used : a) stress* or “life event*” or “negative event*” or hassles or trauma* or abuse or neglect or "child* maltreatment" or "child* experiences" or violence or disaster*. The second component used: b) psychopathol* or "mental disorder*" or anxiet* or depress* or "CIDI" or "DSM" or phobia* or "ptsd" or "panic disorder*" or "GAD" or "MDD" or “MDE”. The last component used: c) diary or daily or "time series" or "time-series" or "experience sampling" or "ESM" or "ecological momentary assessment*" or "EMA" or "intensive longitudinal" or ambulatory or “micro-longitudinal”.

2.3 Selection process

A preparation stage was conducted, in addition to a pilot screening of 1200 hits, an update on selection criteria and continuation of work on screening, pilot extraction, extraction and synthesis stage. After removing duplicates using RStudio and Rayyan, abstract screening was conducted using ASReview available at <https://asreview.nl/> (van de Schoot et al., 2021). This software uses active learning to prioritize abstracts based on the similarity of included articles. The software was trained using 400 records as signifiers of articles that should be included or excluded (200 each). The prioritized records were then screened by four

individuals, each looking at a different subset of abstracts. Only the title and abstract of the record were displayed on the screen with two decision options (relevant/irrelevant). The screening process continued until fifty records in a row were marked as irrelevant, after which, the criteria was met to stop semiautomatic screening, the remaining articles were not included and not seen by reviewers. Another round of screening of the excluded records was done by a different reviewer, also using ASReview. For the purpose of this review, we only included published articles in peer-reviewed journals.

2.4 Data collection process and items

A data extraction sheet in Excel was set up to be used for the primary data extraction phase. Twelve extractors were given instructions on how to code the articles, with each of them coding approximately 100 articles in five weeks. The coding was supervised and assisted by one of the project leaders, to ensure extraction reliability. From the included articles, the following data was extracted regarding the population characteristics: year of publication, sample country, sample size, mean age, population, physical health, and mental health diagnosis. The data extraction sheet was separated into two blocks: for ambulatory measurements and cross-sectional measures. sampling frequency per day, as well as type of report (subjective, objective, or mixed) was collected for the ambulatory measurements part, and the following variables were extracted when measured either ambulatory or cross-sectionally: stress response (stressor, stress, affect/emotions, cognitions, physiology, behavior), and mental health symptoms (coping, mental health concept, measurement). Additionally, there was an 'other' column, where variables that do not fit into the other categories, could be coded. Each study was coded as either including an intervention (1) or not (0). Information that couldn't be obtained was referred to as non-available (N/A).

2.4 Study selection from the database

The first step for identifying suitable studies for the research question was filtering the database. The filters were only applied to the variables measured ambulatory (e.g. on a daily basis) as the research question concerns daily fluctuations in PTSD symptoms and substance use. There was no restriction for population type, as recent research suggests that subclinical PTSD can also put individuals at risk for substance use (Haller & Chassin, 2014; Yarvis & Schiess, 2008). As a first step the column “Behavior” was filtered so that all studies measuring substance use of any kind were included. There was no focus on specific substances as SMH is applicable to many different types of drugs (Khantzian, 2003). Following that the column “MH concept” was filtered with the search term PTSD. After the initial filtering full text screening was carried out. In the full text screening, there was a list of predefined selection criteria a) substance use, as well as PTSD symptoms were measured daily b) a statistical measure for the relation between substance use and PTSD symptoms was presented. Full text screening was only carried out by one investigator, and no other tools were used for selecting studies.

2.5 Data Extraction

Extraction of the data was carried out by one reviewer, and information was organized in an Excel sheet. Extracted data included authors, year of publication, origin of sample, number of participants, mean age, type and subtype, consumed substances and how consumption was measured, measure for PTSD symptoms, number of daily measurements, duration of study, p-values and effect measures. The effect measures used to present the results are Odds Ratios (OR), Incidence Rate Ratios (IRR), Relative Risk (RR), gamma (γ), b, and betas (β). Additionally, when available measures of precision (Confidence Intervals and Standard Errors) are presented.

