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Subjective stress and alcohol use among young adult and adult drinkers: Systematic review of studies using Intensive Longitudinal Designs[☆]

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A B S T R A C T

Background: Understanding how stress dynamically associates with alcohol use could provide a finer-grain resolution of drinking behavior, facilitating development of more effective and personalized interventions. The primary aim of this systematic review was to examine research using Intensive Longitudinal Designs (ILDs) to determine if greater naturalistic reports of subjective stress (e.g., those assessed moment-to-moment, day-to-day) in alcohol-drinkers associated with a) greater frequency of subsequent drinking, b) greater quantity of subsequent drinking, and c) whether between-/within-person variables moderate or mediate any relationships between stress and alcohol use. **Methods:** Using PRISMA guidelines, we searched EMBASE, PubMed, PsycINFO, and Web of Science databases in December 2020, ultimately identifying 18 eligible articles, representing 14 distinct studies, from a potential pool of 2,065 studies. **Results:** Results suggested subjective stress equivocally predicted subsequent alcohol use; in contrast, alcohol use consistently demonstrated an inverse relationship with subsequent subjective stress. These findings remained across ILD sampling strategy and most study characteristics, except for sample type (treatment-seeking vs. community/collegiate). **Conclusions:** Results appear to emphasize the stress-dampening effects of alcohol on subsequent stress levels and reactivity. Classic tension-reduction models may instead be most applicable to heavier-drinking samples and appear nuanced in lighter-drinking populations, and may depend on specific moderators/mediators (e.g., race/ethnicity, sex, relative coping-strategy use). Notably, a preponderance of studies utilized once-daily, concurrent assessments of subjective stress and alcohol use. Future studies may find greater consistency by implementing ILDs that integrate multiple within-day signal-based assessments, theoretically-relevant event-contingent prompts (e.g., stressor-occurrence, consumption initiation/cessation), and ecological context (e.g., weekday, alcohol availability).

1. Introduction

Alcohol misuse is a prominent public health concern. Worldwide, alcohol use results in an estimated 3-million deaths annually and approximately 5.1% of the global disease burden (World Health Organization, 2018). Within the United States alone, alcohol misuse is responsible for approximately 1-in-10 deaths of working-age adults (Centers for Disease Control and Prevention, 2020) and estimated fiscal costs of \$249 billion (Sacks et al., 2015). These costs underscore the need to advance our understanding of risk factors for alcohol misuse, such as subjective stress (Blaine and Sinha, 2017; Higley et al., 2011; Sin et al., 2017; Smyth et al., 2007). Subjective stress is dynamic, often changing rapidly from day-to-day or even moment-to-moment (e.g., subjective states, environmental context). As such, evaluating subjective stress cross-sectionally may not accurately represent the experience of stress or changes in other contexts, behaviors, or states associated with increased stress. Assessing the time course and associations with subjective stress has become increasingly feasible with the proliferation of mobile technology and near-real-time-data capture (Doherty et al., 2020). Under-

standing the temporal relationship between subjective stress and alcohol consumption could provide a finer-grain resolution of stress-motivated drinking behavior that might facilitate development of more effective and personalized interventions. Therefore, this systematic review examines the association between subjective stress and alcohol use as assessed through Intensive Longitudinal Designs (ILDs). For this review, use of ILD is defined as any study that includes repeated assessment $\geq 1x/day$ for multiple consecutive days.

1.1. Defining the stress for the current review

Before discussing the stress-alcohol relationship in ILD's, it is first necessary to define "stress", a construct whose conceptualization varies throughout the literature. Stress is a multifaceted process beginning when an individual perceives and interprets an event as harmful or threatening, following which the individual then responds or attempts to adapt if the threat persists (Lazarus and Folkman, 1984; Sinha, 2001). Critical components of this process are the 1) occurrence of a stressor (i.e., an event), 2) stressor appraisal (i.e., engagement of cognitive and

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affective processes to determine whether an event is “stressful”), 3) activation of biological responses in accordance with stressor appraisal (e.g., activation of the autonomic nervous system), and 4) coping (i.e., cognitive and behavioral responses to the stressful event).

The stress process is complex and dynamic, fluctuating across time, places, and persons (Lazarus et al., 1985; Lazarus, 2006; Sacco et al., 2016). Stress produces a series of distinct biological processes, such as hypothalamic-pituitary-adrenal (HPA) axis activation and associated autonomic nervous system responses (Wemm and Sinha, 2019). While stress may produce or be accompanied by negative affect (e.g., distress), it may also include pleasant or exciting emotional states in response to thrilling experiences (e.g., competitions) that can similarly elevate HPA-axis responding (Sinha, 2001). Considering this complexity, defining subjective stress clearly is essential for arriving at valid and reliable conclusions about stress-alcohol associations. Here, we focus on the role of “perceived stress” or “subjective stress”, terms which we will use interchangeably. Drawing from Sinha (2001), we define subjective stress as the perception, interpretation, and affective or cognitive responses to harmful, threatening, or challenging events.

1.2. Theoretical conceptualizations of subjective stress and alcohol use

Multiple theories suggest stress is associated with alcohol use, which is typically characterized as a coping strategy used for its tension-reducing properties (e.g., Baker et al., 2004; Cox and Klinger, 1988; Cooper et al., 2016; Koob and Le Moal, 1997; Koob and Volkow, 2016; Verheul et al., 1999). When considering acute stress in response to immediate stressors, alcohol may serve as a means of enhancing positive affect and tension-reduction (e.g., Koob and Volkow, 2016; Wemm and Sinha, 2019). As acute stress intensity increases, or stress itself becomes chronic, alcohol use can become increasingly compulsive, shifting from an initial method of alleviating stress to the dominant, or sole, means of maintaining homeostasis (Koob and Volkow, 2016). This is in part due to chronic stress’ ability to shift the salience attributed to drugs at a state-level, enhancing neural sensitivity to alcohol’s reinforcing properties (Koob et al., 1997; 2016). Thus, long-term alcohol users may come to experience continually elevated basal stress levels that prompt ongoing motivation for alcohol use (i.e., hyperkatifeia; Koob, 2021).

1.3. Intensive Longitudinal Designs and their value in assessing the stress-alcohol use relationship

Within the past approximately two decades, research using ILDs has become increasingly popular and, by design, permits examining phenomena in the “real world” that had previously been limited to the laboratory. In ILDs, investigators obtain repeated self-report data, more recently via mobile devices like smartphones, throughout the course of a given time-period (e.g., days, weeks). As participants provide data in near-real-time, phenomenon can be studied temporally-proximate to their occurrence. ILDs thus provide an opportunity to capture the time-course of perceived stress in relation to alcohol use as it occurs in daily life. Further, ILDs allow investigators to model the stress-alcohol relationship within- and between-individuals; this is advantageous as it allows investigators to parse who is impacted across time/contexts and examine potentially disparate relationships that might occur across within/between levels.

These advantages are noteworthy, as multiple factors can impact how, when, and why stress might lead to alcohol use. Factors like the temporal proximity of events to stress-onset, whether repeated assessments occur within/between individuals, and the temporal spacing of assessments could impact how the stress-alcohol use relationship is delineated. Additionally, alcohol produces both acute effects in stress upon consumption (i.e., within-person changes), as well as inter-individual across-persons changes based on consumption chronicity (i.e., between-persons changes; Wemm and Sinha, 2019). Stress’ effects on drinking may also vary according to ecological context and alcohol’s immediate

availability. Thus, effectively modeling the alcohol-stress relationship requires parsing within- and between-person effects.

To fully understand the relationship between perceived stress and alcohol use, it appears essential to investigate how stress and alcohol relate across time during daily life. This introduces challenges in assessing alcohol use cross-sectionally, where individuals typically rate stress over broad time-periods (e.g., past week) temporally-distal from the actual experience of stress. Although laboratory methods offer the advantage of manipulating stress, this may only capture narrow bands of perceived stress in unfamiliar and possibly contrived settings compared to what is experienced in daily life. Despite these methods’ notable benefits (e.g., feasibility for cross-sectional methods, experimental rigor for laboratory paradigms), their limitations may explain the mixed results often observed in examining stress and alcohol use (e.g., Bresin, 2019). ILDs offer unique advantages through their ability to assess stress and alcohol in situ.

1.4. Aims of the systematic review

The primary aim of this systematic review was to examine the commonly theorized notion that increased subjective stress promotes increased alcohol use in daily life by examining literature using ILD and to provide an overview of how ILDs were employed to study this relationship. Specifically, we sought to answer the following questions: 1) are greater naturalistic reports of subjective stress (e.g., those assessed moment-to-moment, day-to-day) in alcohol-drinkers associated with a) greater frequency of subsequent alcohol use and b) greater quantity of subsequent alcohol use? and 2) what variables robustly moderate or mediate the stress alcohol relationship (e.g., craving, sex, coping strategy use)?

