# Contextual Influences on Impulsivity and Associations with Alcohol Use

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## Abstract

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Impulsivity is a central risk factor for multiple types of psychopathology including substance abuse. However, research has primarily focused on trait impulsivity as a marker for who may be most at risk, and less is understood about whether or not impulsivity may also represent a causal mechanism of use. Individuals regularly deviate from their average level of impulsivity, and research suggests that this variability is predictable and stable. Furthermore, these deviations may be contingent on situation cues and may reflect individual differences in sensitivity to context. Contextual factors, including mood, stress, and peers, have all been shown to be associated with changes in state impulsivity and may also increase the likelihood of substance use. It is less clear, however, how changes in impulsivity may contribute to the association between context and substance use. Understanding individual differences in within-

person variability in impulsive behavior in response to changing context may broaden our understanding of how impulsivity confers risk for substance abuse.

The current study explored how contextual factors influence within-person fluctuations in impulsivity and how this variability may be associated with alcohol use. 160 self-reported drinkers between the ages of 21-36 completed baseline assessments and ten days of ecological momentary assessments. Facets of impulsivity was measured using the UPPS-P Impulsive Behavior Scale, and past year alcohol use and problems were measured using the Substance Use Questionnaire (SUQ). Participants also completed a state adaptation of the UPPS-P as well as ratings of stress, stimulation, sedation, and peer presence up to six times each day. Participants also reported the number of alcoholic drinks consumed daily. Within-person effects were tested using hierarchical linear models. Models predicting past year drinking behavior were tested using regression. Mediated models predicting daily drinking were tested using general estimating equations accounting for clustering.

Results suggested that there was significant within-person variability in all facets of impulsivity. Only variability in cognitive facets of impulsivity (lack of premeditation and lack of perseverance) was predictive of past year drunkenness and binge drinking. There was no evidence that variability in any facet of impulsivity was associated with past year alcohol problems. Stimulation, sedation, stress, and peer presence were associated with state changes in facets of impulsivity, although the effects differed across facets. Lack of premeditation was found to mediate the association between stress and sedation and the likelihood of drinking on a given day, however no other indirect effects were found. Finally, there was some evidence that participants who reported heavier alcohol use and more alcohol problems also demonstrated stronger associations between contextual factors and changes in state impulsivity.

These findings highlight the importance of considering within-person variability in trait-related behavior and the corresponding situational factors associated with deviations from mean levels of behavior. Identifying who demonstrates the greatest variability and the greatest reactivity to context may provide further insight into identifying who is at greatest risk of developing problematic or harmful levels of substance use. Additionally, exploring individual differences in the associations between context and changes in state impulsivity may provide information for when individuals are most likely to engage in alcohol use as well as factors that may increase their risk of use.

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## Chapter 1: Introduction

Impulsivity represents an important risk factor for harmful substance use and substance use disorders (Dick et al., 2010; Stautz & Cooper, 2013). Individuals who report higher levels of impulsivity may experience an increased sensitivity to the effects of alcohol, increased use of alcohol for emotion regulation, and increased engagement in associated risk behaviors, all leading to increased alcohol use (Dick et al., 2010; Stautz & Cooper, 2013). Although the association may be bi-directional, as alcohol use may also increase impulsive behavior, trait impulsivity has been shown to be elevated in populations who later develop substance use disorders (Verdejo-García, Lawrence, & Clark, 2008). As such, impulsivity represents an important personality trait identifying who may be most at risk for problematic alcohol use.

Problematic substance use may represent one manifestation of a more generalized lack of impulse control, and impulsogenic traits represent a trans diagnostic indicator of risk for multiple types of psychopathology (Krueger, Markon, Patrick, Benning, & Kramer, 2007; Marmorstein, 2013). In addition to substance use disorders, impulsivity is associated with externalizing disorders in children including Oppositional Defiant Disorder, Conduct Disorder, and ADHD, as well as Antisocial Personality Disorder, Borderline Personality Disorder, and pathological gambling in adults (Dawe & Loxton, 2004). Recent evidence also suggests that some facets of impulsivity, specifically urgency, may be associated with depression in youth as well (Smith, Guller, & Zapolski, 2013). As such, understanding tendencies for impulsive behavior may have important implications for a range of mental health disorders.

Research has primarily focused on trait impulsivity as a marker for who may be most at risk, and less is understood about whether or not impulsivity may also represent a causal mechanism of use (Dick et al., 2010). Specifically, impulsivity may directly contribute to

increased alcohol use and problems. However, it may be that a third variable causes both increased alcohol use and increased impulsivity, in which case impulsivity only identifies those with a greater predisposition toward substance use. Current findings suggesting an association between impulsivity and substance use are primarily correlational, and differentiating between these possibilities is hampered by the paucity of research exploring within-person fluctuations in impulsivity and factors influencing when someone might behave more or less impulsively than their average. Although research has identified several contextual factors that have been shown to influence impulsivity, little is known about how momentary fluctuations may be associated with alcohol use. The proposed study will test four questions about the associations between context driven deviations in impulsivity and alcohol use: 1) how is within-person variability in facets of impulsivity associated with substance use, 2) how do contextual factors influence within-person variability in facets of impulsivity, 3) do changes in daily impulsivity explain the association between contextual factors and increased alcohol use, and 4) does greater reactivity to contextual factors predict alcohol use.

### 1.1. Conceptualization and measurement of impulsivity

Impulsivity is not a unitary construct, and is a term broadly applied to a range of lower order traits that have been shown to be only moderately correlated and differentially associated with substance use and other psychopathology (King, Patock-Peckham, Dager, Thimm, & Gates, 2014; Sharma, Markon, & Clark, 2014; Whiteside & Lynam, 2001). Furthermore, impulsive tendencies are measured by both self-report questionnaires and laboratory behavioral tasks, two approaches that have developed unique conceptualizations that do not necessarily overlap or assess the same underlying dispositions (Cyders & Coskunpinar, 2012; King et al., 2014; Sharma, Kohl, Morgan, & Clark, 2013).

The most widely accepted model of "impulsogenic traits" (i.e. traits that produce impulsive behavior) includes emotion-based and cognitive dimensions (Smith et al., 2007; Whiteside & Lynam, 2001). Specifically, positive and negative urgency are the tendencies to act rashly when experiencing positive and negative affect respectively. Lack of premeditation is the tendency to act before thinking. Lack of perseverance is the tendency to become distracted from a task or become bored. Sensation seeking is the tendency to pursue risky and exciting activities.

While all of these traits are associated with alcohol use and alcohol related problems, each facet demonstrates differential prediction of characteristics of alcohol use (Stautz & Cooper, 2013). All facets have been shown to predict frequency of alcohol use (Coskunpinar, Dir, & Cyders, 2013). However, negative and positive urgency have demonstrated the largest association with problematic use (Berg, Latzman, Bliwise, & Lilienfeld, 2015; Coskunpinar et al., 2013; Smith et al., 2007b; Stautz & Cooper, 2013). Negative urgency and lack of planning show the greatest association with alcohol dependence, and sensation seeking was the largest predictor of binge drinking (Coskunpinar et al., 2013).

Impulsivity is also measured through performance on a variety of laboratory behavioral tasks. Behavioral tasks measure a range of neurocognitive functions believed to underlie impulsive behavior and measure distinct but related tendencies (Sharma et al., 2014). One type of behavioral task measures impulsive choices, or risky decision making. These tasks include delay discounting tasks, which assess preferences for smaller, sooner rewards over larger, later rewards. Other risky decision making tasks measure a participant's willingness to risk large losses in order to win small, incremental gains. Examples of these tasks include the Balloon Analogue Risk Task (BART) and the Iowa Gambling Task (IGT) (Bechara, Damasio, Damasio, & Anderson, 1994; Figner, Mackinlay, Wilkening, & Weber, 2009; Lejuez et al., 2007). A

second type of behavioral task measures impulsive action, which includes an array of executive functions such as the ability to initiate a response, inhibit a response, execute a plan, or choose the appropriate response despite interference (Caswell, Morgan, & Duka, 2013; King et al., 2014; Reynolds, Ortengren, Richards, & de Wit, 2006). Examples include the Go/No-Go, Stop Task, and Stroop Task.

Performance on behavioral tasks has also been shown to predict alcohol use behavior. Increased discounting of delayed rewards has been found in alcoholics (Petry, 2001) and heavy drinking adolescents (Field, Christiansen, Cole, & Goudie, 2007). Delay discounting has also been shown to predict alcohol consumption, severity of alcohol problems, and time since last drink (Courtney et al., 2012; Field et al., 2007). Additionally, risky decision making on the IGT was higher in participants with a lifetime history of substance use disorders (Barry & Petry, 2008), alcoholics (Cordovil De Sousa Uva et al., 2010), adolescent binge drinkers (Xiao et al., 2009, 2013), heavy binge drinkers (Goudriaan, Grekin, & Sher, 2007), and alcohol dependent subjects (Kim, Sohn, & Jeong, 2011; Salgado et al., 2009; Tomassini et al., 2012). As such, laboratory behavioral tasks also demonstrate important predictive utility in identifying who may most be at risk for risky substance use.

### 1.2. Individuals regularly deviate from their average levels of impulsivity

Although trait impulsivity has demonstrated significant predictive utility in identifying who may most be at risk for substance use, trait measures only provide an estimate of an individual's average behavior across time and situation (Fleeson, 2007). However, individuals regularly deviate from their mean levels, making trait measures poor predictors of any single instance of behavior (Hartshorne & May, 1929; Sharma et al., 2013; Wu & Clark, 2003). Impulsivity also demonstrates this variability: people behave more impulsively on some days

than others (Tomko et al., 2013). Most self-report questionnaires, however, do not capture this aspect of trait related behavior.

Recent conceptualizations of personality have evolved to incorporate within-person variation in trait related behavior. Evidence suggests that there are meaningful individual differences in the frequency and magnitude of deviations from mean trait levels, and that this variability is itself predictable and stable (Fleeson, 2001; Sherman, Rauthmann, Brown, Serfass, & Jones, 2015). One approach to capturing these deviations suggests that traits may best be characterized by a density distribution of states, which includes descriptions of variability in addition to mean levels (Fleeson, 2007). However, this approach to conceptualizing personality has yet to be applied to describing facets of impulsivity.

The association between variability in trait related behavior and mental health outcomes is unclear. One theory suggests that variability should be associated with positive outcomes, as flexibility and adapting to context may predict better functioning, while high levels of consistency may represent an inability to cope with changing situations (Mischel, 1984). Other theories suggest that extreme variability may reflect a weak sense of self or behavior that is dependent only on the situation and not driven by internal values or beliefs, and will thus predict worse functioning (Baird, Le, & Lucas, 2006).