2.6 Synthesis of Results

A narrative synthesis was used, and data was grouped into studies that consider PTSD severity in general, and those that examine the specific symptom clusters of PTSD. Within these two categories, studies were subdivided according to the used substance. This approach makes it possible to evaluate whether SMH is a useful framework for various substances.

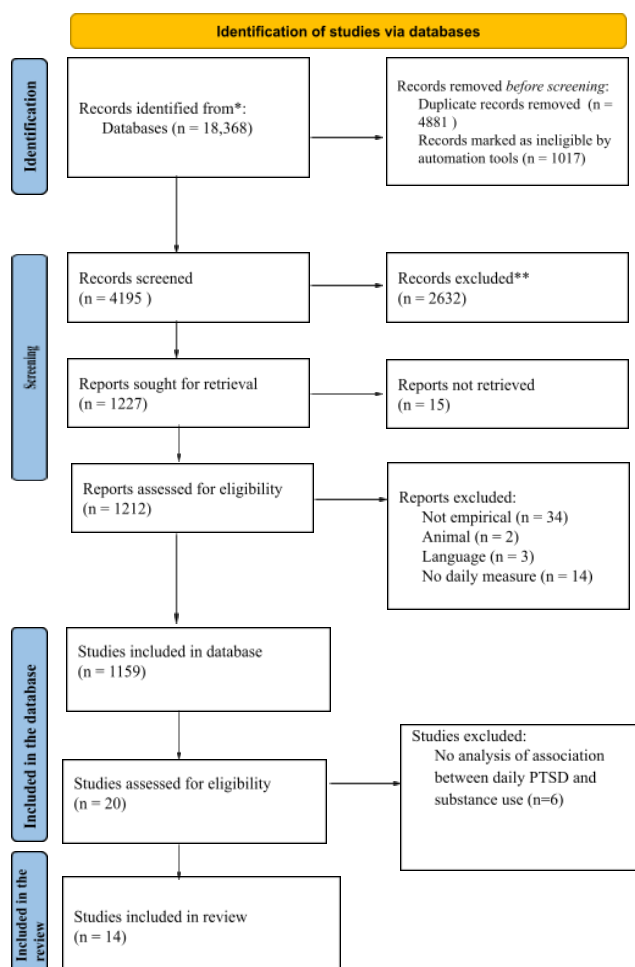
Results

Search Results

Overall, 19 studies were identified by searching the database with the search criteria. After screening the full text, 14 articles were eligible to be included in this literature review. The flow chart (Figure 1) shows the screening process, and characteristics of the included studies can be found in Table 1.

Figure 1

Flow Chart of Systematic Literature Review



Study Characteristics

All the included studies were conducted in the US, between the years of 2014 to 2023. Sample sizes ranged from 28 to 276 participants ($M = 112.6$). Out of the 14 studies eight assessed the general population and seven a clinical population. In the clinical sample present diagnosis were PTSD, SUD, and AUD. Participants were all over the age of 18 and mean ages ranged from 18.8 to 45.2 years. The number of female participants differed substantially with some studies only having male participants, while other samples were fully female. Eight studies investigated alcohol consumption only, two studies focused on cannabis use, and the remaining four studies looked at several substances at once. The majority of studies ($n=8$) only considered overall PTSD severity, while the remaining studies ($n=6$) looked at the effects of different symptom clusters on substance use. The studies conducted between one and eight daily measurements, with most studies assessing PTSD symptoms and substance use three times a day ($n=5$). The study period was differing widely between the studies and ranged from seven days up to a month ($M=21.5$ days). A summary of the sample characteristics can be found in Table 1.

Study Outcomes and the Relation to Self-Medication Hypothesis

In this section findings for the relationship between daily PTSD symptoms and substance use are presented. The findings are organized into two groups, studies looking at overall PTSD symptoms and studies focusing on the specific symptom clusters. Furthermore, differences between various substances were analyzed to determine whether distinct patterns emerged. The synthesis of the results provides evidence for SMH concerning alcohol consumption, while findings for other substances are mixed. A detailed depiction of the outcomes can be found in Table 2.