2. Method

2.1. Search strategy and selection criteria

We searched EMBASE, PubMed, PsycINFO, and Web of Science using the following predetermined Boolean phrases: (alcohol OR alcohol use OR alcohol dependence OR alcohol use disorder OR binge drinking OR heavy drinking OR alcoholism OR social drinking) AND (ecological momentary assessment OR daily diary OR experience sampling OR ambulatory assessment OR intensive longitudinal methods) AND stress. References of identified articles were also reviewed to screen for potentially eligible articles. All searches were conducted in December of 2020, with no publication date restrictions. Our methods were carried out in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses guidelines (PRISMA; Siddaway et al., 2019). Due to expected heterogeneity in assessment methods (e.g., items, assessment time-frame, different populations) a meta-analysis was not performed. We registered this systematic review with PROSPERO (CRD4202022483).

2.2. Study eligibility

Studies were included if they were published, peer-reviewed studies and met the following criteria: 1) available in English, with 2) quantitative analysis using ILD, 3) included a subjective stress measure (e.g., “Rate your current stress intensity”), 4) contained data indicating participants consumed alcohol at least monthly (e.g., self-reported alcohol use, TimeLine FollowBack [TLFB]), 5) examined humans, 6) college-aged or adult participants (i.e., age 17-or-older), 7) were not treatment studies (i.e., studies that were not examining the effect of a clinical intervention such as a clinical trial; however, studies using clinical or non-clinical populations were included). Additionally, studies were excluded if they: 1) included only adolescents or mixed adolescent-adult sample where young adult or adult participants could not be independently examined, 2) were not available in English, 3) were qualitative studies, or

4) were case studies, case reports, editorials, commentaries, letters to the editor, book chapters, narrative reviews, or dissertations/theses.

Following article search,¹ data extraction was performed using a Microsoft Excel template to collect study information, including the following: citation (e.g., author, year, study title), sample characteristics (e.g., *n*, age, sex and race/ethnicity), sample type (e.g., clinical, community, collegiate), ILD methodology type (e.g., written daily-diary vs. smartphone survey), ILD protocol details (e.g., length, # of daily assessments, compliance rates), ILD sampling-strategy (e.g., event-contingent, interval-contingent), subjective stress and alcohol measure(s) and reference frames, stress-alcohol association results and analysis level (e.g., within-/between-persons). Results and corresponding tables are organized first in accordance with ILD sampling strategy (i.e., interval-contingent, signal-contingent, event-contingent, or a combination of these methods) and second according to the analyzed direction(s) of the subjective stress-alcohol relationship (i.e., subjective stress predicting alcohol consumption, vice versa, or reciprocal relationship).

3. Results

3.1. Search results and quality assessment of studies

The PRISMA flow diagram illustrating our search and its results is presented in Fig. 1. Searches returned 2065 articles, of which 265 were removed as duplicates. From the subsequent 1800 records, 1534 were excluded following title and abstract review, resulting in 266 reports sought for full-text retrieval. Following review of articles for inclusion/exclusion criteria, the final sample of included articles was 18 articles from 14 unique datasets. Quality assessment was performed by NRW and RRM using the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies (National Institutes of Health, 2021). Two authors (NRW and RRM) initially independently completed quality assessments and subsequently discussed ratings; no disagreements in ratings emerged. See supplemental materials (Table S1) for additional details on study characteristics and quality assessment.

3.2. Study characteristics

In evaluating the 14 unique datasets, most studies investigated community (*n* = 8) or collegiate samples (*n* = 4), and a smaller portion looked at treatment-seeking adults (*n* = 2; see Fig. 2a). Sample drinking characteristics varied widely, with studies examining actively participants who were actively heavily drinking (e.g., community adults drinking $\geq 4x$ /week; Carney et al., 2000) or treatment-seeking (e.g., Maisto et al., 2017), to studies whose participants maximally consumed <2 standard drinks on recorded drinking days (Strahler et al., 2020). ILD protocol durations ranged from 4-days to 2-years. From unique datasets, studies utilized a variety of ILD protocols, including automated surveys commonly administered through smartphones (*n* = 6), handwritten daily-diaries mailed back to authors (*n* = 2) or typed via web-browsers (*n* = 2), interactive voice-response surveys through touch-tone phones (*n* = 3), and daily telephone-based interviews (*n* = 1). See Table 1 for summary statistics of reviewed articles (e.g., sample sizes, # of sampling-days).

3.2.2. Sampling strategies, measurement timing and reference frames

ILD studies employ a variety of sampling strategies, including interval-contingent (participants respond regularly at set time-periods, such as in the evening), signal-contingent (participants respond during given time-periods or time-blocks, such as random alerts between 3 and 6pm), and event-contingent (participants initiate a response when

a given event, like consuming a drink, occurs) assessments. Here, most studies employed interval-contingent methods (*n* = 7; Table 2) that obtained measurements 1x/daily, usually referenced the “past day” or 24-hours, and examined concurrent associations (e.g., simultaneously assessed stress-alcohol associations from the same survey).

Less frequently, researchers used signal-contingent (*n* = 4; Table 3) or a combination of ILD-method prompts (*n* = 4; Table 4).² Signal and combined ILD’s had heterogeneous timeframes for measurement and signaling, but these were narrower than 1x/daily (e.g., alcohol consumption in the past hour or since prior assessment, subjective stress “right now”; Mayhugh et al., 2018; Szeto et al., 2019; Tomko et al., 2017) and included up to 8x/daily signal-contingent prompts alongside additional event-contingent prompts (e.g., Dvorak et al., 2018). Additionally, a portion of signal- and combined-ILDs integrated cognitive tasks or cue-reactivity prompts (e.g., Szeto et al., 2019; Tomko et al., 2017). Amongst all 18 studies, lagged measurement or analysis was more common in signal- and combined-ILD’s (*n* = 5) than for interval-contingent ILD’s (*n* = 3). No studies used only event-contingent strategies. Proportions of sampling frequency and analytic approaches can be found in Figs. 2b-c, respectively (Fig. 3).

3.3. Overview of ILD methods used to study stress and alcohol use amongst all 18 studies

3.3.1. Measurement of subjective stress

Subjective stress was generally measured using face-valid, single-item intensity ratings (*n* = 11). These scales often asked about subjective stress broadly (e.g., “Rate your highest level of stress yesterday on a scale of 0 to 9 with 0 being no stress and 9 being the highest stress you’ve ever experienced.”; Ayer et al., 2011) in the moment or over a specific period of time. Three studies (Armeli et al., 2000; Aldridge-Gerry et al., 2011; McCabe et al., 2013) anchored ratings to stressors (e.g., “Participants... selected the most negative event of the day and rated its overall stressfulness...”; Armeli et al., 2000, p. 982). Studies also administered brief scales, such as the 4-item version of the Perceived Stress Scale (e.g., Todd et al., 2003), or utilized coder severity ratings of daily stressors (Grzywacz and Almeida, 2008). Stress was almost always assessed in reference to discrete time-points (e.g., “right now”, “past 24 h”), though one investigation also assessed “stress pile-up”, representing subjective stress accumulation over the prior 3-days (Grzywacz and Almeida, 2008).

3.3.2. Measurement of alcohol use

Most investigations assessed alcohol consumption quantity only (i.e., the number of alcoholic drinks consumed on a particular occasion; *n* = 12), with fewer examining consumption frequency only (i.e., how often alcohol is consumed in a given time-period; *n* = 3) or examining both consumption quantity and frequency (*n* = 3). Several studies also examined alcohol craving (*n* = 5), typically as a dependent variable. Almost all investigations derived alcohol consumption quantity and frequency through sums of self-reported standard drink counts. Investigators often provided psychoeducation to participants regarding the definition of a “standard drink” prior to initiating ILD protocols (e.g., Aldridge-Gerry et al., 2011; Tomko et al., 2017). Researchers also implemented dichotomous coding of drinking occurrence (e.g., drinking days vs. non-drinking days; Dvorak et al., 2018), consumption scales (e.g., “1 = no drinks, 2 = 1–2 glasses, 3 = 3–4 glasses...”; Szeto et al., 2019) or objective methods such as remote Breath Alcohol Concentration (BAC) monitoring (Mayhugh et al., 2018). One study utilized the TLFB, implemented at the mid- and end-points of their ILD protocol (Maisto et al., 2017).