Evidence suggests that variability in trait related behavior is associated with worse mental health outcomes, however, contradictions exist. In one study, participants who rated their behavior as more consistent across settings also report higher life satisfaction, more positive affect, and less negative affect (Suh, 2002). Greater intra-individual variability has been shown to be associated with increased depression and decreased self-esteem (Donahue, Robins, Roberts, & John, 1993; Sheldon, Ryan, Rawsthorne, & Ilardi, 1997), greater intensity of negative affect

and distress (Charles & Pasupathi, 2003; Erickson, Newman, & Pincus, 2009); poorer interpersonal relationships (Côté, Moskowitz, & Zuroff, 2012), and borderline personality disorder (Russell, Moskowitz, Zuroff, Sookman, & Paris, 2007). However, one study found that increased intra-individual variability in personality predicted increased intensity of positive affect (Charles & Pasupathi, 2003) and another study found that the effect of variability disappeared when controlling for mean levels (Baird et al., 2006).

Although this evidence suggests that intra-individual variability in trait related behavior may be associated with multiple mental health outcomes, no research has explored how variability may be associated with alcohol use and problems specifically. Furthermore, most of these studies have explored average variability across multiple personality traits, and none have explicitly tested variability in specific traits, such as facets of impulsivity. Additionally, most of these studies have examined self-report of behavior and characteristics across contexts and few have utilized experience sampling methodology (Charles & Pasupathi, 2003). As such, no research to date has explored how conceptualizations of personality that include within-person variability may predict alcohol use and problems. Thus, the first goal of this study is to describe within-person variation in positive and negative urgency, sensation seeking, planning, and perseverance and test the association between this characteristic of trait impulsivity and alcohol use and alcohol related problems.

### 1.3. Contextual factors may increase impulsivity

Deviations in trait related behavior from an individual's typical level may be contingent on situational cues, and this variability may reflect individual differences in sensitivity to context (Fleeson, 2001; Sherman et al., 2015). Evidence suggests that individuals differ in the degree to which they respond to situational influences (Baird et al., 2006). Furthermore, individuals may

reliably respond to psychologically relevant features of a situation, and stability that is characteristic of personality traits may stem from idiographic relations between situations and behavior (Shoda & Mischel, 1996). These relations depend on the expectancies, beliefs, affects, goals, values, competencies, and self-regulatory plans an individual holds that may be activated by different situations (Shoda & Mischel, 2006). For example, a stressful experience may elicit mood repair goals in one individual that lead to increased risky decisions and ultimately more impulsive behavior (Reynolds et al., 2013). In a second individual, however, a stressful experience may elicit active coping goals that sensitize the brain, enhancing decision-making, and leading to less impulsive behavior (Gullo & Stieger, 2011). Thus, the cognitive affective associations each individual holds may predict stability in their own behavior over time in response to stressful experiences, although they may reliably differ between individuals (Mischel & Shoda, 1995). Understanding the situational contingencies that influence impulsive behavior may provide insight into the mechanisms by which traits are associated with behavior (Mischel & Shoda, 1998).

Some conceptualizations of impulsive traits already reflect these contingencies, as both positive and negative urgency carry a contingency in their definition (Cyders & Smith, 2007). Specifically, negative urgency represents a tendency to act rashly *when* experiencing negative affect (Cyders & Smith, 2008). However, this is only the first step in beginning to understand the situational factors that may increase or decrease impulsive behavior as well as individual differences in reactivity to these factors. Furthermore, it is currently untested whether or not these trait conceptualizations are actually associated with real world changes in impulsivity in response to context.

Determining the psychologically relevant factors of a situation that may influence impulsive behavior is difficult, and multiple factors may be present in any given situation. Nominal categorizations of situations (i.e. home vs. work) are less meaningful in understanding behavior than factors with psychological impact (Shoda, Mischel, & Wright, 1994). Psychologically relevant factors may encompass external features of a situation as well as internal states and cognitions (Shoda et al., 1994). Between-person studies that demonstrate contextual factors associated with increases in impulsive behavior provide a starting point for understanding within-person variation, and previous research suggests that mood, stress, and peers may all be associated with changes in impulsivity.

**Mood.** Changes in mood may increase impulsive behavior (Leith & Baumeister, 1996). Anecdotally, individuals report engaging in impulsive behaviors when upset such as breaking a diet or smoking, and participants have been shown to procrastinate more and eat more when experiencing a negative emotion (Tice, Bratslavsky, & Baumeister, 2001). Several theories seek to explain this association, however, there are contradictions in the hypothesized direction of effect. Additionally, facets of impulsivity may be differentially influenced by mood. As such, no universal pattern between mood and impulsive behavior has emerged.

Several theories suggest that negative mood will decrease impulsivity. First, mood may influence the type of decision making process utilized (de Vries, Holland, & Witteman, 2008). Research has identified two processes by which decisions may be reached: one that is thoughtful and deliberative and one that is cue-based, quick, and heuristic driven (Yuen & Lee, 2003). Furthermore, mood may bias memory recall, leading individuals in a negative mood to more easily recall negative memories, laden with cues of threat. Thus, individuals making quick, heuristic based decisions may make more conservative and less risky choices in an attempt to

avoid perceived threats. On the other hand, when positive, happy cues are readily available, individuals may be more likely to make risky and impulsive decisions, as potential threats and negative outcomes are less easily recalled. Consistent with these theories, negative mood was associated with decreased risk taking as indexed by performance on the IGT, BART, and self-reported risk choices (Heilman, Crişan, Houser, Miclea, & Miu, 2010; Yuen & Lee, 2003). Similarly, positive mood was shown to predict increases in risky decision making on the same tasks (Haase & Silbereisen, 2011; Heilman et al., 2010; Yuen & Lee, 2003).

Other theories suggest that negative mood may lead to increased risky decision making and impulsive behavior. First, mood may alter the subjective value of consequences. For example, a potential loss appears greater to an individual in a positive mood, because they will incur both the identified loss as well as the loss of their positive mood. Individuals in a negative mood, the theory argues, have less to lose from a poor outcome because they are already in a bad mood. Second, individuals may select high-risk, high-reward options, or smaller, sooner rewards when upset as a potential means of mood repair (Haase & Silbereisen, 2011). Finally, efforts at mood repair may also deplete needed self-control resources, leaving individuals with fewer resources with which to regulate impulsive urges or plan ahead (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Bruyneel, Dewitte, Franses, & Dekimpe, 2009). Multiple studies have found that negative moods were associated with increased risky decision making, as indexed by changes in performance on the IGT and lottery tasks (Buelow & Suhr, 2013; de Vries et al., 2008; Leith & Baumeister, 1996), increased discounting of later rewards in men (Koff & Lucas, 2011), and impaired planning (Oaksford, Morris, Grainger, & Williams, 1996; Phillips, Smith, & Gilhooly, 2002; Robinson & Sahakian, 2009). Similarly, several of these studies found that being happier was associated with decreases in risky decision making and less impulsive choices on the

IGT and lottery tasks (de Vries et al., 2008; Leith & Baumeister, 1996), as well as increased discounting for participants high on extraversion (Hirsh, Guindon, Morisano, & Peterson, 2010).

Finally, some facets of impulsivity appear more robust to the effects of mood on performance. Specifically, response inhibition may be the least susceptible to change in affect, and most studies examining the effects of both positive and negative affect on response inhibition find no evidence that mood influences task performance (Jacob et al., 2013; Martin & Kerns, 2011; Robinson & Sahakian, 2009; Weafer, Baggott, & de Wit, 2013). Two exceptions suggest that positive mood may increase impulsive responding (Phillips, Bull, Adams, & Fraser, 2002; Rowe, Hirsh, & Anderson, 2007). However, both of these positive effects were reported in outcomes not traditionally used to index impulsivity, suggesting that effects may be driven by the influence of mood on alternate executive functions such as attention and switching.

**Stress.** There are several hypothesized mechanisms by which stress may increase impulsive behavior. The influence of stress may be biologically mediated, as stress has been shown to trigger the release of dopamine and cortisol (Gathmann et al., 2014). Dopamine is believed to sensitize the brain to reward based learning and diminish avoidance of negative options (Mather & Lighthall, 2012). Conversely, cortisol may lead to increased impulsivity by impairing prefrontal cortex function, leading to reduced cognitive control (Pabst, Brand, & Wolf, 2013). Stress may also increase impulsive behavior as individuals engage in attempts at mood repair (Reynolds et al., 2013).

Stress has been shown to increase reward sensitivity (White, Lawford, Morris, & Young, 2009) and risk taking (Lighthall, Mather, & Gorlick, 2009). Larger increases in cortisol were associated with increased discounting of delayed rewards (Lempert, Porcelli, Delgado, &

Tricomi, 2012), and increases in risky decision making (Putman, Antypa, Crysovergi, & van der Does, 2010; van den Bos, Harteveld, & Stoop, 2009).

Two studies have explicitly tested how stress was associated with daily variations in impulsivity directly. Participants were asked to complete behavioral tasks in the laboratory twice, once on a day they reported lower than average stress and once on a day when they reported higher than average stress. Stress was not associated with performance on a response inhibition task, however, participants made more risky decisions on a gambling task on a high stress day (Galván & McGlennen, 2012). A second study employing the same design did find worse response inhibition on a high stress day relative to a low stress day (Rahdar & Galván, 2014).

Conversely, others theorize that the experience of stress may sensitize the brain, orienting an individual to potential loss and ultimately enhancing decision-making (Gullo & Stieger, 2011). Consistent with this theory, stress was associated with less risky decision making (Pabst et al., 2013) and a decrease in risk taking for heavy but not light drinkers (Gullo & Stieger, 2011). Stress was also found to increase response inhibition following a stressor in both a community (Schwabe, Höffken, Tegenthoff, & Wolf, 2013) and clinical sample (Krause-Utz et al., 2013).