Table 1*Sample Characteristics*

Authors	Country	Total N	Mean Age (<i>SD</i>)	Female %	Type and Subtype	Substance	Measure	Sampling Frequency	Measurement Period
Dworkin et al. (2017)	US	90	21.7 (2.1)	100	general; sexual minority women	cannabis; dichotomous item about substance use	20-item PCL	2	14 days
Hruska et al. (2017)	US	36	34.8 (10.8)	25	clinical; trauma exposed	Alcohol; number of drinks alcohol; number of drinks in past 30 minutes;	SF-PCL	3	7 days
Gaher et al. (2014)	US	90	28.9 (5.64)	34,15	general; veterans	number of drinks in the current night cannabis; 1-item about use	modified 17- item PCL for Veterans	8	14 days
Newberger et al. (2023)	US	145	40.73 (11.7)	100	general, female IPV	alcohol; number of drinks	7-item PCL-5	3	30 days
Sullivan et al. (2019)	US	244	37.2 (12.9)	100	general; female IPV	alcohol; number of drinks	17-items DSM-IV PTSD symptoms	4	14 days
Possemato et al. (2015)	US	143	30.1 (7.6)	12	clinical; veterans	alcohol; number of drinks	17-item PTSD symptoms	4	28 days

Table 1 (Continued)*Sample Characteristics*

Authors	Country	Total N	Mean Age (SD)	Female %	Type and Subtype	Substance	Measure	Sampling Frequency	Measurement Period
Kaysen et al. (2014)	US	174	20.04 (1.35)	100	general; university women	alcohol; number of drinks in past 24 hours	modified PCL-S	2	28 days
Simpson et al. (2014)	US	86	44.7 (11)	49	clinical; civilians and veterans	alcohol; number of drinks per beverage	12-items of PCL-C	1	average of 7.3 days
Bachrach and Read (2017)	US	128	18.84 (1.14)	50	general; trauma exposed students	alcohol; number of drinks	PCL-C	1	30 days
Campbell et al. (2017)	US	65	45.2 (11.78)	52,3	clinical; volunteers	alcohol; number of drinks	12-items of PCL-C	1	30 days
Black et al. (2018)	US	28	31.4 (5.7)	0	general; veterans	alcohol; number of drinks	PCL-5 adapted for EMA	3	28 days

Table 1 (Continued)*Sample Characteristics*

Authors	Country	Total N	Mean Age (SD)	Female %	Type and Subtype	Substance	Measure	Sampling Frequency	Measurement Period
Rappaport et al. (2021)	US	276	19.23 (1.66)	68,3	general; potentially trauma exposed	alcohol; cannabis; psychoactive substances number of drinks; other substance use	11-items of PCL-5	3	14 days
Sanjuán et al. (2019)	US	32	27.8 (4.48)	100	clinical; pregnant	alcohol; heroin; cocaine. benzodiazepines; amphetamines; cannabis; other drugs number of drinks; any drug use	PCL-5	3	28 days
Badour et al. (2023)	US	40	39.85 (11.6)	60	clinical; NMPOU	alcohol; opioids; illicit drugs; injection drugs use of drugs; number of drinks	20-item adapted PCL-5	1	28 days

Notes: PCL: posttraumatic stress disorder checklist; PCL-C: PTSD checklist civilian; PCL-S: PTSD checklist specific

Table 2*Outcome Data*

Authors	Effect Size	P-Value	Results
Dworkin et al. (2017)	OR=0.97 95% CI [1.71, 4.4]	p=0.778	Women with higher overall PTSD symptom severity were more likely to consume cannabis (between person). However, daily symptom fluctuations within a person were not associated with cannabis use on same day.
Hruska et al. (2017)	IRR= 1.08 95% CI [.99, 1.19]	p=0.1	Daily symptom severity seems to be related to drinking. However, the results are not significant.
Gaher et al. (2014)	b=0.05 SE= .02	p=.002	Increase in PTSD symptoms during the day was associated with greater drinking at nighttime.
Newberger et al. (2023)	Externalizing behavior: OR= 1.37* 95% CI [1.15, 1.65] Dysphoric arousal:OR=1.28* 95% CI [1.09, 1.49] Reexperiencing: OR= 1.18 95% CI [0.98, 1.42] Avoidance: OR= 0.98 95% CI [0.82, 1.19] Negative affect: OR= 1.04 95% CI [0.86, 1.25] Anhedonia: OR= 1.07 95% CI [0.91, 1.31] Anxious Arousal: OR= 1.09 95% CI [0.9, 1.31]	p<.001 p=0.002 p= .074 p= .977 p= .654 p= .428 p= .381	Externalizing behavior and dysphoric arousal were associated with increased concurrent cannabis use. All other symptom clusters did not have significant effects.