¹ Initial article search was conducted by NRW and RRM. Following duplication removal, NRW and RRM each reviewed all study titles and abstracts for initial eligibility. NRW then extracted data from included studies’ full text, which were then checked for eligibility by RRM.

² Note: Strahler and colleagues (2018) used a signal-contingent ILD while Strahler and colleagues (2020) used a combined ILD, though both studies appeared to derive from the same dataset.

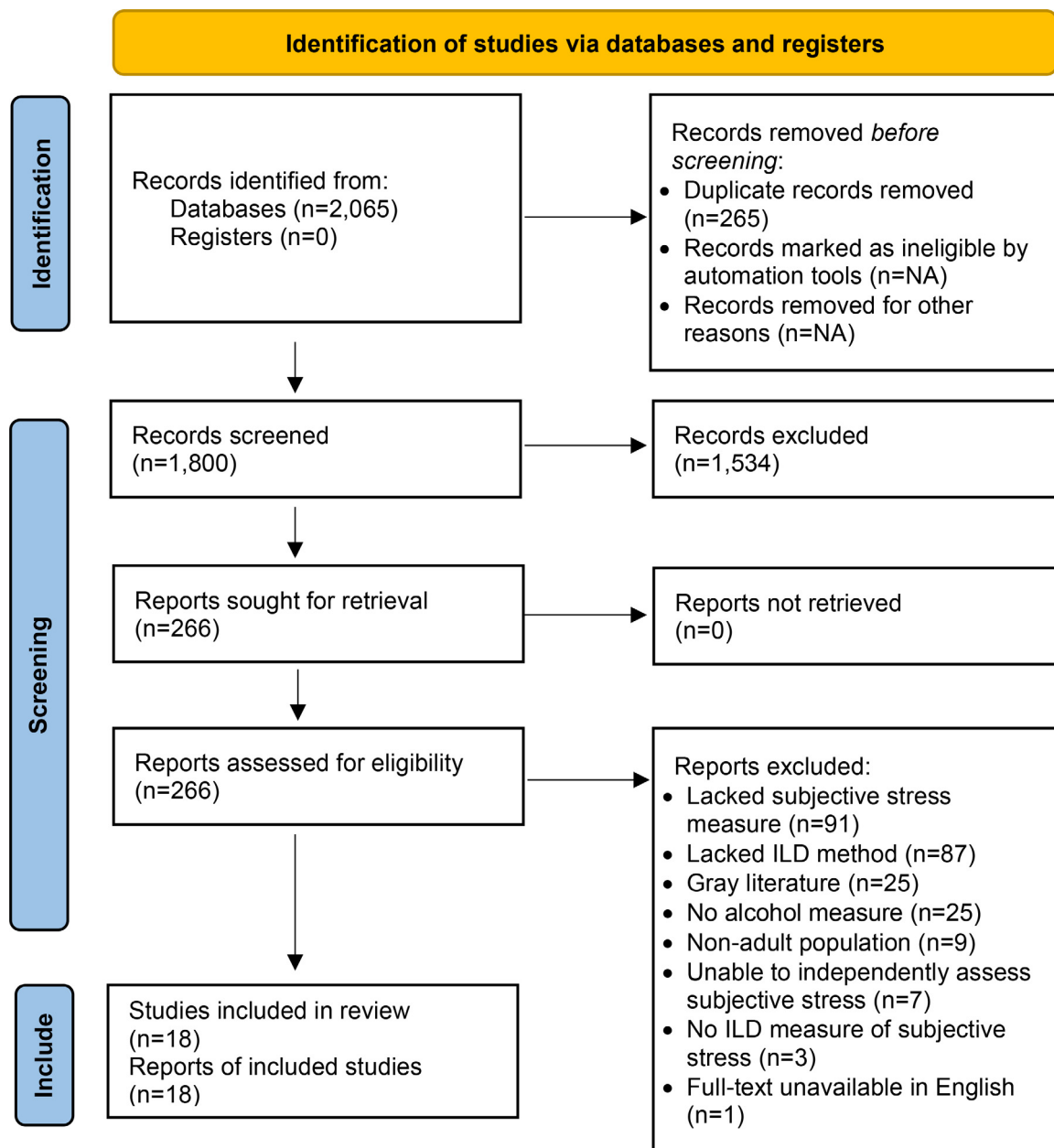


Fig. 1. PRISMA Flow Diagram. Note: Format from Page et al. (2021).

Table 1
Summary Statistics for Study Sample.

Variable	ILD Methodology					
	Combined (n = 4)		Interval (n = 10)		Signal-contingent (n = 4)	
	M(SD)	Range	M(SD)	Range	M(SD)	Range
Sample Size	64(32)*	32 - 102	223(239)	32 - 802	206(131)	77 - 347
# Sampling Days	13(11)	4 - 28	121(220)	5 - 730	88(99)	4 - 196
Daily Samp. Freq.	4.75(2.36)	3.00 - 8.00	1.00(0.00)	1.00 - 1.00	3.80(0.84)	3.00 - 5.00
Total Observations	2,560 (2634)	308 - 6,360	6,009(8374)	1,760 - 24,834	8,011(5,333)	1,510-12,365

Alcohol use was the only “event” used in event-contingent protocols. Two studies asked participants to initiate assessments upon consuming alcohol or experiencing cravings. Mayhugh and colleagues (2018) asked participants to complete assessments at the start/end of drinking episodes Szeto et al. (2019). asked participants to complete additional surveys whenever they experienced strong urges to drink.

3.4. Subjective stress and alcohol outcomes

The review’s next aim was to examine the perceived stress-alcohol use association as assessed through ILDs. We focused on 2 broad questions: 1) Whether greater naturalistic reports of subjective stress predicted greater quantity/frequency of alcohol use and 2) whether

Table 2
Overview of Findings Between Stress and Alcohol Outcomes Using Interval-Contingent ILD Sampling Strategies.

Reference	Sample and Size	ILD Type & Length	Sampling Strategy & Frequency	1. Stress measure 2. Alcohol consumption measures 3. Alcohol craving measure (if relevant)	Dependent Variable	*Direction of Analysis (Stress→ Alcohol, Alcohol→ Stress)	Within-persons level of analysis	Between-persons level of analysis	Moderators or Mediators of stress-alcohol relationship?
Aldridge-Gerry et al. (2011)^c	College students <i>n</i> = 365	Written daily-diary via web page 5 Days	Timing: Participant-initiated at their convenience Concurrent stress-alcohol measurement 1x/day	1. Rating most stressful daily event on 5-point scale (that day) 2. # of drinks consumed (that day)	Consumption Quantity	Stress → Alcohol †(Cont.)	Negative association between stress and alcohol use	NA	Stressor minimization, social support seeking, and emotional rumination associated with more, while greater use of religious or problem-focused coping generally associated with less alcohol consumption; however, strength and sign of coping strategy moderation on stress-alcohol use varied according to ethnicity
Armeli et al. (2000)^a	Community adults without a lifetime DSM-IV alcohol dependence diagnosis, who were not “non-moderate drinkers”, and without illicit drug use <i>n</i> = 88	Written daily-diary via pen & pencil (mailed to authors) 60 days	Timing: Participants instructed to complete each evening Concurrent stress-alcohol measurement 1x/day	1. 4-point stress intensity rating of most negative daily event (that day) 2. # of drinks consumed (that day) 3. 3-item composite (“I felt like I could really use a drink”, “The idea of drinking was appealing”, “I really didn’t feel like drinking”) (that day)	Consumption Quantity Alcohol Craving	Stress → Alcohol (Cont.)	Non-significant association between stress and alcohol consumption quantity Positive association between stress and alcohol craving	Negative association between average stress and alcohol consumption quantity. Non-significant association between stress and aggregated alcohol craving.	Men with strong expectancies for positive or “careless unconcern” effects from alcohol drank more on stressful days; relationship flipped for men with weak expectancies and was absent for women. No moderating effect by sex or alcohol expectancies on alcohol craving.
Breslin et al. (1995)	Female community adults <i>n</i> = 32	Written daily-diary via pen & pencil (mailed to authors) 5 2-week periods, spaced 6 weeks apart	Timing: Participants instructed to complete each evening Concurrent stress-alcohol measurement 1x/day	1. 4-item stress factor from Daily Record Form from Baum et al. (1994) (that day); only upper/lower tercile stress weeks included in analysis 2. # of drinks consumed (that day)	Consumption Frequency Consumption Quantity	Stress → Alcohol (Cont.)	Non-significant association between stress and consumption frequency Negative association between stress and alcohol consumption quantity.	NA	Those low in problem-focused coping consumed more during low stress weeks than high stress weeks; problem-focused coping did not significantly impact drinking frequency
Carney et al. (2000)^a	Community adults who drank ≥4x/week without a lifetime diagnosis of DSM-IV alcohol dependence <i>n</i> = 83	Written daily-diary via pen & pencil (mailed to authors) 60 days	Timing: Participants instructed to complete each evening Concurrent stress-alcohol measurement 1x/day	1. Perceived Stress Scale (that day) 2. # of drinks consumed (that day) 3. Questionnaire of Alcohol Urges (Bohn, Krahn, & Staehler, 1995) (that day)	Consumption Quantity Alcohol Craving	Stress → Alcohol (Cont.)	Non-significant association between daily stress and alcohol consumption quantity Positive association between stress and alcohol craving (considered alongside stressors as covariates)	Positive association between mean daily stress and consumption quantity. Positive association between alcohol consumption quantity and craving NA	No significant moderating effects of neuroticism, trait drinking to cope motives, or sex on stress-alcohol consumption association. Perceived stress weakly, positively mediated association between positive/negative stressors and alcohol craving. Lower educational attainment (<GED vs. college degree) associated with weaker stress and binge-drinking frequency relationship, however, this pattern flipped as stress was more consistently experienced.
Grzywacz & Almeida (2008)	Community adults <i>n</i> = 802	Telephone-based interview 8 days	Timing: Participants responded to evening telephone calls Concurrent stress-alcohol measurement 1x/day	1. Coder stressor severity ratings (low, medium, and high) of participant responses to Daily Inventory of Stressful Experiences (Almeida et al., 2002) (that day) 2. Dichotomous coding of binge drinking (≥5 drinks that day)	Consumption Frequency (binge drinking)	Stress → Alcohol (Lag.)	Positive association between stress severity, as well as stress “pile up” across the week, and binge drinking likelihood	NA	Negative affect did not mediate the relationship between stress and binge drinking frequency.