**Peers.** Adolescents are commonly in the presence of peers when they engage in delinquency, substance use, or risky driving, and peer influence may be an important determinate of risk taking behavior during this developmental period (Steinberg, 2008). The presence of peers has been shown to influence performance on several laboratory behavioral tasks. Specifically, adolescents showed increased preference for smaller, sooner rewards when observed by peers than when alone (O'Brien, Albert, Chein, & Steinberg, 2011; Weigard, Chein, Albert, Smith, & Steinberg, 2014). Participants have also been shown to increase risky decision

making when in the presence of peers (Cascio et al., 2015; Chein, Albert, O'Brien, Uckert, & Steinberg, 2011; Gardner & Steinberg, 2005). This effect has been shown regardless of whether the risks were uncertain or explicit (Smith, Chein, & Steinberg, 2014), whether the peers were known or anonymous (Weigard et al., 2014), or even if participants were simply told they were being observed and no peers were actually present (Smith et al., 2014). Other findings suggest that it is not the mere presence of peers that leads to changes in risk taking. Rather, peer statements that actively encourage risk taking may be necessary (Reynolds, Macpherson, Schwartz, Fox, & Lejuez, 2013). However, real world findings may contradict laboratory results, as g-force ratings from real-world driving data suggested that adolescents actually demonstrated lower risky driving rates when teen passengers were in their car (Simons-Morton et al., 2011).

**Reconciling inconsistencies.** Although these findings provide evidence that mood, stress, and peers are associated with changes in impulsive behavior, there are many contradictions in the direction of effect. Conceptual and methodological limitations have prevented further understanding about how these contextual factors may predict within-person deviations in impulsivity, and several factors may account for disparate effects.

First, few studies have explored individual differences in reactivity to context. Studies of these associations have highlighted important moderators, including personality. Studies including potential moderators have found that these effects may only be true for some people. For example, one study found that only individuals high in behavioral impulsivity showed decreased risk perception when experiencing positive affect (Haase & Silbereisen, 2011). Further exploration of individual differences in reactivity are needed.

Second, many of these studies rely on between-person study designs. Given that relationships between variables differ between population level associations and individual

associations, we cannot simply extend research on between-person associations to within-person mechanisms (Hamaker, Nesselroade, & Molenaar, 2007). For example, one study found that average levels of stress and drinking were negatively associated (i.e. those who reported more stress on average tended to drink less), however, within-person levels of stress suggested a positive association, finding that daily increases in stress predicted daily increases in drinking (Park, Armeli, & Tennen, 2004). Similar findings have been true for covariation between traits. For example, neuroticism and conscientiousness are negatively associated, and individuals who are more neurotic on average tend to be lower on conscientiousness on average. However, at a within-person level, individuals are more likely to be conscientious when they are experiencing higher neuroticism (Beckmann, Wood, & Minbashian, 2010). These findings suggest that evidence for between-person associations should not be universally applied to within-person associations.

Evidence suggests that differentiating between within- and between-person effects may explain contradictory findings on how mood is associated with delay discounting specifically. Between-person studies have found that both positive and negative mood may be associated with increases in discounting of delayed rewards (Koff & Lucas, 2011). However, within-person studies find a different pattern. Specifically, one study found that relative to their own performance, participants reported decreased preference for smaller, sooner rewards when happier (Weafer et al., 2013). Similarly, another study found that a non-clinical control group showed decreased discounting when in a negative mood relative to a neutral mood (Lawrence, Allen, & Chanen, 2010). Further examination of within-person associations may also clarify other contradictory findings.

Finally, the research on contextual factors influencing impulsive behavior is further limited by the reliance on laboratory behavioral tasks performed in controlled environments. Performance on behavioral tasks is only weakly correlated with self-report measures of impulsivity (Cyders & Coskunpinar, 2012). This creates a disconnect between what is known about how mood, stress, and peers increase impulsive responding and how these factors may influence constructs like negative and positive urgency or sensation seeking. Additionally, few studies have assessed behavior in ecologically valid contexts, so it is unclear how these findings translate outside the laboratory. Thus, the second goal of this study is to explore how mood, stress, and peers may influence momentary deviations from mean levels of positive and negative urgency, sensation seeking, perseverance, and premeditation in real world contexts.

**1.4. Contextual factors may increase daily alcohol use**

Changes in mood, stress, and peer context may also be associated with daily variation in substance use. Students who reported more negative affect on average also reported more frequent drinking (Rankin & Maggs, 2006). Moreover, changes in affect may predict drinking episodes. Specifically, daily diary studies have shown that negative affect is associated with the quantity of evening consumption (Park et al., 2004; Simons, Gaher, Oliver, Bush, & Palmer, 2005; Simons, Wills, & Neal, 2014), same day intoxication (Simons, Dvorak, Batien, & Wray, 2010), and alcohol related problems (Simons et al., 2005). Furthermore, weeks that were characterized by higher negative affect were associated with increased frequency of drinking (Rankin & Maggs, 2006). Positive affect has also been shown to predict quantity of consumption (Park et al., 2004; Simons et al., 2005, 2014), and likelihood of same day drinking (Simons et al., 2014). Weeks characterized by higher positive affect were associated with increased alcohol use, more heavy drinking episodes, and increased drinking frequency (Rankin & Maggs, 2006).

However, other studies have failed to find associations between daily affect and alcohol use (Gottfredson & Hussong, 2013; Rankin & Maggs, 2006; Simons et al., 2014). These findings suggest that the experience of affect is not associated with alcohol use for all individuals, and individuals may be differentially vulnerable to using alcohol for tension reduction or to enhance positive emotions (Gottfredson & Hussong, 2013). The authors also suggest that variability in affect, and not level, may predict substance use. Individual differences in the cognitive affective units, such as goals or motives, may further moderate this association. For example, one study found that the association between negative affect and drinking frequency was strongest for individuals with social enhancement drinking motives (Armeli, Conner, Cullum, & Tennen, 2010).

Daily stress has also been shown to predict daily drinking. Specifically, the odds of binge drinking increases as daily stress accumulates (Grzywacz & Almeida, 2008a). Interpersonal stress was also associated with increased nighttime drinking (Armeli, Dehart, Tennen, Todd, & Affleck, 2007), likelihood of earlier initiation of drinking (Todd, Armeli, & Tennen, 2009), and increased frequency of drinking alone (Mohr et al., 2001). Finally, days with more stressful events (Park et al., 2004) and as well as positive and negative non-work events (Carney, Armeli, Tennen, Affleck, & O'Neil, 2000) were associated with increased drinking. However, it was also found that cognitive affective units may shape these associations, as alcohol expectancies moderated who chose to drink when stressed (Armeli et al., 2007).

Thus the same contextual factors which are thought to increase impulsivity may also increase alcohol use, suggesting that impulsivity may mediate the effects of context on alcohol use. However, no research has explored whether changes in state impulsivity in response to mood, stress, and peers underlie these associations with substance use and whether or not

individuals are more likely to drink when feeling more impulsive. Epidemiological data demonstrate that alcohol problems decrease on average during the mid to late twenties, and recent evidence suggests that this "maturing out" covaries with declines in impulsivity (Littlefield, Sher, & Wood, 2009; Littlefield, Vergés, Wood, & Sher, 2012). Specifically, adults who reported the greatest declines in problematic alcohol use and also reported the steepest declines in impulsivity (Littlefield et al., 2009). This suggests that individuals who decrease in impulsivity may be more able to access adaptive and effective coping strategies. However, it has not been tested whether or not these associations hold at the momentary level, and whether daily increases in impulsivity are associated with daily alcohol use. Thus, the third goal of this study is to explore whether or not changes in impulsivity mediate the effect of contextual factors on substance use.

### 1.5. Individual differences in reactivity to context may predict alcohol use and alcohol-related problems

Personality traits may predict how behavior is influenced by contextual factors. Specifically, Bolger and Zuckerman (1995) suggest that personality may influence exposure and reactivity to contextual factors. For example, individuals high in neuroticism reported more conflicts over a period of two weeks, as well as greater depression and anger in response to conflict (Bolger & Zuckerman, 1995). Personality may influence exposure and reactivity through multiple pathways (Settles, Cyders, & Smith, 2010). First, personality-driven preferences may influence what environment an individual spends time in. Second, individuals may evoke different reactions from the same environment. Finally, personality may lead individuals to react to or interpret the same environment differently, such that individuals experiencing the same event retain different perceptions and memories.

Trait impulsivity may serve as a marker for problematic alcohol use because it identifies individuals who experience the largest fluctuations in impulsivity in response to context. Unique if-then situation-behavior signatures, or individual differences in reactivity to context, may predict specific outcomes over and above trait levels. For example, individuals who reported increased alcohol use when experiencing positive affect in social contexts were more likely to report alcohol problems (Mohr et al., 2013). Additionally, greater increases in negative affect in response to stress predicted who would develop more depressive symptoms two months later (Cohen, Gunthert, Butler, O'Neill, & Tolpin, 2005), as well as slower responses to cognitive therapy for depression (Cohen et al., 2008; Gunthert, Cohen, Butler, & Beck, 2005). These findings suggest that reactivity, and not simply mean levels, are important predictors of mental health outcomes, including substance use, and may explain contradictory findings in the field (Gunthert et al., 2005). Thus, the final (exploratory) goal of this study is to test whether or not greater changes in negative and positive urgency, sensation seeking, perseverance, and premeditation in response to mood, stress, and peers is associated with increased alcohol use and alcohol related problems.

### 1.6. Summary of the dissertation study: Aims and hypotheses

The goal of this study is to increase our understanding of the mechanisms by which impulsivity may confer risk for psychopathology by incorporating within-person variation in trait related behavior. The study seeks to explore how contextual factors may influence an individual to behave more or less impulsively than their mean as well as how these fluctuations may be associated with alcohol use.

1. The first aim of the proposed study is to characterize within-person variation in momentary measures of impulsivity. The magnitude and frequency of deviations from

one's mean level of impulsivity has emerged as an important characteristic of trait related behavior in and of itself. Furthermore, although research has established that mean levels of impulsivity are an important marker of risk for substance use, it is currently unclear whether or not variability in impulsivity also predicts risky substance use above and beyond trait levels.

***Hypothesis 1a***. Describe within-person variability in momentary measures of impulsivity.

***Hypothesis 1b (exploratory)***. Participants who have the most variability in impulsivity will report more alcohol use and alcohol related problems.

2. The second aim of this study is to explore how mood, stress, and peers may influence momentary deviations from mean levels of impulsivity in real world contexts.

***Hypothesis 2a***. In moments characterized by more stress, participants will report deviations from their average level of impulsivity.

***Hypothesis 2b.*** In moments characterized by higher than average affect, participants will report deviations from their average level of impulsivity.

***Hypothesis 2c***. In moments characterized by more time spent with peers, participants will report deviations from their average level of impulsivity.

***Hypothesis 2d***. There will be individual differences in the effect of mood, stress, and peers on impulsivity.

3. The third aim of this study is to test whether or not changes in impulsivity mediate the effect of contextual factors on substance use.

***Hypothesis 3a***. On days characterized by higher than average impulsivity, participants will report increased substance use.