Table 2 (Continued)*Outcome Data*

Authors	Effect Size and Estimate of Precision	P-Value	Results
Sullivan et al. (2019)	reexperiencing: b=0.305 avoidance: b=0.213 numbing: b=0.201 arousal: b=0.34	p < .001 p= .001 p= .004 p< .001	On days with more PTSD symptoms participants drank more. There was also more drinking at the time of the day with greater symptom severity (within day). The results were significant for all symptom clusters.
Possemato et al. (2015)	3-hr time block: IRR=1.05 95% CI [1.02, 1.07] Next time block: IRR= .91 95% CI [.88, .94]	p=.001	Increase in PTSD symptoms compared to persons average increased drinking in same time block. However, there was less drinking reported in the next time block.
Kaysen et al. (2014)	trauma-specific symptoms: b= 0.42 Dysphoric symptoms: b= 0.12 Hyperarousal symptoms: b= -0.09	p<.05 p>.05 p>.05	Intrusive and behavioral avoidance symptoms (trauma-specific symptoms) are related to drinking. However, dysphoric symptoms and hyperarousal were not related to drinking.
Simpson et al. (2014)	same day: IRR= 1.2 95% CI [1.13, 1.28] next day drinking: IRR= 1.08 95% CI [1.01, 1.16]	p<.001 p<.05	An increase in PTSD symptoms was associated with elevated same day, as well as next day alcohol consumption.
Bachrach and Read (2017)	RR= .99 95% CI [.96, 1.02]	N/R	PTSD symptom severity during the week did not increase the alcohol consumption on the following weekend. Daily associations between PTSD and alcohol were also not significant. When looking closer, symptom clusters of avoidance/numbing and hyperarousal were both significant predictors of drinking.

Table 2 (Continued)*Outcome Data*

Authors	Effect Size and Estimate of Precision	P-Value	Results
Campbell et al. (2017)	Total PTSD: Y= 1.10 SE= .22 Reexperiencing: Y= 1.13 SE= .23 Avoidance: Y= 1.11 SE= .26 Numbing: Y= 1.26 SE= .29 Arousal: Y= .92 SE= .21	p < .001	More drinking on days with elevated PTSD symptoms.
Black et al. (2018)	alcohol use: IRR=1.03 95% CI [1.003, 1.05]	p<.05	When PTSD symptoms increased there was more alcohol consumption reported at the following point of assessment.
Rappaport et al. (2021)	alcohol: OR=2.41* 95% CI [1.27, 4.59] cannabis: OR= 1.01 95% CI [.57, 1.79] other substances: OR=2.71 95% CI [.96, 7.67]	p<.01	Participants were more likely to consume alcohol on days with higher PTSD symptom severity. However, this did not apply to other substances measured.

Table 2 (Continued)*Outcome Data*

Authors	Effect Size and Estimate of Precision	P-Value	Results
Sanjuán et al. (2019)	drug use: $\beta=0.37^*$ 95% CI [.05, .71] cannabis use: $\beta=0.35^*$ 95% CI [.10, .57] cigarette use: $\beta=0.24^*$ 95% CI [.02, .16] heroin use: $\beta=0.09$ 95% CI [-.09, .28] alcohol use: $\beta=0.11$ 95% CI [-.01, .06]	N/R	Moderate effects of peak daily PTSD symptoms on daily substance use. Significant (at $p=.05$) only for drug, cannabis use, and cigarette use.
Badour et al. (2023)	same day NMPOU: OR=1.05 95% CI [1.01, 1.09] same day NMPOU and co-use: OR=1.06 95% CI [1.02, 1.1] next day NMPOU: OR=0.99 95% CI [0.95, 1.02] next day NMPOU and co-use: OR=1.02 95% CI [0.99, 1.05]	$p=.02$ $p=.01$ $p=.5$ $p=.29$	Daily fluctuations in PTSD symptoms increased the likelihood of NMPOU and NMPOU with co-use on the same day. The association is only driven by arousal and reactivity symptoms. There was no significant effect on the next day's use.