(continued on next page)

Table 2 (continued)

Reference	Sample and Size	ILD Type & Length	Sampling Strategy & Frequency	1. Stress measure 2. Alcohol consumption measures 3. Alcohol craving measure (if relevant)	Dependent Variable	*Direction of Analysis (Stress→ Alcohol, Alcohol→ Stress)	Within-persons level of analysis	Between-persons level of analysis	Moderators or Mediators of stress-alcohol relationship?
McCabe et al. (2013) ^c	College students n = 365	Written daily-diary via web page 5 days	Timing: Participants instructed to log on and complete each evening Concurrent stress-alcohol measurement 1x/day	1. 5-point stress intensity rating of most stressful daily event (that day) 2. # of drinks consumed (that day)	Consumption Quantity	Stress → Alcohol (Cont.)	Non-significant association between stress and alcohol consumption quantity	NA	Moderating effects of extraversion on stress-alcohol association not reported.
Park et al. (2004)	College students n = 137	Written daily-diary via web page 28 Days	Timing: 3:30–7:00pm Concurrent stress-alcohol measurement 1x/day	1. 7-point intensity rating (previous day) 2. # of drinks consumed (previous day)	Consumption Quantity	Stress → Alcohol (Cont.)	Positive association between daily stress (compared to student's average) and alcohol consumption quantity	Negative association between aggregated stress and alcohol consumption quantity	Women and those high in sensation seeking had positive stress-alcohol consumption association, while men and those low in sensation seeking had negative stress-alcohol consumption association; students also drank more on days with less problem-focused coping and higher positive or negative affect
Todd et al. (2003) ^a	Community adults without a DSM-IV lifetime alcohol dependence diagnosis who drank >monthly n = 83	Written daily-diary via pen & pencil (mailed to authors) 60 days (study 1)	Timing: Participants instructed to complete each evening Concurrent stress-alcohol measurement 1x/day	1. Perceived Stress Scale (that day) 2. # of drinks consumed (that day) 3. Questionnaire of Alcohol Urges (Bohn, Krahn, & Staehler, 1995) (that day)	Consumption Quantity Alcohol Craving	Stress→ Alcohol (Cont.)	Non-significant association between stress and alcohol consumption and craving alongside covariates (neuroticism and sex)	Positive association between average stress and alcohol consumption quantity and craving	No moderation effect of trait drinking to cope motives on alcohol consumption quantity or alcohol craving
Ayer et al. (2011) Ayer et al. (2011) cont.	Treatment-seeking adults who consumed >14/7 drinks per week or >5/4 drinks per day for men/women n = 246	Interactive Voice Response via cell phone 180 Days	Timing: Participant initiated call at their convenience Concurrent stress-alcohol measurement 1x/day	1. 10-point stress intensity rating (previous 24 h) 2. # of drinks consumed (previous 24 h)	Consumption Quantity	Stress → Alcohol (Lag.) Alcohol → Stress (Lag.)	Positive association between previous-day stress and next-day # of daily drinks Negative association between stress and previous-day # of drinks	NA	For men, previous day stress positively associated with next day drinking quantity; no association for women. For women, previous day drinking associated with greater decrease in next day stress
Helzer et al. (2006)	Male community adults n = 33	Interactive Voice Response via cell phone 2 years	Timing: Participants received call at personally-specified time Concurrent stress-alcohol measurement 1x/day	1. 10-point stress intensity rating (previous day) 2. # of drinks consumed (previous day)	Consumption Quantity	Stress → Alcohol (Cont. & Lag.) Alcohol → Stress (Cont. & Lag.)	Negative association between stress and same-day consumption; non-significant negative trend for next-day consumption Negative association between alcohol consumption and same-day, as well as next 2-day, stress	NA	Lifetime diagnosis of alcohol dependency did not moderate stress-alcohol relationships

Note: ILD = Intensive Longitudinal Design. *Direction of analysis refers to what was considered a predictor/outcome (i.e., subjective stress, alcohol, or both) in authors' analyses. †Denotes whether analyses were conducted looking at stress and alcohol contemporaneously ("Cont."; e.g., stress predicting alcohol use at the same time point) or in a lagged fashion ("Lag."; e.g., stress predicting alcohol use the next day). ^aMatching superscript letters denote studies that appeared to derive from the same data set. NA = Not Applicable or not assessed in study. AUD = Alcohol Use Disorder (DSM-5). All significant results were reported at $p < .05$.

Table 3
Overview of Findings Between Stress and Alcohol Outcomes Using Signal-Contingent ILD Sampling Strategies.

Reference	Sample and Size	ILD Type & Length	Sampling Strategy & Frequency	1. Stress measure 2. Alcohol consumption measures 3. Alcohol craving measure (if relevant)	Dependent Variable	*Direction of Analysis (Stress→Alcohol, Alcohol→Stress)	Within-persons level of analysis	Between-persons level of analysis	Moderators or Mediators of stress-alcohol relationship?
Maisto et al. (2017)	Treatment-seeking adults with DSM-IV alcohol dependence engaged in abstinence-focused treatment program n = 119	Interactive Voice Response via cell phone 28 Days	Signal: Block random (4-hour blocks; times of block starts not reported) Lagged stress-alcohol measurement 4x/day	1. 7-point stress intensity rating (previous 10 min) 2. TLFB for previous 14 days completed at study mid- and end-point	Consumption Frequency Consumption Quantity	Stress → Alcohol †(Cont.)	Positive association between daily-level stress and 1) drinking likelihood and 2) # of drinks consumed on drinking occasions	NA	NA
Luk et al. (2018)	College freshmen-juniors who drank ≥2x/week in prior month n = 347	Automated survey via cell phone 2 weeks per quarter over 1 year	Signal: Block random (3-hour blocks; 9am-12pm; 3–6pm; 9pm-12am) Lagged stress-alcohol measurement 3x/day: 1x for yesterday's alcohol consumption (morning); 1x for expectancies and drinking plans (afternoon); 1x for social context, mood, and stress (evening)	1. Average of 2 9-point items assessing how stressed/overwhelmed participants felt (that day) 2. # of drinks consumed (previous day)	Consumption Frequency Consumption Quantity	Stress → Alcohol (Cont. & Lag.)	Stress predicted greater same-day likelihood of abstinence and lower consumption quantity; non-significantly associated next-day consumption frequency and quantity	Average stress predicted greater same- and next-day likelihood of abstinence, non-significantly associated with same- and next-day consumption quantity	Females (vs. males) and non-Greek-affiliated (vs. Greek-affiliated) students had a stronger negative relationship between stress and alcohol drinking likelihood as well as consumption quantity
Strahler & Nater (2018) ^b	Community adult non-smokers without alcohol/substance use or other chronic physical or mental illnesses n = 77	Automated survey via cell phone 4 days	Signal: Fixed (waking, 30 min after waking, 11am, 2pm, 6pm, 9pm on T-F) Concurrent and lagged stress-alcohol measurement Stress: 6x/day; Alcohol: and 5x/day (excluding waking assessment)	1. 5-point stress intensity rating (right now) 2. Dichotomous “yes/no” consumption report	Consumption Frequency	Alcohol → Stress (Lag.)	Negative association between alcohol consumption and next-day stress	NA	Salivary alpha amylase (sAA; biological stress marker) weakly mediated relationship between alcohol consumption and stress, such that greater drinking reduced sAA, which in turn reduced subjective stress.
Tomko et al. (2017)	Community adult smokers without a substance dependence diagnosis (apart from nicotine or caffeine) n = 138	Cue-Reactivity EMA (CREMA) via cell phone 14 days	Signal: Block-random (3hr blocks; times of block starts not reported) Concurrent stress-alcohol measurement 4x/day	1. 5-point stress intensity rating (right now) 2. # of drinks consumed (past hour)	Consumption Quantity	Alcohol → stress (Lag.)	Negative association between past-hour alcohol consumption quantity and stress	NA	1) Higher pre-stress cue stress intensity in combination with past-hour alcohol consumption predicted increased post-cue stress, 2) Males were less likely to report increased stress following stress cue exposure, 3) those who more frequently drank and who reported greater average stress showed greater post-cue stress