***Hypothesis 3b***. Changes in facets of impulsivity will mediate the effect of stress, peers, and mood on daily substance use.

4. The fourth exploratory aim of this study is to test whether or not individual differences in reactivity to context predict increased alcohol use and alcohol related problems.

   ***Hypothesis 4a***. Greater reactivity to peers, stress, and mood will be associated with increased substance use and substance related problems.

## Chapter 2: Methodology

### 2.1. Research design

The proposed study is part of a larger study examining how daily variability in mood and impulsivity differs between individuals with and without Attention Deficit/Hyperactivity Disorder (ADHD) and how these differences may explain the heightened risk of individuals with ADHD for alcohol use disorders. The larger study included a subset of participants from the Pittsburgh ADHD Longitudinal Study (PALS: AA011873), which is described in further detail in Molina, Sibley, Pedersen, & Pelham (2017). The larger study also had an alcohol administration component, and all participants in the current study had to meet the larger requirements of being current drinkers (defined as having drank any alcohol in the last month) as well as having consumed an equivalent amount of alcohol provided during the laboratory administration in the past six months.

### 2.2. Participants

Participants were recruited from two sources. One group of participants were recruited from the ADD Clinic, Western Psychiatric Institute and Clinic in Pittsburg, PA following a diagnosis of ADHD in childhood between 1987 and 1996, as part of the PALS study. Five hundred and sixteen youth with ADHD were recruited. Exclusion criteria included a full-scale IC < 80, a history of seizures or other neurological problems, and/or a history of pervasive developmental disorder, schizophrenia, or other psychotic or organic mental disorders. Participants were also excluded if they were currently an abstaining alcoholic or were currently taking medication for which the use of alcohol is contraindicated. From the follow-up PALS sample, eighty participants were recruited to participate in the ecological momentary assessment protocol.

A non-ADHD comparison group was recruited from the greater Pittsburgh area through fliers and Craigslist advertisements. Of the two hundred and forty non-ADHD participants, eighty were recruited to participate in the ecological momentary assessment protocol. Comparison participants were matched based on year, sex, race, and highest parental education to ADHD participants. Participants with and without ADHD were also matched on self-reported past 30 day drinking behavior.

Between the two recruitment sources a total of one hundred and sixty participants completed ecological momentary assessments in addition to baseline measures. The sample was predominately male ($n$ = 147, 91.9%). Participants ranged in age from 21 to 35 years old, and the median age was 29. 72.5% of the sample was white, 25% was African American or black, and 2.5% reported other ethnicity.

**2.3. Procedures**

All study procedures were approved by the University of Pittsburgh's Institutional Review Board. Participants completed baseline assessment measures in the laboratory. For ten days, starting on a Friday and including two weekends, participants also completed up to 6 ecological momentary assessments each day on a smartphone. Participants reported their wake and bed times, and the first and last assessments were sent 15 minutes after waking and 15 minutes before bedtime. Four additional assessments were sent randomly throughout the day. All prompts were sent via a text message including a direct link to a password protected web based questionnaire. Participants could complete measures on their personal smartphone, and were provided one by the study if they chose or did not have their own. Participants could also self-initiate prompts for pre and post assessments of each drinking episode through icons installed on the phone. All participants received in-person training in completing the momentary

assessments. Participants who completed at least 80% of the prompts could earn up to $110.00. Participants completing less than 80% received a prorated amount (e.g. completing 60% of the prompts earned 60% of $110.00, or $66.00).

### 2.4. Measures

#### 2.4.1. Baseline measures

**Demographics.** Participants completed a demographics questionnaire assessing age, gender, ethnicity, and socio-economic status.

**Impulsivity**. Trait negative urgency, positive urgency, sensation seeking, lack of premeditation, and lack of perseverance were measured using the UPPS-P Impulsive Behavior Scale (Lynam, Smith, Cyders, Fischer, & Whiteside, 2007). All items were assessed on a scale of 1 (agree strongly) to 4 (disagree strongly). Negative urgency ($\alpha = .91$) was assessed with 12 items including "I have trouble controlling my impulses" and "I often act without thinking when I am upset." Positive urgency ($\alpha = .95$) was assessed by 15 items including "I am surprised at the things I do while in a great mood" and "I tend to act without thinking when I am really excited." Sensation seeking ($\alpha = .87$) was measured by 12 items including "I will try anything once" and "I like doing things that are a bit frightening." Lack of premeditation ($\alpha = .90$) was assessed by 11 items including "I have a reserved and cautious attitude toward life" and "I usually think carefully before doing anything." Lack of perseverance ($\alpha = .85$) was assessed by 10 items including "I finish what I start" and "I concentrate easily." The UPPS-P has been shown to have good internal reliability and consistency (Cyders & Smith, 2008).

**Alcohol use**. Alcohol use was assessed with the Substance Use Questionnaire (Molina & Pelham, 2003). The SUQ assesses lifetime alcohol use as well as the quantity and frequency of current use. The SUQ has demonstrated adequate reliability (Molina & Pelham, 2003). Because

the current sample were self-identified drinkers, measures of high risk use as opposed to general quantity x frequency measures were chosen for the current study. Furthermore, research has suggested that multiplying binned counts (such as quantity and frequency of use) can threaten construct validity and may impair the ability to accurately measure alcohol use (McGinley & Curran, 2014). As such, past year drunkenness and past year binge drinking were used as predicted outcomes when testing associations to within-person variability. An additional variable, heavy alcohol use, was also calculated as an average of the z scores of past year frequency and quantity of binge drinking and drunkenness. This variable was used as a predictor, specifically to test whether or not participants who report greater changes in impulsivity in response to contextual factors are characterized by greater alcohol use.

**Alcohol problems**. Alcohol problems were assessed using the Young Adult Alcohol Problems Screening Test (YAAPST; Hurlbut & Sher, 1992). The YAAPST consists of 27 items measuring past year negative consequences of alcohol use. Eight of the items are measured on a scale ranging from 0 (no, never), 1 (yes, but not in the past year) to 9 (40 or more times). Eleven items are measured with a scale that ranges from 0 (no, never), 1 (yes, but not in the past year) to 4 (3 or more times in the past year). Six items are measured with a scale including 0 (no, never), 1 (yes, but not in the past year), and 2 (yes, in the past year). Example items include “Has a doctor ever told you that your drinking was harming your health?” and “Have you felt very sick to your stomach or thrown up after drinking?” The YAAPST has demonstrated good internal consistency and concurrent validity (Hurlbut & Sher, 1992). This study used the past year count of alcohol problems endorsed.

### 2.4.2. Ecological momentary assessment measures

**Stimulation and sedation**. Current mood facets were assessed through the Brief Biphasic Alcohol Effects Scale (B-BAES) (Rueger & King, 2013). This scale includes six items: "up", "sluggish", "excited", "slow thoughts", "sedated", and "energized". All items were assessed on a scale of 1 (not at all) to 10 (extremely). Two subscales were calculated. "Energized", "excited", and "up" were averaged to create the stimulated subscale ($\alpha = .88$). "Sedated", "slow thoughts", and "sluggish" were averaged to create the sedated subscale ($\alpha = .90$). The B-BAES demonstrated strong reliability and predictive validity (Rueger & King, 2013). In addition to the momentary assessments, mean daily ratings were calculated by averaging all EMA mood assessments for each stimulated and sedated subscale completed in that day.

**Peer context**. Current peer presence was measured by one item asking participants to report all categories of individuals they have been with in the past 15 minutes, including romantic partner, family member, friend/acquaintance, boss/teacher, coworker, roommate, other, or alone. This item was adapted from previous ecological momentary assessment studies (Piasecki et al., 2011; Piasecki, Wood, Shiffman, Sher, & Heath, 2012). For this study, peer presence was indicated by the endorsement of the presence of friend/acquaintances, romantic partner/spouse, or roommate.

**Stress**. Current stress was measured by one item assessing the degree to which stress has weighed on the participant since the last assessment. Response options ranged from 1 (not at all) to 7 (extremely). Daily stress was calculated as an average of the day's EMA stress items. Participants also reported once per day whether or not they had experienced stress in any of

multiple categories. Response options included work/school, finances, interpersonal/romantic, health, experienced discrimination, or other.

**Alcohol use**. Daily alcohol use was calculated as the number of drinks participants reported consuming that day, modeled after previous ecological momentary assessments (Piasecki, McCarthy, Fiore, & Baker, 2008).

**Impulsivity**. State impulsivity was measured using a brief version of the UPPS-P (Lynam et al., 2007). 19 items were selected from the UPPS-P and modified. Participants reported to what degree they experienced the items since their last assessment on a scale from 1 (strongly agree) to 4 (strongly disagree). State negative urgency ($\alpha$ = .82), positive urgency ($\alpha$ = .91), sensation seeking ($\alpha$ = .79), and perseverance ($\alpha$ = .81) were assessed with 4 items; state premeditation ($\alpha$ = .86) was assessed with 3 items. Items were reverse coded so that higher numbers indicate greater impulsivity. Example items include "I thought carefully before doing anything" and "I had trouble controlling my impulses". In addition to state levels of each facet of impulsivity, I also calculated mean levels for each facet across all EMA points.

Table 2.1 presents means and standard deviations of relevant study variables. Table 2.2 presents bivariate correlations between facets of impulsivity, contextual factors, and substance use.

**2.5. Data analytic plan**

Descriptive statistics and multilevel models were analyzed using SPSS 23. Additional hypotheses were tested using *Mplus* 6.1 (Muthén & Muthén, 1998-2008), using the Maximum Likelihood Estimator with Robust Standard Errors (MLR) with one exception. The final model for Aim 4 predicting a binary outcome required a robust weighted least squares estimator (WLSMV).

**EMA response.** Compliance with the EMA protocol was moderate, with participants completing an average of 38 of 60 prompts (64%; SD = 14.54; range 1 – 58). Participants were removed from analyses if they completed less than 10% of the prompts, resulting in 6 participants being excluded and a final sample of one hundred and fifty-four. The average number of assessments completed each day declined over the ten day EMA period ($b$ = -.015, $p$ < .01, *95% CI* [-.017, -.013]).

**Accounting for time.** EMA models predicting daily drinking also included a covariate to account for day of the week, indicating whether or not it was a weekend. Categorization of Thursday and Sunday as weekend days was determined empirically. Results suggested that the best characterization of weekend alcohol use in the current sample occurred when only Fridays and Saturdays where considered weekend days. Figure 1 demonstrates the total number of drinks consumed by day of week. Study day was also included to control for change over time as function of development or reactivity to the assessment (Simons et al., 2014).