Notes: N/R: not reported

Studies considering overall PTSD symptoms

Of the eight studies looking at overall PTSD symptoms in relation to substance abuse, four looked at alcohol only, one looked at cannabis only, and the remaining three looked at alcohol and additional substances.

Of the studies considering alcohol consumption three found a significant effect of elevated PTSD symptoms on drinking on the same day (Gaher et al. 2014; Rappaport et al. 2021; Simpson et al. 2014). Additionally, Simpson et al. (2014) found that increased PTSD symptoms were associated with more alcohol consumption on the subsequent day and Gaher et al. (2014) reports that elevated drinking occurs at night. Two of the results were more specific in the regards of time in which the drinking occurs. Possemato et al. (2015) found that in a sample of combat veterans elevated PTSD symptoms were related to drinking in the same three-hour time span. However, at the next point of assessment (i.e. three hours later) participants drank less. Black et al. (2018) found that increased PTSD symptoms compared to last assessment led to more alcohol consumption in the following assessment (5-hour intervals). Two studies did find directionally consistent but non-significant results for the relationship between PTSD symptoms and drinking (Hruska et al. 2017; Sanjuán et al. 2019).

The results of the three studies looking at cannabis consumption were conflicting. One study found support for the relationship between daily PTSD symptoms and cannabis use (Sanjuán et al. 2019), while the two other studies did not find a significant result (Rappaport et al. 2021; Dworkin et al. 2017).

Three studies assessed additional substances and found significant effects for drug use (benzodiazepines, amphetamines, “other”), and cigarettes (Sanjuán et al. 2019). The relationship for heroin (Sanjuán et al. 2019), psychoactive substances (stimulant, sedative, opioid, “other”) (Rappaport et al. 2021), and substance use (marijuana, cocaine, opiates, “other”) (Black et al. 2018) was not significant.

Studies considering individual PTSD symptom clusters

Of the six studies assessing the relationship between specific PTSD symptom clusters and substance use four focused on alcohol, one on cannabis, and one on multiple substances.

Two studies found that all PTSD clusters (reexperiencing, avoidance, numbing, and arousal) were associated with elevated drinking (Sullivan et al. 2019; Campbell et al. 2017). Another two studies investigating PTSD symptoms and alcohol consumption found that only some symptoms show an association. Bachrach and Read (2017) found that elevated symptom clusters of avoidance/numbing, as well as hyperarousal symptoms had a significant relationship. Contrary to that, Kaysen et al. (2014) found that only symptom cluster of intrusion and behavioral avoidance were associated with elevated drinking in female college students while dysphoric (i.e. alterations in cognition and mood in the words of DSM-5) and hyperarousal (i.e. marked alterations in arousal and reactivity in the words of DSM-5) symptoms did not show a significant effect.

The remaining two studies focused on other substances than alcohol. Newberger et al. (2023) investigated PTSD and cannabis use in women experiencing intimate partner violence (IPV). They found that only symptom clusters of externalizing behavior and dysphoric arousal were associated with cannabis use in the same 6-hour time block. All other tested symptom clusters (i.e. re-experiencing, avoidance, negative affect, anhedonia, anxious arousal) did not have a significant effect. Another study investigated nonmedical prescription opioid use (NMPOU) and concurrent use of other substances in relation to PTSD symptom fluctuations (Badour et al., 2023). They found that heightened PTSD symptoms were associated with NMPOU alone, as well as in combination with other substances on the same day but not in the following day. However, this association was driven by changes in arousal and reactivity symptoms (Badour et al. 2023).