Note: ILD = Intensive Longitudinal Design. *Direction of analysis refers to what was considered a predictor/outcome (i.e., subjective stress, alcohol, or both) in authors' analyses. †Denotes whether analyses were conducted looking at stress and alcohol contemporaneously (“Cont.”; e.g., stress predicting alcohol use at the same time point) or in a lagged fashion (“Lag.”; e.g., stress predicting alcohol use the next day). ^aMatching superscript letters denote studies that appeared to derive from the same data set. NA = Not Applicable or not assessed in study. AUD = Alcohol Use Disorder (DSM-5). All significant results were reported at $p < .05$.

Table 4
Overview of Findings Between Stress and Alcohol Outcomes Using Combined (e.g., signal- and event-contingent) ILD Sampling Strategies.

Reference	Sample and Size	ILD Type & Length	Sampling Strategy & Frequency	1. Stress measure 2. Alcohol consumption measures 3. Alcohol craving measure (if relevant)	Dependent Variable	*Direction of Analysis (Stress→Alcohol, Alcohol→Stress)	Within-persons level of analysis	Between-persons level of analysis	Moderators or Mediators of stress-alcohol relationship?
Strahler et al. (2020) ^b	Community adults who are non-smokers <i>n</i> = 77	Automated survey via cell phone 4 days	Signal: Fixed (30 min after waking, 11am, 2pm, 6pm, 9pm on T-F) Interval: 1x daily alcohol assessment Concurrent and lagged stress-alcohol measurement 5x/daily signal-contingent prompt + 1x/daily interval-contingent prompt	1. 5-point stress intensity rating (right now) 2. Single item rating 0, 1, 2, or >2 “glasses” consumed (past 24 h)	Consumption Quantity	Stress → Alcohol †(Cont.)	Non-significant association between stress and alcohol consumption quantity	NA	No moderating effect of sex
Szeto et al. (2019)	Community adults with DSM-IV alcohol dependence diagnosis who were abstinent ≥2 weeks <i>n</i> = 43	Automated survey via cell phone 4 weeks	Signal: Pseudo-random between participant-set wake/bed-times Event: When experiencing strong drinking urge Concurrent stress-alcohol measurement 3x/daily signal-contingent prompts + event-contingent prompts	1. 7-point stress intensity rating (right now) 2. 5-point scale (no drinks, 1–2, 3–4, 5–6, 7+) (since prior assessment) 3. 7-point single-item (past hour)	Consumption Quantity Alcohol Craving	Stress → Alcohol (Cont.)	Non-significant association between stress and alcohol consumption quantity Positive association between stress and alcohol craving	NA	No moderating effect of trait mindfulness on alcohol consumption or craving (though stress was independently associated with greater craving).
Dvorak et al. (2018)	College students with no psychiatric comorbidities who consumed alcohol within 2 weeks of starting participation <i>n</i> = 102	Automated survey via cell phone 15 days	Signal: Pseudo-random between 8am–2am Event: Start of participant’s drinking episode Concurrent stress-alcohol measurement 8x/daily signal-contingent prompts + event-contingent prompts	1. Composite score of 3 items asking how “stressed”, “overwhelmed”, and “tense” participants felt (right now) 2. Dichotomous coding of day as “drinking day” or not	Consumption Frequency	Stress → Alcohol (Lag.) Alcohol → Stress (Lag.)	Negative association between stress and initiation of drinking (stress lower pre consumption on drinking days) Negative association between alcohol consumption and subsequent stress	NA	NA
Mayhugh et al. (2018)	Community adults who consumed alcohol ≥50% of past 3 days and drank 2–4/1–3 drinks per day for men/women on average <i>n</i> = 32	Automated survey via cell phone 6 days (3 day normal drinking routine; 3 day abstinence trial)	Signal: Waking, going to bed, randomly between 9am–9pm Event: Upon starting and finishing a drinking episode Concurrent stress-alcohol measurement 3x/daily signal-contingent prompts + event-contingent prompts	1. 11-point stress intensity rating (right now) 2. Mobile BAC rating through breathometer 3. Trait Craving assessed through ACE; momentary craving through 11-point single-item rating (right now)	Consumption Quantity Alcohol Craving	Alcohol → Stress (Lag.) Stress → Alcohol (Lag.)	Negative association upon alcohol consumption with acute stress. Positive association between stress and EMA-assessed alcohol craving	NA	Higher trait craving predicted greater overall stress, more rapid increase in stress intensity, and stronger overall stress-craving association. Additionally, those higher in trait craving failed to show stress reduction following alcohol consumption

Note: ILD = Intensive Longitudinal Design. *Direction of analysis refers to what was considered a predictor/outcome (i.e., subjective stress, alcohol, or both) in authors’ analyses. †Denotes whether analyses were conducted looking at stress and alcohol contemporaneously (“Cont.”; e.g., stress predicting alcohol use at the same time point) or in a lagged fashion (“Lag.”; e.g., stress predicting alcohol use the next day). ^aMatching superscript letters denote studies that appeared to derive from the same data set. NA = Not Applicable or not assessed in study. AUD = Alcohol Use Disorder (DSM-5). All significant results were reported at *p* < .05.