**Modeling past year alcohol use and problems.** Given that the measures of binge drinking, drunkenness, and alcohol problems were neither continuous nor true counts, I explored the distribution of these variables and used empirical testing to identify a model best representing the pseudo-count data. I tested a series of models using only covariates as predictors, assuming three different distributions: Gaussian, Poisson, and negative binomial. I also tested whether or not adding a zero-inflated or hurdle component improved model fit. Log likelihood, Akaike Information Criteria (AIC), and Bayesian Information Criteria (BIC) were used to determine the best fitting distribution. Table 2.3 provides these values for each distribution tested. For past year alcohol problems, all three negative binomial models were superior to Gaussian and both Poisson based models across all fit indices. There was also no significant difference in -2 log likelihood

between the negative binomial model and both the zero-inflated negative binomial and negative binomial hurdle model. There was disagreement in the AIC and BIC values, with the former indicating that the negative binomial hurdle model demonstrated the best fit and the latter indicating that the negative binomial model fit best. Given this discrepancy, the negative binomial model was chosen in the interest of parsimony. A similar pattern emerged in modeling past year drunkenness. Again, negative binomial based models were superior to Gaussian and Poisson based models across all fit indices. There were no significant differences in log likelihood between the negative binomial model and both the zero-inflated negative binomial model and negative binomial hurdle model. There was a discrepancy between AIC and BIC, and being more parsimonious, the negative binomial model was chosen. Past year binge drinking demonstrated a different pattern. Negative binomial models were again superior to all Gaussian and Poisson based models. Zero-inflated negative binomial and negative binomial hurdle models had a significantly lower log likelihood relative to the negative binomial model. Of these, AIC and BIC both indicated that the zero-inflated negative binomial model fit was better, and thus this model was chosen for past year binge drinking.

**Modeling daily alcohol use**. Because the number of drinks consumed each day had the potential to be zero-inflated, I first tested the same series of distributions described in modeling past year alcohol use and problems to determine the most appropriate modeling strategy. I tested the number of drinks consumed daily as the same three different distributions: Gaussian, Poisson, and negative binomial. I then tested whether adding a zero-inflated component or hurdle model to Poisson and negative binomial models improved fit. Again, I used a combination of -2 Log Likelihood, AIC, and BIC to determine the most appropriate distribution to model the data

with. Across all indicators, the negative binomial model appeared to fit the data best, as seen in Table 2.4.

### 2.5.1. Aim 1: Variability in facets of impulsivity

The first aim of this study was to characterize within-person variation in momentary measures of impulsivity and explore how this variability may be associated with substance use. To test this, I first ran separate unconditional multilevel models of each facet of impulsivity. The intraclass correlation (ICC) from these models provided an estimate of the proportion of variance that was accounted for by individual differences between participants. I then calculated two indicators of variability in facets of impulsivity: standard deviation (SD) and mean squared successive difference (MSSD). Standard deviation was chosen because it is a commonly understand statistic representing within-person variability (Jahng, 2008). However, standard deviation is limited in that is does not account for temporal dependency, or the possibility that a rating of impulsivity at any given moment is not independent of the prior rating and may instead be directly influenced by how impulsive a participant was feeling at a previous moment. The mean squared successive differences, however, is an indicator of both variability and temporal dependency.

First, the standard deviation was calculated for each facet of impulsivity from the up to six momentary assessments gathered each day. This ‘daily standard deviation’ represented how variable a participant was on any given day. Standard deviation was also calculated from all momentary assessments collected across the entire EMA period. This ‘total standard deviation’ represented the total variability participants reported across the study. Because standard deviation may be dependent upon mean levels (Baird et al., 2006; Eid & Diener, 1999), I also calculated corrected total standard deviations. I regressed the standard deviations on mean levels

and squared mean levels to control for potential linear and curvilinear dependence. Residuals from these regressions represent the degree to which an individual has a high or low standard deviation relative to other individuals with the same mean level (Baird et al., 2006).

Similarly, MSSD was also calculated in two ways. Short-term MSSD (ST-MSSD) represented the changes a participants reported in each facet of impulsivity in a given day. ST-MSSD was calculated as follows:

$$ST - MSSD = \frac{1}{N - J}\sum_{j=1}^{J}\sum_{i=1}^{n_j - 1}(x_{(i+1)_j} - x_{ij})^2$$

Long-term MSSD (LT-MSSD) was calculated as the successive differences between each day's average level of impulsivity, representing total variability across the EMA period. LT-MSSD was calculated as follows:

$$LT - MSSD = \frac{1}{J - 1}\sum_{j=1}^{J-1}(\overline{x}_{j+1} - x_i)^2$$

For both ST-MSSD and LT-MSSD, a minimum of two intervals were required to complete the calculation. Because disparate time intervals between successive assessments can bias ST-MSSD estimates, I next tested whether the expected absolute successive difference (EASD) was dependent upon the length of the time interval. I first plotted the absolute successive difference against time interval in minutes and then added a loess line. A straight line would indicate that the size of the successive difference was independent from the time between assessments. Loess lines indicated that successive differences between assessments were independent of the length of interval for all facets of impulsivity, and no additional adjustments were made to the ST-MSSD (see Figure 2).

To understand how different measures of variability were associated with each other, I calculated correlations between ST-MSSD and daily standard deviation for each facet of impulsivity as well as correlations between LT-MSSD and total standard deviations for each facet. To understand the degree to which within day variability is associated with between day variability, I also calculated correlations between daily and total standard deviations as well as ST-MSSD and LT-MSSD.

To understand how within-person variability in impulsivity may be associated with substance use, I regressed past year binge drinking, past year drunkenness, and past year alcohol problems on the two indicators of variability described above, running separate models for total standard deviation and LT-MSSD. Because standard deviation may be dependent on mean levels, I next tested several iterations of the standard deviation model. I ran a second model including mean levels of facets of impulsivity to test whether or not variability was associated with substance use over and above trait levels. Finally, I regressed past year binge drinking, past year drunkenness, and past year alcohol problems on corrected standard deviations, further testing whether or not potential associations were dependent upon mean levels. For all models I included gender, race, and age, testing the effects of indicators of variability above and beyond the effects of covariates.

**2.5.2. Aim 2: Effects of contextual factors**

The second aim of this study was to explore how mood, stress, and peers may influence momentary deviations from mean levels of impulsivity in real world contexts. A series of multilevel models predicting momentary levels of facets of impulsivity were used to test these hypotheses. At level 1 I included participant ratings of momentary stress, stimulation, sedation, and peer context. At level 2 I included average stress, stimulation, sedation, and peer context to

accurately estimate between and within-person variance. To test whether or not participation in the study protocol was associated with participant responses, I also included study day as a covariate at level 1.

All level 1 predictors (state impulsivity, mood, stress, and peers) were within-person centered (Enders & Tofighi, 2007; Sherman et al., 2015). For this aim, this meant that momentary assessments were centered relative to the participant's mean across all ecological momentary assessments. All level 2 predictors of interest (average stimulation, sedation, stress, and peer context) were grand mean centered to facilitate interpretation. This strategy also partitions within- and between-person variability fully. Age and gender were included as covariates.

Example equations are as follows:

$$Level\ 1:\ Negative\ Urgency_{ij} = \beta_{0j} + \beta_{1j}(stim_{ij} - \bar{x}stim_j) + \beta_{2j}(sed_{ij} - \bar{x}sed_j) + \beta_{3j}(stress_{ij} - \bar{x}stress_j) + \beta_{4j}(peer_{ij} - \bar{x}peer_j) + \beta_{5j}day_{ij} + r_{ij}$$

$$Level\ 2:\ \beta_{oj} = \gamma_{00} + \gamma_{01}age + \gamma_{02}gender + \gamma_{03}(\bar{x}stim_j) + \gamma_{04}(\bar{x}sed_j) + \gamma_{05}(\bar{x}stress_j) + \gamma_{06}(\bar{x}peer_j) + u_{oj}$$

$$\beta_{1j} = \gamma_{10} + u_{1j}$$

$$\beta_{2j} = \gamma_{20} + u_{2j}$$

$$\beta_{3j} = \gamma_{30} + u_{3j}$$

$$\beta_{4j} = \gamma_{40} + u_{4j}$$

$$\beta_{5j} = \gamma_{50} + u_{5j}$$

The design of the ecological momentary assessments necessitated that I offset the stimulation and sedation ratings. Specifically, in rating stimulation and sedation, the protocol asked participants to "rate the extent to which these words describe your feelings at the present time".

In assessing facets of impulsivity, however, the protocol asked participants to rate their experience "since the last assessment". As such, ratings of facets of impulsivity provided during the same ecological momentary assessment would temporally precede ratings of stimulation and sedation. To correct for this, ratings of stimulation and sedation were offset by 1 time point. The same adjustment was not necessary for reports of peer context and stress. Participants were asked to what degree stress weighed on them since the last assessment, providing a concurrent assessment of stress and facets of impulsivity. Peer context was assessed by asking who the participant had been with in the past 15 minutes, with concurrent assessments providing the most overlapping assessment period.

To best explore the influence of contextual factors on momentary levels of impulsivity, I engaged in sequential model building, adding each predictor one at a time first as a fixed effect and then as a random effect. This allowed me to monitor how each factor influenced model fit, indicated by change in -2 log likelihood. I tested several covariance structures of the random effects; because there was no significant change in results, the covariance structure was set to unstructured for all models except lack of premeditation. This model failed to converge using this covariance structure and was thus run using the variance components (VC) structure. The model building process was repeated for each of the five facets of impulsivity.

To test for independence of effects, I tested all possible interactions between the covariates that were retained in the model and all predictors, and included significant interactions in the final model. This strategy reduces the possibility of model mis-specification, but does increase the risk of alpha inflation. To account for this, only interactions significant at the a-priori criterion of $p < .01$ were included. No retained interactions were interpreted, given that there was

no a-priori hypotheses about possible interactions. Rather, they served only to provide appropriate model specification.

### 2.5.3. Aim 3: Impulsivity as a mediator

The third aim of this study was to test whether or not changes in facets of impulsivity mediate the effect of contextual factors on substance use. After determining the best model fit for daily alcohol use, I ran two series of regressions. I regressed daily averages of each facet of impulsivity on daily averages of stress, stimulation, and sedation, testing the direct effect of contextual factors on level of impulsivity. I then regressed the number of drinks consumed that day on average daily impulsivity, testing whether or not participants drank more on days they reported higher impulsivity. Given previous findings that daily alcohol consumption is dependent upon daily mood, I also included the direct effect of daily stress, stimulation, and sedation on daily alcohol use behavior.