Discussion

This systematic review summarizes the content of 14 EMA studies concerning associations between daily fluctuations in PTSD symptoms and substance use. As there is a lot of evidence supporting SMH, and it is currently the most promising hypothesis, the aim of the review was to see if the results of the studies fit the framework. The heterogeneity in study designs were substantial as different substances were studied, the way of measuring substance use differed, and some studies considered symptom clusters individually while others did not. Some of the included studies also investigated whether increased substance use is related to more PTSD symptoms later on. However, none of the studies did find support for that relationship (Badour et al., 2023; Rappaport et al., 2021; Sullivan et al., 2019).

Findings for Different Substances

The literature review included studies investigating different substances. Outcomes per substance differed. Alcohol was the substance studied most often and the results point in the direction that SMH is useful in explaining the association between PTSD and alcohol use. Out of the ten studies looking at alcohol consumption, only two studies did not find any relationship. The effect sizes are small with $IRR = 1.08$ ($p = .1$) and $\beta = 0.11$ ($p > .05$) respectively (Hruska et al., 2017; Sanjuán et al. 2019). The samples of both studies are small which may have contributed to the non-significant results. Nevertheless, these two studies did show directionally consistent results which point in the direction of SMH. What is worth mentioning is that these two studies had small samples in comparison to most included studies which could have reduced the power to detect an effect. Furthermore, one of the studies that did not find significant results used participants 6 weeks postinjury (Hruska et al. 2017). It could be hypothesized that this timespan is not long enough for individuals to develop problematic alcohol use as a reaction to their symptoms. The results for cannabis consumption were mixed, out of the four studies only two found support for the SMH. However, the studies

only considered whether the participants used any cannabis instead of asking about the consumed amount. It could be that individuals consumed more on days with increased symptoms. Outcomes for other substances were varied, some studies found support for SMH while others did not. Overall, a lack of studies concerning other substances than alcohol can be seen.

The exact reason and mechanism behind these findings are unclear. They may result from the fact that alcohol consumption is legal, and the substance is easy to obtain. Or it could be related to alcohol being accepted by society which makes it less shameful to report on drinking. Lastly, alcohol may be the substance that helps with alleviating PTSD symptoms the most effectively.

Findings for Different Symptom Clusters of PTSD

More than half of the included studies (N= 8) only looked at overall PTSD symptom severity instead of looking at the effects of the symptom clusters separately. The way symptom clusters were split differed considerably between the studies. Some studies used the four symptom clusters proposed by DSM-5 (intrusions, avoidance, alterations in mood and cognitions, and alterations in arousal and reactivity) while others used additional symptoms in their analysis. Only two of these studies, which concerned alcohol consumption, found that all symptom clusters were predictive of drinking. The rest of the studies found that only some of the symptom clusters seem to have a relationship to substance use. This could be due to the fact that different populations and types of traumas are included in the review which may influence the presentation of symptoms and the attempts to alleviate them. Overall, the outcomes for symptom clusters are not in line with each other and further research is needed. These findings are partly conflicting and inconclusive which is in line with findings of previous research (Avant et al., 2011; Somohano et al. 2019). In line with Somohano et al. (2019) alcohol was predicted by overall PTSD severity in two of the studies. However, the

other studies only partly support the hyperarousal symptoms drives the association with alcohol craving (Somohano et al. 2019). Findings for other substances do not fit the findings of previous literature. The hypothesis of previous literature that avoidance symptoms are mostly predictive for substance use was supported in this review only for alcohol use (Avant et al., 2011).

Time Specific Findings

The studies used differing sampling frequencies and following that some of the studies reported more time specific outcomes regarding the temporal relationship between PTSD symptoms and substance use. The findings were conflicting. Some studies reported that the use of a substance followed heightened symptoms immediately (Possemato et al., 2015; Newberger et al., 2023), while other studies found that the consumption of a substance occurred after some time (Black et al., 2018; Gaher et al., 2014). Only one of the studies reports more substance use on the same as well as the next day following heightened symptoms (Simpson et al., 2014). Taken together it seems that there may be a specific temporal relationship between heightened PTSD symptoms and the occurrence of substance use. However, there is a need for more research to understand the relationship better and use the results to inform interventions.