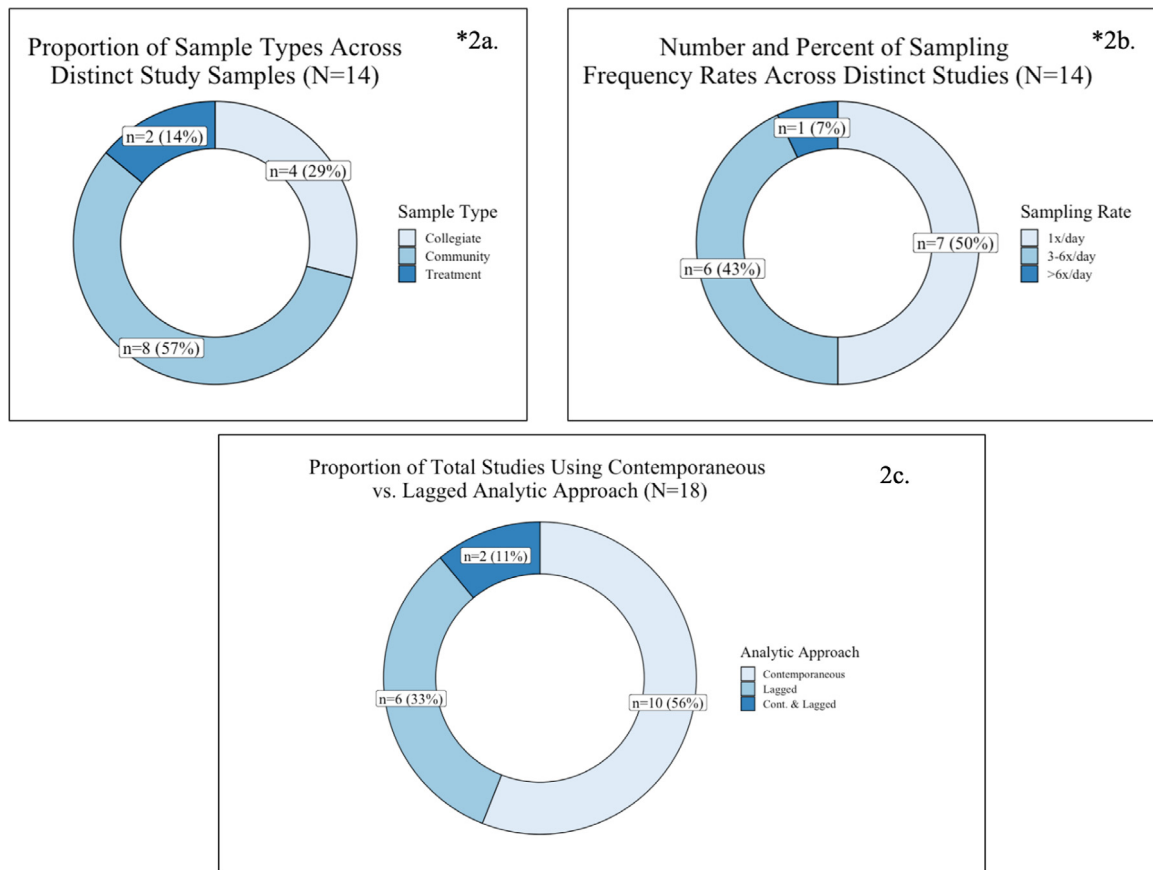


Fig. 2. Sample Proportions for Sample Types, Sampling Rates, and Analytic Approach. Note: *"Distinct Studies" and "Distinct Study Samples" refers to studies whose data were drawn from unique populations. Several studies, noted by letter super-scripts in Tables 2-4, appeared to conduct multiple analyses on the same sample.

between-/within-person variables (e.g., alcohol craving, sex, coping strategy use, etc.) moderated or mediated the stress-alcohol use relationship? Associations were categorized according to positive/negative (i.e., an increase in one variable associating with a statistically significant increase/decrease with another variable), or non-significant (i.e., one variable failing to show a statistically significant association with another variable). Additionally, results were examined with respect to analytic level (i.e., within-persons vs. between-persons); within-person analyses examine variables within single participants (e.g., examining participant X's stress today predicting that same participant's drinking tomorrow), while between-persons analyses examine variables across persons (i.e., examining if participants reporting greater stress drink more than participants reporting less stress). As the timing of measurement could impact results, whether conclusions were drawn from contemporaneous (e.g., stress predicting alcohol use at the same timepoint) or lagged (e.g., stress predicting alcohol use the next-day) analyses was also considered. Alcohol craving was commonly assessed as a dependent variable (e.g., Armeli et al., 2000; Carney et al., 2000; Szeto et al., 2019), and thus was included as both an outcome and moderator/mediator.

3.4.1. Stress and alcohol use outcomes from interval-contingent ILLD studies (Table 2)

Within-persons results from interval-contingent studies in which subjective stress predicted consumption quantity typically demonstrated non-significant ($n = 5$) or mixed findings (positive: $n = 2$; negative: $n = 3$), generally drawn from contemporaneous stress-alcohol associations. Two studies, Helzer et al. (2006) and Ayer et al. (2011), employed lagged analytic approaches to examine stress and next-day alcohol use and found non-significant and positive associations, respec-

tively. Between-persons examinations, all using contemporaneous analytic approaches, showed similar equivocality (positive: $n = 2$; negative: $n = 2$). Drinking frequency was only examined in 2 interval-contingent studies using lagged (Grzywacz and Almeida, 2008) and contemporaneous (Breslin et al., 1995) analytic approaches; results were again mixed (positive $n = 1$; non-significant $n = 1$). When reviewing the opposite predictive pathway, alcohol negatively predicted subjective stress in two studies. No interval-contingent studies analyzed drinking frequency between-persons. Finally, three interval-contingent investigations also examined alcohol craving, and found positive (Armeli et al., 2000; Carney et al., 2000) or non-significant associations (Todd et al., 2003) with all studies using contemporaneous analytic approaches.

3.4.2. Stress and alcohol consumption outcomes from signal-contingent ILLD studies (Table 3)

Within-persons results from signal-contingent studies in which subjective stress predicted consumption quantity and frequency were again mixed Maisto et al. (2017). found stress positively predicted both outcomes, analyzing results contemporaneously Luk et al. (2018). found stress was non-significantly associated with same- and next-day drinking quantity, but predicted greater likelihood of same- and next-day abstinence. The only signal-contingent study examining subjective stress and alcohol use between-persons (Luk et al., 2018) found greater stress predicted greater likelihood of abstinence but was unassociated with consumption quantity. Signal-contingent studies examining the opposite predictive pathway alcohol consumption quantity ($n = 1$) non-significantly, and consumption frequency ($n = 1$) negatively predicted subsequent subjective stress. No signal-contingent investigations examined alcohol craving.

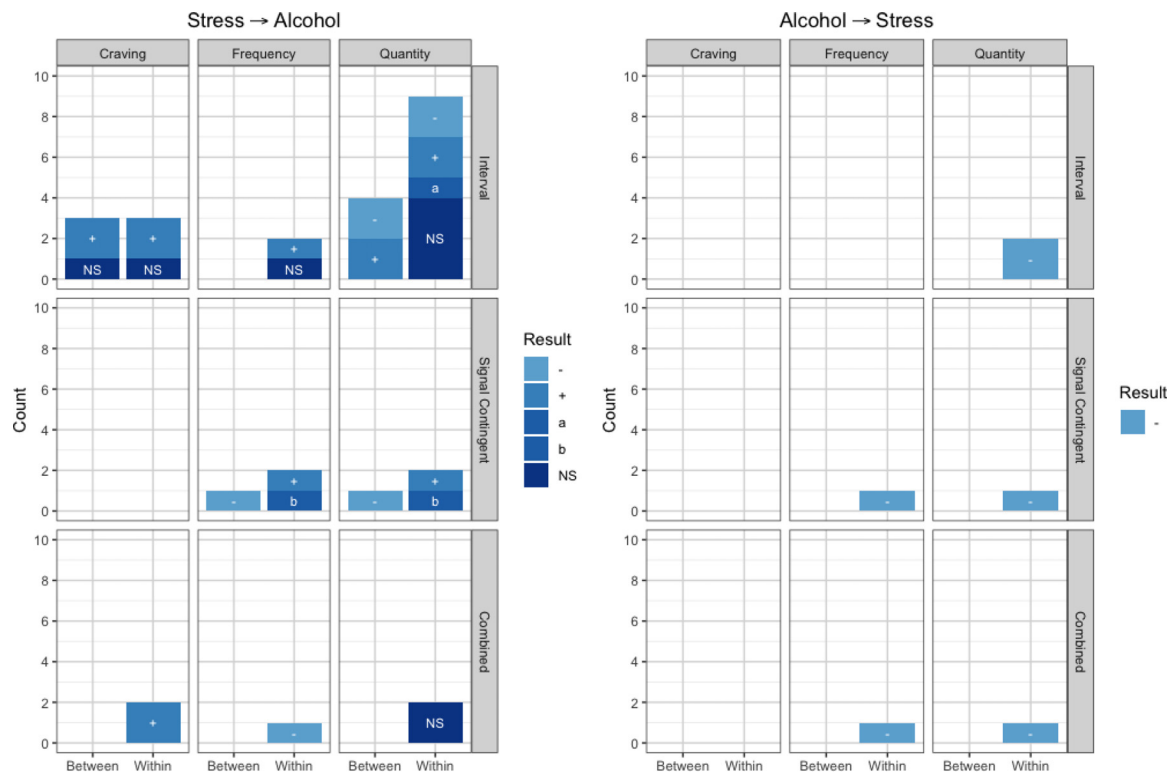


Fig. 3. Study Counts and Result Types According to Analytic Direction, and Sampling Strategy. Note: - = Negative association, + = positive association, NS = Non-significant association. ^aDenotes Helzer et al. (2006) who found negative association between stress and same-day consumption, but a non-significant negative trend for next-day consumption. ^bDenotes Luk et al. (2018) who found greater same- and next-day stress respectively predicted increased abstinence likelihood but was non-significantly associated with drinking quantity.

3.4.3. Stress and alcohol consumption outcomes from combined-method (i.e., signal- and event-contingent or signal- and interval-contingent) ILD studies (Table 4)

Within-persons results from combined-ILD investigations suggested stress did not significantly predict alcohol consumption ($n = 2$), with both studies utilizing contemporaneous analytic approaches. Only one combined-method study, using a lagged analytic approach, investigated drinking frequency and found subjective stress negatively predicted the likelihood of subsequent alcohol consumption. Combined-methods studies assessing the impact of alcohol consumption on subsequent subjective stress, both using lagged analytic approaches, again found inverse effects within-persons ($n = 2$). No combined-methods studies included between-persons examinations of subjective stress and alcohol use. Combined-method studies, using both lagged and contemporaneous analytic approaches, found subjective stress predicted greater alcohol craving ($n = 2$).