Because the number of daily drinks was so zero-inflated and had low variability, I also tested the same mediated model using a binary outcome of whether any drinking occurred on a given day. These models included the same series of regressions, first regressing daily impulsivity on contextual factors, and then regressing alcohol use on daily impulsivity.

To test for mediation, I calculated the indirect effect using the distribution of the product of the coefficients method (MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002). Because Mplus cannot calculate the bias-corrected bootstrap procedure when also using a sandwich estimator to account for clustering, I used the online program RMediation to calculate the confidence interval for the indirect effect (Tofighi & Mackinnon, 2011).

### 2.5.4. Aim 4: Moderation by heavy alcohol use and problems

To test whether or not individual differences in reactivity to context characterizes individuals who also report alcohol use and alcohol problems, I extended the multilevel models used in hypothesis 2. Heavy alcohol use and alcohol problems were included as level 2 predictors. Cross level interactions with state variables (mood, stress, and peers) were included. A significant interaction would suggest that how state contextual factors and state impulsivity are associated depends on the level of alcohol use or problems. This will indicate whether or not reactivity is a marker of those who drink more riskily or report more alcohol problems. Example equations are as follows:

$$Level\ 1:\ Negative\ Urgency_{ij} = \beta_{0j} + \beta_{1j}(stim_{ij} - \bar{x}stim_j) + \beta_{2j}(sed_{ij} - \bar{x}sed_j) + \beta_{3j}(stress_{ij} - \bar{x}stress_j) + \beta_{4j}(peer_{ij} - \bar{x}peer_j) + \beta_{5j}study\ day_{ij} + r_{ij}$$

$$Level\ 2:\ \beta_{oj} = \gamma_{00} + \gamma_{01}age + \gamma_{02}gender + \gamma_{03}(\bar{x}mood_j) + \gamma_{04}(\bar{x}stress_j) + \gamma_{05}(\bar{x}peer_j) + \gamma_{06}heavy\ use + u_{oj}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}heavy\ use + u_{1j}$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}heavy\ use + u_{2j}$$

$$\beta_{3j} = \gamma_{30} + \gamma_{31}heavy\ use + u_{3j}$$

$$\beta_{4j} = \gamma_{40} + heavy\ use + u_{4j}$$

$$\beta_{5j} = \gamma_{50} + u_{5j}$$

I used the same process of model building, adding each new predictor one at a time and monitoring how each factor influenced model fit as indicated by change in -2 log likelihood. Effects that worsened model fit and did were not significant were not retained in the final model. Because all new predictors were at level 2, no additional random effects were included. However, all models for this aim were run using the variance components covariance structure

because many of the models would not converge with the additional parameters while using an unstructured covariance structure.

Significant interactions were probed and graphed using the pick-a-point approach (Aiken & West, 1991). To explore the interaction further, I also used the region of significance (Johnson-Neyman technique) approach to determine when the effect was significantly different from zero (Preacher, Rucker, & Hayes, 2007). This was calculated using the online macro (Preacher, Curran, & Bauer, 2006). As before, all main predictors were centered at zero to facilitate interpretation.

# Chapter 3: Results

## 3.1. Descriptive statistics of study variables

In their baseline assessment of the past year, participants reported drinking on average between 2-3 times a month and once a week. On each drinking occasion participants reporting consuming an average of 3-4 drinks. All participants reported at least drinking 1-3 times in the past year. 80% of the sample reported binge drinking (having at least 5 drinks in one occasion) at least one time in the past year, and 25% of the sample reported binge drinking on weekly basis. Eight participants reported experiencing no alcohol related consequences ever.

In the ecological momentary assessments over the ten day study period, participants reported drinking on average 2.44 days. 52 participants (33%) did not drink on any day during the study period, and approximately 20% reported drinking on 4 or more days. The average number of drinks consumed on days any drinking occurred was 2.23.

I next tested correlations between baseline levels of impulsivity and the mean of their ecological momentary assessments provided during the study period. Correlations between the two measures varied across facets. The correlation between baseline and the EMA average for sensation seeking was small ($r$ = .34). Correlations between the two measures for cognitive facets of impulsivity were moderate (premeditation: $r$ = .54; perseverance: $r$ = .61). Correlations between the two measure for mood-based facets were also moderate (negative urgency: $r$ = .61; positive urgency: $r$ = .67). The full correlation matrix is presented in Table 3.1.

### 3.2. Aim 1: Variability in facets of impulsivity

#### 3.2.1. Indicators of variability

The first goal of this study was to understand how impulsivity varied within individuals. Based on the ICCs from unconditional models, between 25 and 32 percent of variance across all facets of impulsivity was due to within-person variability. This suggests that participants experienced different levels of each facet over the course of a day or week. Specific ICCs are reported in Table 3.2.

The calculation of MSSD and standard deviation further suggested that people varied in the degree to which they express different levels of facets of impulsivity. ST-MSSD ranged from 0.0 to 9.0, and LT-MSSD ranged from 0.0 to 1.90. Daily standard deviations ranged from 0.0 to 2.12. Table 3.3 presents the means and standard deviations of all indicators of variability. To provide an illustration of how participants may differ in their state levels, Figure 4 depicts the distributions of reported state negative urgency for two participants, one with a lower standard deviation (.50) and one with a higher standard deviation (1.08).

Like LT-MSSD, total standard deviation had a smaller range overall than daily standard deviation. Fifteen participants had a total standard deviation of 0 for negative urgency, indicating that they reported the same level for every state assessment during the study period. For all of these participants they consistently reported that they "strongly disagreed" with any item measuring negative urgency at any time during the study period. Of these participants, 3 also reported the lowest level of negative urgency at baseline. Standard deviation of state negative urgency ranged between 0 and 1.31, with a mean standard deviation of .32. Figure 5 depicts the distribution of total standard deviation of all facets of impulsivity across participants. Twenty-four participants had a total standard deviation of zero for positive urgency, 23 of which reported

that they “strongly disagreed” with every item measuring positive urgency during the study period. Five of these same participants also strongly disagreed with every positive urgency item at baseline. Standard deviation of state positive urgency ranged between 0 and 1.27, with a mean standard deviation of .25. Six participants had a standard deviation of zero for sensation seeking, five of which consistently reported the lowest level of sensation seeking possible. However, none of these participants reported the lowest level of sensation seeking at baseline. Standard deviation of state sensation seeking ranged between 0 and 1.3, with a mean standard deviation of .33.

Participants reported more variability in cognitive facets of impulsivity on average. Ten participants had a standard deviation of zero for premeditation, eight of which consistently reported the lowest level of lack of premeditation during the study period (indicating high foresight and planning). Standard deviation of state lack of premeditation ranged between 0 and 1.34, with a mean standard deviation of .38. No participants had a standard deviation of zero for lack of perseverance, suggesting that all participants reported at least some differences in their level over the study period. Standard deviation of state lack of perseverance ranged between .03 and .96, with a mean standard deviation of .34.

Total standard deviation and LT-MSSD for each facet of impulsivity were correlated between .71 - .76, suggesting that although there is significant overlap between the measures of variability they are also capturing something unique. Daily standard deviation and ST-MSSD were also highly correlated (.76 - .81). The association between LT-MSSD and ST-MSSD was fairly weak, with correlations ranging between .21 and .30. Associations between total standard deviation and daily standard deviation were moderate, ranging between .54 and .62. This suggests that at least some participants who experience more frequent or more intense changes in

trait-related behavior within a day may still experience fairly consistent averages across days. Table 3.4 provides these correlations in full.

### 3.2.2. Associations between variability and substance use

*Past Year Alcohol Problems*

To test whether or not variability in facets of impulsivity was associated with alcohol problems, I tested a series of four models, predicting alcohol problems from the total standard deviation, standard deviation in addition to mean levels, corrected standard deviation, and finally LT-MSSD. Convergence across models would provide more evidence that variability is indeed an important predictor of alcohol use behavior. All models include age, gender, and ethnicity as covariates. Effects for all models predicting alcohol consequences can be found in Table 3.5.

*Covariate effects.* Although associations between covariates and alcohol problems varied slightly between models, several consistent patterns emerged. Across all but one model, age was associated with alcohol problems (*RR* = .94), such that every one year increase in age was associated with a 6% decrease in alcohol problems. Across most models gender was either significantly associated or showed a trend with problems (*RR* = 1.72). Females reported more alcohol problems on average than males. Ethnicity consistently demonstrated no association with alcohol problems (*RR* = 1.11).

*Effects of Variability.* SD of negative urgency was positively associated with past year alcohol problems (*RR* = 2.9), such that a one unit increase in variability was related to a 190% increase in the level of past year alcohol problems. However, these effects did not hold over and above mean levels or when using a corrected standard deviation. Additionally, there was no evidence that LT-MSSD predicted alcohol problems.

A similar pattern emerged predicting alcohol problems from variability in positive urgency. Total standard deviation of positive urgency was associated with problems (*RR* = 2.78), such that a one unit increase in variability was related to a 178% increase in the level of past year problems. Again, no other model found significant associations between variability and alcohol problems. Total standard deviation was not associated with alcohol problems when mean levels were included. Neither corrected standard deviation nor LT-MSSD demonstrated evidence of an association with alcohol problems.

Total standard deviation of sensation seeking was associated with alcohol problems (*RR* = 2.35). For every one unit increase in variability participants reported there was a 135% increase in past year alcohol problems. This effect did not hold above mean levels of sensation seeking, however. Corrected standard deviations were also positively associated with alcohol problems (*RR* = 2.73), also suggesting that greater variability predicted experiencing more problems. Every one unit increase in corrected SD of sensation seeking was associated with a 173% increase in past year alcohol problems. LT-MSSD of sensation seeking was not associated with alcohol problems.

There was no evidence for any association between variability in premeditation and alcohol problems. Across all models including total standard deviation, standard deviation with mean levels, corrected standard deviation, and LT-MSSD, indicators of variability in premeditation did not predict past year alcohol problems.

SD in perseverance as indicated by the total standard deviation was associated with alcohol problems (*RR* = 3.57). For every one unit increase in SD there was a 257% increase in past year alcohol problems. Similar to the mood-based facets of impulsivity, this was the only model demonstrating an association. Total standard deviation above mean levels, corrected

standard deviation, and LT-MSSD all failed to demonstrate evidence of an association between variability and alcohol problems.

*Past Year Drunkenness*

*Covariate effects*. There were no significant associations between any covariates and past year drunkenness across all models.