Strengths and Limitations

There are a number of strengths concerning this literature review. To begin with, this is the first literature review assessing daily fluctuations in PTSD symptoms in relation to substance abuse only considering EMA studies. This is important to deepen the understanding of functional mechanism and temporal relationship, Next the literature encompasses studies investigating a variety of populations with different types of traumas. This holds particular significance in understanding whether the SMH can be widely applied. Lastly, the inclusion of both clinical and sub-clinical levels of PTSD can deepen the

understanding and makes the analysis more comprehensive. It can offer insights in the severity of PTSD symptoms and how that relates to the SMH.

However, there also are a number of limitations in this literature review. The shortcomings can be categorized into limitations related to the systematic literature review itself and limitations pertaining in the included studies. When it comes to the process of conducting this review one shortcoming is that only studies published in English were included. That can lead to biased results and reduced generalizability (Jackson & Kuriyama, 2019). Furthermore, the search strategy used may have failed to identify all suitable studies for this review. The review solely focuses on the database, and no snowballing was applied which could have identified additional sources. Lastly, the number of reviewed studies is relatively low and therefore not sufficient to draw a definite conclusion. Additionally, there are limitations of the included studies that are worth mentioning. To start, all included studies used a sample from the US which is a developed country. Availability of drugs, cultural, and political factors specific to the US can bias the outcomes of the studies. The focus on only one geographical region also makes it hard to generalize the findings to countries with a lower income and different standards of living. Another shortcoming is that some of the included studies had a small sample size, which can cause problems with generalizability, statistical power, and variability.

Implications for Research and Treatment

The outcomes of the conducted literature review can give rise to new research questions and can be informative for treatment providers. First of all, future studies should focus more on the mechanisms by which specific PTSD clusters influence substance use. For this it would be useful to use a more uniform way of symptom clusters. This is crucial to compare results from different studies and reduce ambiguity. Second, as only the results for alcohol consumption in relation to PTSD symptoms were clear it would be informative to

have more studies focusing on substances other than alcohol to better understand how and if SMH applies to them. Third, studies should have a closer look at specific time frames between PTSD symptoms and substance use. Understanding the temporal dynamics between psychological symptoms and substance use can help with identifying critical time points at which participants are more prone for negative outcomes. More time specific information can help to refine existing models to better understand the complex interaction between PTSD symptoms and substance use. Furthermore, it can help to prevent substance use by targeting the population at risk at the point of highest vulnerability. Fourth, it would be informative to look into moderating factors between PTSD and substance use. Examples could be type of trauma, gender, comorbid psychological conditions, and coping styles. Findings could be informative for revising and expanding the theoretical framework. Lastly, studies should also look at samples from different regions of the world to make results more generalizable across populations.

When it comes to treatment, there are several take aways from the conducted literature review. To begin with, it is of importance to fund research attempting to develop new and effective ways to treat comorbid PTSD and substance use. The concurrent treatment is essential given the high co-occurrence of the disorders, and increased suffering of individuals facing both conditions. Based on the reviewed studies it seems advisable to implement more real-time interventions. It would be an option to use Mobile health interventions that provide support in vulnerable or triggering moments and thereby help to prevent substance use as means of reducing symptom severity. This is important as PTSD symptoms are fluctuating throughout the day and substance use seems to follow increased symptom severity. It appears that the relationship between PTSD symptoms and substance use develops over time instead of being present directly after the traumatic event (Hruska et al. 2017). Based on this finding,

it would be advisable to implement prevention and intervention programs early for individuals at potential risk.

Conclusion

The current systematic literature review looked at the relationship between daily PTSD symptoms and substance use in 14 EMA studies. Outcomes were analyzed in the light of SMH as it is currently the most widely used theory to explain the relationship. Findings for alcohol point in the direction that SMH is a useful framework to explain the link. However, when looking closer at specific symptom clusters findings are inconclusive. That underscores the importance of additional research that explores the role of specific symptom clusters in the relationship between PTSD and substance use. Outcomes for substances other than alcohol are less available and mixed. Therefore, further research is needed to see if SMH also applies to other substances.

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Note: *: Studies included in the review