3.4.4. Moderators and mediators of the stress and alcohol associations

Studies examined a wide range of moderators, including between-persons variables (e.g., demographic variables, traits) and within-person variables (e.g., pre-stress cue subjective stress intensity; Tomko et al., 2017; coping-strategy use, Park et al., 2004). Sex was the most frequently examined moderator ($n = 7$), nonetheless, results appeared equivocal across studies. Certain investigations found subjective stress positively predicted male but not female consumption quantity (Ayer et al., 2011), while others identified the reverse pattern (Park et al., 2004). Studies also found negative associations between subjective stress and alcohol use for collegiate men and women but a stronger association for collegiate women (Luk et al., 2018). Still other studies found the absence of a moderating effect for sex among community adults (e.g., Carney et al., 2000; Strahler et al., 2020).

Coping strategies were examined in several studies ($n = 3$) but effects appeared nuanced. In an all-female community sample, Breslin and colleagues (1995) found those low in problem-focused coping consumed more during low-stress weeks, while Park and colleagues (2004) found the opposite pattern in college students. Aldridge-Gerry and colleagues (2011) found the influence of coping strategy use varied substantially among college students according to race/ethnicity. For example, emotional rumination reduced alcohol consumption for African American students, had no effect for Hispanic/Latinx students, but increased alcohol consumption for White students.

Few studies considered mediators of the subjective stress-alcohol relationship ($n = 3$) Strahler and Nater (2018). investigated repeated salivary alpha amylase measures as a biological mediator and found it weakly, positively mediated the association between subjective stress and alcohol craving Grzywacz and Almeida (2008). examined negative affect but did not identify a significant mediation effect. Interestingly, Carney and colleagues (2000) looked at subjective stress itself as a mediator, and found a small, positive mediating effect between stressors and alcohol craving, such that positive/negative stressors were indirectly related to greater alcohol craving via increased subjective stress.

3.4.5. Differences amongst studies using the same datasets and impacts on alcohol-related outcomes

To briefly re-iterate, several studies appeared to draw from the same datasets. In certain cases, result patterns differed even when outcome variables and analytic directions were consistent. This appeared most notably due to slight changes in model specification, such as the inclusion/exclusion of moderator variables (e.g., Aldridge-Gerry et al., 2011; McCabe et al., 2013). For example, Aldridge-Gerry et al. (2011) examined dual-moderators of coping strategy use and race/ethnicity, finding stress negatively predicted alcohol use, while McCabe et al. (2013) found no significant affects of extraversion on

stress and alcohol use. Sample differences may also have contributed [Armeli et al. \(2000\)](#). used a sample of 88, while [Carney et al. \(2000\)](#) and [Todd et al. \(2003\)](#) appeared to use a subset from this sample of 83, and all authors varied in their use of moderators and covariates. While all these authors reported stress non-significantly impacted within-subject drinking quantity, their findings varied between-persons and with respect to alcohol craving. Other studies drawing from the same dataset ([Strahler and Nater, 2018](#); [Strahler et al., 2020](#)) used differing sampling frequencies for stress measurement, quantification of alcohol use, inclusion of mediators, analytic direction, and outcome variables.

4. Discussion

This systematic review examined the relationship between subjective stress and alcohol use, as assessed via ILDs. We evaluated whether increases in subjective stress prompted increases in alcohol use and if evidence drawn from ILD methods indicated moderator or mediator variables of this relationship. Results were surprisingly mixed across studies. Stress appeared equally as likely to predict increased, decreased, or have no association with alcohol use, though it generally demonstrated positive associations with alcohol craving. In the reverse predictive pathway, however, alcohol use robustly predicted decreased stress.

The equivocality of subjective stress' prediction of either alcohol consumption quantity or frequency across ILD studies was notable. Results varied regardless of ILD sampling strategy (i.e., interval-contingent, signal-contingent, event-contingent, or combinations of these approaches) and generally appeared independent of other study or sample characteristics; the only potential exception appeared for sample population, in which treatment-seeking samples ($n = 2$) showed positive associations between stress and drinking quantity. In contrast, when alcohol use was assessed as a predictor, studies consistently identified an inverse relationship in which greater and/or more frequent alcohol use predicted reduced subjective stress, regardless of sample type (i.e., treatment-seeking, collegiate, community). In certain investigations, alcohol's subjective stress-reducing properties even occurred into the next day ([Ayer et al., 2011](#); [Helzer et al., 2006](#)) and included reduced fluctuations in subjective stress ([Dvorak et al., 2018](#)). These findings suggest tension-reduction theories of subjective stress predicting alcohol use may be more complex and could depend on sample or factors related to assessment time-frames ([Conger, 1956](#); [Cappell and Herman, 1972](#); [Young et al., 1990](#)).

Our results highlight potential distinctions in the difference between tension-reduction hypotheses, in which subjective stress prompts greater use, and the stress-dampening effects of alcohol, or the notion that alcohol reduces acute levels of subjective stress and/or reactivity to subsequent stress ([Sher, 1987](#); [Sher et al., 2007](#)). Stress-dampening effects may be more prominent during earlier stages of alcohol use, while alcohol's tension-reduction effects might follow more sustained and clinically-significant alcohol use (e.g., alcohol use disorder). That is, stress-dampening would likely correspond with the timecourse of alcohol's acute effects; over time however, increased pairing of alcohol subjective stress reduction would increase motivation to drink to avoid negative feelings. This repeated pairing would be important for establishing alcohol as a reliable means of subjective stress reduction, as well as for developing important motivational factors like craving. Heavier drinking samples (e.g., those drinking multiple drinks per drinking episode, multiple times per week, for at least several months) would theoretically become more stress-/malaise-prone in alcohol's absence (i.e., hyperkatifia), and more likely to pursue alcohol upon experiencing stress ([Koob and Volkow, 2016](#); [Koob, 2021](#)). This is consistent with the fact that 1) while only 2 studies used treatment-seeking samples, both found subjective stress positively predicted greater consumption quantity or frequency ([Ayer et al., 2011](#); [Maisto et al., 2017](#)), and 2) 4/5 studies examining alcohol craving, all of which utilized regular-drinking or alcohol-dependent community samples, found positive associations.

Alternatively, at earlier stages of alcohol use, subjective stress' effects may be more moderator-dependent. While this rationale should be considered in the context of measurement designs (e.g., causal-ordering of stress and alcohol use is challenging in studies sampling once-daily), research suggests that variations in the stressor-type and the individual experiencing it may determine whether subjective stress ultimately associates with alcohol use (e.g., [Chen et al., 2020](#); [Heikkilä et al., 2012](#); [Pedersen, 2017](#); [Peltier et al., 2019](#)). This is consistent with the number of distinct and impactful moderators of the stress-alcohol relationship identified in this review including sex, coping-strategy type, race/ethnicity, and alcohol expectancies (e.g., [Armeli et al., 2000](#); [Carney et al., 2000](#); [Luk et al., 2018](#); [Park et al., 2004](#); [Strahler et al., 2020](#)), as well as the fact that studies drawing from the dataset, employing similar designs, but varying moderator specification identified different results. Further, some studies suggested these moderators may operate simultaneously (e.g., the influence of coping-strategy type on the stress-alcohol relationship being moderated race/ethnicity; [Aldridge-Gerry et al., 2011](#)). The extent and apparent impacts of multiple moderators suggest that trying to isolate the influence of subjective stress on proximate, subsequent alcohol use independent of sample characteristics will likely produce inconsistent results.

Results also underscored important design considerations for testing commonly theorized patterns in the time-course of the subjective stress-alcohol relationship. Considering the tension-reduction hypothesis, alcohol use is posited to occur following increases in subjective stress ([Baker et al., 2004](#); [Koob and Volkow, 2016](#); [Verheul et al., 1999](#)), after which, subjective stress is then posited to decrease. Thus, ILDs examining subjective stress and alcohol use would be expected to observe within-day, and potentially across-day, increases in subjective stress closely followed by alcohol use and subjective stress reductions. However, clarifying this pattern and testing theoretical hypotheses (e.g., tension-reduction) is difficult with ILDs sampling few times-per-day, especially when contemporaneous (vs. lagged) analytic procedures are employed. Tests of these broader theoretical hypotheses require investigations capable of mapping the time-course of subjective stress and ideally anchoring this to theoretically-relevant events (e.g., stressors, drinking episode initiation/conclusion). Critical to these questions is the timing of subjective stress and alcohol assessments. In ILD research, decisions about the timing of assessments should be carefully considered and theoretically driven ([Hopwood et al., 2021](#)). Ideally, assessments of stress would be consistent with "psychological time", spanning the time before and after stressful events. Given that this may be difficult, or impossible, to predict for each individual, it is necessary to sample assessments with a sufficient range to capture stress events and related behaviors like alcohol use. Therefore, the variable subjective stress-alcohol use patterns across studies in this review does not necessarily refute the tension-reduction hypothesis, but rather reflects variability in the way both variables were measured.