*Variability effects.* There was also no evidence that variability in negative urgency, positive urgency, or sensation seeking was associated with past year drunkenness across all models. Neither standard deviation of negative urgency nor LT-MSSD were associated with drunkenness. There was a similar lack of association between both standard deviation of positive urgency and LT-MSSD and drunkenness. Finally, standard deviation and LT-MSSD of sensation seeking also did not predict past year drunkenness. Results are presented in Table 3.6.

Variability in cognitive based facets of impulsivity showed a different pattern. Standard deviation of lack of premeditation was positively associated with past year drunkenness (*RR* = 2.95). For every one unit increase in standard deviation there was a 195% increase in past year drunkenness. This effect held over and above trait levels (*RR* = 2.54). Corrected standard deviation of lack of premeditation was also positively associated with drunkenness (*RR* = 2.30), further suggesting that reporting greater variability was associated with being drunk more frequently. Finally, LT-MSSD showed the same pattern and also predicted greater drunkenness (*RR* = 1.73). Every one unit increase in LT-MSSD was associate with a 73% increase in past year drunkenness.

Variability in lack of perseverance also demonstrated a consistent positive association with past year drunkenness across all models. Standard deviation controlling for mean levels (*RR* = 5.62), corrected standard deviation (*RR* = 5.79) and LT-MSSD (*RR* = 3.01) all predicted

greater past year drunkenness. A one unit increase in variability was associated with an increase of past year drunkenness between 201-479%.

*Past Year Binge Drinking*

*Covariate effects*. Across all models, ethnicity was associated with the likelihood of binge drinking (*OR* = .01). Because the odds ratio predicts the likelihood of being a zero, this suggested that white participants were more likely to report any binge drinking. Across almost all models, age was negatively associated with the count of past year binge drinking (*RR* = .96). Specifically, every one year increase in age was associated with a 4% decrease in past year binge drinking. No other associations emerged between covariates and binge drinking.

*Variability effects*. Variability in negative urgency, positive urgency, and sensation seeking was not associated with both the likelihood of past year binge drinking as well as the count frequency of binge drinking. Results are presented in table 3.7.

Variability in lack of premeditation was not associated with the likelihood of reporting any binge drinking across all models (*OR* = .03). However, total standard deviation of lack of premeditation was positively associated with the frequency of binge drinking in the past year (*RR* = 1.59). Every one unit increase in standard deviation was associated with a 59% increased risk of binge drinking. This effect did not hold over and above mean levels or with corrected standard deviation. LT-MSSD did predict past year binge drinking, however (*RR* = 1.42). A one unit increase in LT-MSSD was related to a 42% increased risk of binge drinking.

Total standard deviation of lack of perseverance was associated with the likelihood of past year binge drinking (*OR* = .01), and this effect held above mean levels (*OR* = .00) and when using corrected standard deviation (*OR* = .01). Because an odds ratio predicts the likelihood of being a zero, this indicated that participants who reported more variability in perseverance were

also more likely to report any binge drinking. There was no association between LT-MSSD of perseverance and likelihood of binge drinking. Total standard deviation of lack of perseverance was also associated with the frequency of binge drinking (*RR* = 1.94). Every one unit increase in standard deviation was associated with a 94% increase in risk for binge drinking. However, this association was no longer significant when mean levels were included or when using corrected standard deviations. LT-MSSD was also not associated with the count model of binge drinking.

### 3.3. Aim 2: Effects of contextual factors

#### 3.3.1. Negative urgency

The grand mean of all momentary ratings of negative urgency was 1.96 (with a scale maximum of 4), although the average level varied significantly across participants (*SD* = .48). Thus, 68% (i.e. ± 1 standard deviation) of all participant averages ranged between 1.48 and 2.44. Although study day was not associated with state negative urgency on average (*b* = -.02), there was significant variance in the effect of day across participants (*SD* = .03). 68% of participants had an effect between -.03 and .03, suggesting that some participants tended to report increased levels of negative urgency later in the study period while other participants tended to report decreased levels. Given the significant variance, study day was retained in subsequent models.

*Covariates*. I next tested the effects of covariates on state levels of negative urgency. Age was initially negatively associated with negative urgency and was thus retained, but was not significant in the final model (*b* = -.02). Gender and ethnicity were not associated with level of negative urgency and did not significantly improve model fit. Thus, neither were retained in the final model. There were no significant interactions at $p < .01$ between age and any other predictor, thus none were retained in the final model.

*Stimulation and Sedation*. State stimulation was not associated with negative urgency, however, the effect of stimulation varied significantly across participants (*SD* = .03). For 68% of participants, the effect of stimulation ranged between -.04 and .03, suggesting that some participants reported increased negative urgency when feeling more up or stimulated relative to their own average, while other participants reported decreased negative urgency when feeling the same way. Average stimulation did not predict level of negative urgency.

There was no evidence for an association between state sedation on negative urgency, although this effect varied significantly across participants (*SD* = .02). Average sedation was positively associated with state negative urgency (*b* = .16), indicating that for every one unit increase in average sedation there was a one unit increase in average negative urgency.

*Stress*. State levels of stress were positively associated with level of negative urgency (*b* = .06). At times when participants were experiencing more stress than their own average, they also reported higher than average levels of negative urgency. This effect also varied significantly across participants (*SD* = .10), suggesting that the effect of stress on level of negative urgency was stronger for some participants. Average level of stress was also positively associated with negative urgency (*b* = .17). Every one unit increase in average stress was associated with a one unit increase in average levels of negative urgency.

*Peer context*. The presence of peers was not associated with state level of negative urgency, however this effect varied significantly across participants (*SD* = .10). For 68% of participants the effect of peer presence ranged between -.08 and .12.

**3.3.2. Positive urgency**

The average level of positive urgency across all ecological momentary assessments was 1.43 (with a scale maximum of 4), although this varied significantly across participants (*SD* =

.56). 68% of all participants reported an average level of positive urgency between .87 and 1.99. Study day was not associated with state level of positive urgency. However, there was significant variance in the effect of study day (*SD* = .04), suggesting that how levels of positive urgency changed over the study period differed among participants. This effect ranged between -.04 and .04 for 68% of participants, indicating that some participants reported higher levels of positive urgency while other participants reported lower levels of positive urgency over the course of the study. No interactions between study day and all predictors were significant at $p < .01$ and were thus not retained in the final model.

*Covariates*. Age, gender, and ethnicity were all not associated with state level of positive urgency and failed to improve model fit when included. Because they failed to explain any meaningful variance in the outcome, none were retained in the final model.

*Stimulation and Sedation*. State ratings of stimulation were not associated with positive urgency, however, this effect did vary across participants (*SD* = .04). There was no evidence for an association between average level of stimulation and positive urgency.

State ratings of sedation were also not associated with positive urgency. This effect did not significantly vary across participants and the random component was not retained in the final model. Average sedation was predictive of level of positive urgency (*b* = .12). Participants who reported feeling sluggish, sedated, or having slow thoughts more often also reported greater levels of positive urgency on average.

*Stress*. Momentary stress was not associated with positive urgency, however, this effect varied significantly across participants (*SD* = .03). For 68% of participants, the effect ranged between -.02 and .04, indicating that some participants reported higher levels of positive urgency in moments characterized by higher than average stress while other participants reported lower

levels of positive urgency in moments characterized by higher than average stress. Average stress level was positively associated with level of positive urgency (*b* = .13). Participants who reported more stress across the entire study period also reported higher levels of positive urgency.

*Peer presence*. Peer presence was positively associated with state levels of positive urgency (*b* = .03), such that participants were more likely to report higher positive urgency when they reported being with a peer. This effect did not vary significantly across participants, and the random component was thus not retained in the final model.

**3.3.3. Sensation seeking**

The average state level of sensation seeking was 2.72 (on a scale maximum of 4), although this varied significantly across participants with 68% reporting an average level between 1.98 and 3.46. Study day was not significantly associated with state sensation seeking, although this effect also varied significantly across participants (*SD* = .04). Participants tended to both increase and decrease their report of sensation seeking across the study period. Interactions between study day and all predictors were not significant and were thus not retained in the final model.

*Covariates*. Gender and ethnicity were not associated with state sensation seeking and did not improve model fit when included. As such, neither were retained in the final model. Age was associated with level of sensation seeking (*b* = -.03). For every one unit increase in age there was a decrease of .03 in average level of sensation seeking.

*Stimulation and Sedation*. State stimulation was positively associated with sensation seeking (*b* = .02), suggesting that in moments characterized by higher than average excitement or feeling up or energized participants also reported higher than average sensation seeking. This

effect also varied across participants (*SD* = .06), and ranged between -.03 and .08 for 68% of participants. This indicates that for at least some participants momentary sensation seeking was lower than average when participants were experiencing higher than average stimulation. Average stimulation was also associated with sensation seeking (*b* = .07), suggesting that participants who reported feeling more stimulation across the entire study period were more likely to report higher levels of sensation seeking. Neither state nor average sedation was associated with sensation seeking. The effect of state sedation did vary significantly across participants, however, suggesting that how sedation and sensation seeking were associated in the moment differed between participants (*SD* = .03).

*Stress*. There was no evidence for a main effect of state stress on sensation seeking, however the effect varied significantly across participants (*SD* = .09). Average stress was positively associated with sensation seeking (*b* = .11). Every one unit increase in average stress was associate with a .11 unit increase in sensation seeking.

*Peer Presence*. Being in the presence of a peer was associated with increased state sensation seeking (*b* = .07). Participants were more likely to report higher sensation seeking relative to their own average when around friends, partners, roommates, or family members. This effect also varied significantly across participants (*SD* = .11), suggesting that how peers were associated with sensation seeking was different among participants.

**3.3.4. Lack of premeditation**

The final model estimated the mean level of lack of premeditation to be 1.82 (scale maximum of 4), although this estimate varied significantly across participants (*SD* = .52). 68% of participants had a mean between 1.30 and 2.34. Study day did not significantly predict premeditation. The effect of study day did vary across participants (*SD* = .04), and was thus

retained in subsequent models. The effect of study day ranged between -.04 and .04 for 68% of participants, suggesting that participants tended to both increase and decrease their report of premeditation across the study period. There were no significant interactions between study day and all predictors at $p < .01$, and thus none were retained in the final model.

*Covariates*. There was no evidence that age, gender, or ethnicity were associated with level of premeditation. Because they did not predict meaningful variance in the outcome and did not improve model fit, none were retained in subsequent models.

*Stimulation and Sedation*. There was no association between state stimulation or average stimulation and lack of premeditation. However, there was significant variance in the effect of state stimulation (*SD* = .05), suggesting that how feeling "up" or "excited" was associated with premeditation in the moment was different across participants.