Considering the timing and measurement of subjective stress and theoretically relevant events in relation to alcohol use may also help explain the equivocality across results. Most investigations ($n = 10$) contemporaneously measured subjective stress and alcohol use 1x/day via the same survey. While this provides finer temporal resolution than retrospective examinations of longer time-periods (e.g., "past week"), it precludes the ability to map stress' within-day fluctuations to alcohol use, especially when analysis is limited to contemporaneous relationships at the day-level. Signal-based ILDs obtain multiple measures of subjective stress, affording the opportunity to examine subjective stress' temporal fluctuations, frequency, longevity, and intensity more accurately, with minimal impact on feasibility (e.g., [Tomko et al., 2017](#)). Findings from more frequent assessments in ILDs may reveal distinct patterns within- and across-days.

Another possible avenue is combining multiple ILD-survey types, which further facilitate comparing within-day fluctuations of subjective stress and alcohol use risk factors. This appeared important as certain studies found within-day changes in subjective stress and risk factors,

like alcohol craving, that related to consumption (e.g., Mayhugh et al., 2018). Unfortunately, 4/18 studies employed such combined sampling strategies and of these, only 3 sampled subjective stress >1x/day. Further, when event-contingent sampling strategies were employed, they exclusively used alcohol use as the response-initiating event as opposed to stressors or subjective stress experiences. To test prominent theories about stress and alcohol, researchers must be able to delineate temporal ordering (e.g., if alcohol is a coping mechanism, subjective stress would be expected to occur/fluctuate before consumption). While more complex ILDs are not without barriers (e.g., complex surveys requiring participant training prior to initiating studies), they offer distinct advantages through ensuring anchoring to theoretically-relevant events, alongside sufficient sampling frequency to fully capture the unfolding of hypothesized processes.

Beyond sampling strategy, another crucial area of consideration is to ensure the integration of contextual factors, which were minimally incorporated within our ILD sample. While several studies controlled for temporal considerations like weekday/weekends (e.g., Aldridge-Gerry et al., 2011; Grzywacz and Almeida, 2008), factors such as alcohol availability, social setting, or stressor timing were rarely incorporated. This is notable as the ability to accurately detect relationships between subjective stress and alcohol use could be heavily context-dependent (e.g., increased stress may only predict greater alcohol use in certain social settings; non-significant findings could be spurious if researchers have not verified alcohol availability during participation). This reasoning aligns with other ILD-substance use literature (e.g., Naughton et al., 2016). Preston et al. (2017), for example, found stress in an OUD sample was more likely to be reported in non-familial social situations and that opioid craving increased alongside stress. Byrnes et al. (2017) found reports of alcohol-consuming teens, alongside GPS-labeled indicators of alcohol availability and social disorganization predicted alcohol use. Use of ILDs thus seems ideally suited to capture such contextual variables as they naturally occur and in doing so, can enhance our understanding of stress and alcohol use.

Finally, the ambiguity in definitions of “subjective stress” might also explain some of our findings’ variability. During initial searches, many articles were excluded due to the absence of subjective stress measures, which were often conflated with related constructs (e.g., “stressors”, negative affect). Further complicating this issue is the fact that stress can be assessed either subjectively (i.e., via self-report) or objectively through passive measurement (e.g., heart-rate, galvanic skin response, cortisol levels). Clearly delineating what is being measured and greater terminology concordance may facilitate a better understanding of how subjective stress associates with alcohol use.

4.1. Limitations

Our findings should be considered alongside several limitations. First, our review was based on a particular set of search terms employed in a limited number of databases and excluded non-published (i.e., “gray”) literature. Thus, articles that did not include our search terms, were not indexed in the searched databases, or were not published in peer-reviewed outlets would have been excluded. Nonetheless, our searches yielded a large literature pool ($N = 2065$) producing 18 studies, representing 14 unique datasets, for review. Second, methodologies and study designs were variable, precluding the ability to conduct meta-analysis. Such variability is useful from a qualitative standpoint however, as it highlights the need to refine increasingly popular ILDs to maximally test relevant theories (e.g., tension-reduction hypotheses). Third, while our study focused on college-aged and adult populations (groups often with high alcohol misuse prevalence), it excluded other developmental groups such as adolescents. Stress and alcohol may differentially associate across the lifespan and the patterns observed here may not be generalizable to non-adult populations. Fourth, our review focused on alcohol consumption quantity/frequency, precluding us from examining subjective stress’ relationship with other substances and ex-

cluding studies which may have focused on other risk factors (e.g., craving). Nevertheless, this review may serve as a starting point for future examinations of subjective stress and use of other substances in ILDs. Fifth, we focused on subjective stress assessed via self-report, which was often assessed in ways which emphasized specific components of the stress process (e.g., emphasizing the affective component via questions such as “How stressed do you *feel* right now...”), rather than on stressors or other aspects of the subjective stress response (e.g., stress-related cognitions, autonomic activity). The direction of the subjective stress-alcohol relationship might differ according to particular aspects of the stressor-subjective stress process (e.g., interpretations of stressors) or through use of passive and/or biological measurement methods (e.g., transdermal alcohol or stress measurements; van Egmond et al., 2020; Raugh et al., 2019). This remains an important area for future investigations. Finally, we used the term “sex” to generally accord with study language observed; however, future research should incorporate more inclusive language that acknowledges individual differences more accurately (e.g., gender-identity, sex-assigned-at-birth).

5. Conclusions

Our review of ILDs showed subjective stress equivocally predicted subsequent alcohol use, while alcohol use robustly predicted decreases in subjective stress. This relationship was further complicated by the impact of numerous moderators (e.g., sex, coping strategies, race/ethnicity) whose effects varied across studies. Such findings suggest alcohol use for tension-reduction, or subjective stress prompting alcohol use, may be more prominent after longer periods of clinically significant drinking (e.g., alcohol use disorder) when conditioned responses between stress and alcohol have been established (e.g., craving in response to stress). Conversely, alcohol’s acute stress-dampening effects, or alcohol’s inhibition of subsequent stress responding/reactivity may consistently present across stages of use.

Considering the plethora of cross-sectional and laboratory research suggesting a connection between subjective stress and alcohol use, the equivocality found across the ILD studies here might be explained by design considerations. Interval-contingent ILDs that concurrently sampled and contemporaneously analyzed subjective stress and alcohol use were predominant in our sample. Future research may benefit from ILD’s that combine signal- and event-contingent approaches and 1) employ multiple measurements of subjective stress over narrow timeframes, 2) map subjective stress’ dynamic fluctuations onto theoretically-important events (e.g., stressor occurrences, initiation/cessation of drinking episodes), 3) incorporate ecological context (e.g., alcohol availability), and 4) utilize lagged-analytic approaches (e.g., stress assessed “right now” predicting alcohol use later that evening).

Finally, research examining subjective stress and alcohol use may benefit from greater concordance on definitions, as conflating distinct but related constructs (e.g., stressors, negative affect) increases the challenges in delineating what appear to be nuanced, dynamic relationships. Thoughtful refinement of ILD study design has the potential to more effectively evaluate theory and may produce more consistent results of the subjective stress-alcohol use relationship.

Contributors

Author contributions are as follows: Conceptualization (Noah R. Wolkowicz), initial article search (Noah R. Wolkowicz, R. Ross Maclean), article eligibility and data extraction (Noah R. Wolkowicz, R. Ross MacLean), writing the original draft (Noah Wolkowicz), quality review of articles (Noah R. Wolkowicz, R. Ross MacLean), cross-check of reviewed articles (R. Ross Maclean, MacKenzie Peltier), revisions and editing (Noah R. Wolkowicz, R. Ross Maclean, MacKenzie Peltier, Stephanie Wemm). This manuscript has been read and ap-

proved by all authors. The manuscript was pre-registered with PROSPERO (CRD42020222483).

Declaration of Competing Interest

None.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.dadr.2022.100039.

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