State sedation was not associated with lack of premeditation, however, this effect varied across participants (*SD* = .05). Average sedation was associated with lack of premeditation (*b* = .16). Every one unit increase in average sedation was associated with a .16 increase in difficulty thinking carefully before acting or considering advantages and disadvantages before making up their mind.

*Stress*. State stress was positively associated with lack of premeditation (*b* = .05). In moments characterized by higher than average stress, participants also tended to report lower premeditation. This effect varied significantly across participants (*SD* = .10). There was no evidence for an association between average stress and premeditation.

*Peer presence*. Being around a partner, roommate, friend, or loved one was not associated with level of premeditation. However, this effect did vary significantly across participants (*SD* = .10).

### 3.3.5. Lack of perseverance

The grand mean of lack of perseverance across all participants was 1.74 (scale maximum of 4). This varied significantly (*SD* = .44) and ranged between 1.29 and 2.18 for 68% of participants. The average effect of study day was not associated with perseverance, although this also varied significantly across the sample (*SD* = .04). Participants tended to both increase and decrease their reports of perseverance over the study period. Interactions between study day and all predictors were not significant and thus not retained in the final model.

*Covariates*. There was no evidence that age, gender, and ethnicity were associated with lack of perseverance and did not improve model fit. As such, none were retained in the final model.

*Stimulation and Sedation*. State stimulation was negatively associated with lack of perseverance (*b* = -.01). In moments participants reported feeling more "excited" or "up" than their own average, they also reported an increased ease of concentration and the ability to finish what they started. Average stimulation was not associated with level of perseverance.

State sedation was positively associated with lack of perseverance (*b* = .02). When participants reported feeling more "sluggish" or having more "slow thoughts" relative to their own average, participants were also more likely to report giving up easily having greater difficulty concentrating. Average sedation was also associated with lack of perseverance (*b* = .11), suggesting that participants who reported more sedation across the entire study period were more likely to report lower perseverance on average.

*Stress*. State stress was also positively associated with lack of perseverance (*b* = .04). In moments characterized by higher than average stress, participants also tended to report lower perseverance. This effect varied significantly across participants (*SD* = .06), indicating that stress

and perseverance were associated differed among participants. Average stress predicted lack of perseverance (*b* = .11) Participants who reported less stress throughout the entire study period also reported less difficulty concentrating and being more likely to finish what they started.

*Peer presence*. Having a peer present was not associated with state level of perseverance. This effect did vary across participants (*SD* = .09), and ranged between -.11 and .08 for 68% of participants. This suggests that participants differed in whether or not a peer tended to increase or decrease their level of perseverance.

### 3.4. Aim 3: Mediation

#### 3.4.1. Predicting number of drinks consumed daily

As depicted in Figure 3, the number of drinks consumed each day was heavily zero-inflated. Participants reported consuming zero drinks on 627 days. The maximum number drinks consumed in one day was reported to be 11. Across all indicators (-2 LL, AIC, and BIC), the negative binomial distribution best fit the data and was used for subsequent models predicting number of drinks consumed each day.

*Covariates.* Weekend designation was significantly associated with the number of drinks consumed each day (*RR* = .54), such that weekdays were associated with a 46% decrease in drinking. Age was also negatively associated with number of drinks consumed each day (*RR* = .93). Every year increase in age was associated with a 7% decrease in daily drinks. Study day, ethnicity, and gender were not associated with number of drinks consumed each day.

*Contextual Factors Predicting Daily Impulsivity*. Daily sedation (*b* = .14) and daily stress (*b* = .13) were both associated with daily negative urgency. Every one unit increase in stress was associated with a .15 increase in negative urgency, while a one unit increase in sedation was

associated with a .13 increase in negative urgency. Daily stimulation was not associated with negative urgency.

A very similar pattern was found with positive urgency. Daily sedation ($b$ = .10) and daily stress ($b$ = .11) were both associated with daily positive urgency. Every one unit increase in stress was associated with a .10 increase in positive urgency, while every one unit increase in sedation was associated with a .11 increase. Daily stimulation was not associated with positive urgency.

Daily sensation seeking was predicted by daily stimulation ($b$ = .07) and daily stress ($b$ = .10). Every one unit increase in stimulation was associated with a .7 unit increase in sensation seeking. Every one unit increase in daily stress was associated with a .10 unit increase in sensation seeking. Daily sedation was not associated with sensation seeking.

The cognitive facets of impulsivity showed a similar trend to negative and positive urgency. Daily sedation and daily stress were both associated with daily lack of premeditation (sedation: $b$ = .12; stress: $b$ = .09) and daily lack of perseverance (sedation: $b$ = .13; stress: $b$ = .11). A one unit increase in sedation was associated with a .12 unit increase in lack of premeditation and a .13 increase in lack of perseverance. A one unit increase in stress was associated with a .9 unit increase in lack of premeditation and a .11 unit increase in lack of perseverance. Daily stimulation was not associated with lack of premeditation or lack of perseverance.

*Daily Impulsivity and Contextual Factors Predicting Daily Alcohol Use*. No facets of impulsivity were associated with number of drinks consumed daily. Daily sedation was associated with daily drinking ($RR$ = .82). Every one unit increase in sedation was associated with an 18% decrease in drinking. Daily stimulation was also associated with daily drinking ($RR$

= 1.13). Every one unit increase in stimulation was associated with a 13% increase in drinking. Daily stress was not associated with daily drinking. There were no significant indirect effects explaining the association between contextual factors and daily drinking.

### 3.4.2. Predicting whether any drinking occurred daily

Because daily drinks were so zero-inflated and limited in the variability in number of drinks consumed, I also replicated the mediated models testing a binary outcome of whether any drinking occurred on a given day or not during the ecological momentary assessment.

*Covariates*. Study day was associated decreased odds of drinking (*OR* = 1.04), suggesting that participants were more less likely to report any drinking on a given day as the study went on. Weekend designation was also associated with likelihood of drinking (*OR* = .66), such that participants were less likely to report consuming alcohol on a weekday. Age was also associated with likelihood of drinking (*OR* = .95). Older participants were more likely to report drinking during the study.

*Contextual Factors Predicting Daily Impulsivity.* The effects of contextual factors predicting daily impulsivity was very similar to the previous model. Daily sedation (*b* = .13) and daily stress (*b* = .13) were both associated with increased negative urgency. Days characterized by higher sedation and stress were also characterized by higher negative urgency. Stimulation was not associated with negative urgency.

The same trend was seen with positive urgency. Daily sedation (*b* = .10) and daily stress (*b* = .11) were both associated with increased positive urgency. On days participants reported feeling more “sluggish”, “having slow thoughts”, or stressed, they also reported higher levels of positive urgency. Stimulation was not associated with positive urgency.

Higher sensation seeking was predicted by stimulation ($b$ = .07) and stress ($b$ = .10). On days participants reported feeling more "up" and "excited", they also reported greater levels of sensation seeking. Similarly, on days characterized by higher stress participants also reported higher levels of sensation seeking. Sedation was not associated with sensation seeking.

Premeditation again showed the same pattern as negative and positive urgency. Daily sedation was associated with increased lack of premeditation ($b$ = .13). Daily stress was also associated with lack of premeditation ($b$ = .09). On days participants reported feeling more stress they also reported being less able to think carefully before acting or consider all the advantages and disadvantages.

Perseverance demonstrated an association with all contextual factors. Stimulation was negatively associated with lack of perseverance ($b$ = -.03). On days participants reported feeling "up" and "excited" they also reported feeling more able to see things through to the end or concentrate. Sedation ($b$ = .14) and stress ($b$ = .11) were also positively associated with lack of perseverance. On days when participants felt more stressed or more sedated, they also reported giving up more easily or having greater difficulty finishing what they started.

*Daily Impulsivity and Contextual Factors Predicting Daily Alcohol Use.* Of the contextual factors, only sedation was associated with the likelihood of drinking ($OR$ = .85). On days characterized by higher sedation participants were more likely to report drinking alcohol. There was no association between stimulation or stress and likelihood of drinking. Lack of premeditation was also associated with daily drinking ($OR$ = 1.32). On days participants reported greater difficulty considering advantages or disadvantages or thinking rationally or sensibly, they also reported a lower likelihood of drinking.

*Impulsivity as a Mediator.* Given that stress was positively associated with lack of premeditation, which was in turn associated with likelihood of drinking, I next tested the significance of the indirect effect to understand whether or not lack of premeditation served a mediator. As hypothesized, there was a significant indirect effect of stress on daily drinking, mediated by changes in lack of premeditation ($b$ = .035, *95% CI* [.004, .052]). Specifically, reporting greater stress was associated with lower premeditation, or the ability to think rationally, which surprisingly was associated with a lower likelihood of drinking that day.

There was also a significant indirect effect of sedation on likelihood of drinking, mediated by lack of premeditation ($b$ = .024, *95% CI* [.008, .068]). Specifically, days participants reported feeling more sluggish or having slow thoughts were characterized by lower premeditation, which also predicted a lower likelihood of drinking that day. No other significant indirect effects were found.

### 3.5. Aim 4: Moderation by heavy alcohol use and problems

#### 3.5.1. Negative urgency

To test whether or not participants who drank more heavily and experienced greater alcohol problems had stronger associations between contextual factors and state impulsivity, I included heavy alcohol use and alcohol problems as main predictors of impulsivity as well as cross level interactions with all contextual factors. Heavy alcohol use was not significantly associated with negative urgency ($b$ = -.10). Past year alcohol problems was associated with negative urgency ($b$ = .04). Consistent with previous findings, participants who reported more alcohol problems also reported higher average levels of negative urgency. As shown in Figure 6, there was a significant interaction between heavy alcohol use and state stimulation ($b$ = .02). While significantly different from each other, the simple slopes at the mean and ±1 *SD* of heavy

alcohol use were all not significant (-1 *SD*: $b$ = -.01, $p$ = .07; mean: $b$ = -.002, $p$ = .70; +1 *SD*: $b$ = .01, $p$ = .21). However, regions of significance test suggests that this effect was significant at lower levels of alcohol use (-1.34 *SD* and below) and very high levels of alcohol use (+3.45 *SD* and above). For participants who reported the least binge drinking and drunkenness (6% of the sample), experiencing higher than average stimulation, or feeling "up" or "excited" was associated with lower negative urgency. In contrast, participants who reported the highest levels of binge drinking and drunkenness reported greater negative urgency when also experiencing higher than average stimulation. Further examination of the data suggested that only one participant reported heavy alcohol use at or greater than 3.45 *SD*. As such, this effect does not represent data from the current sample. Findings are presented in Table 3.16.

### 3.5.2. Positive urgency

Heavy alcohol use as not associated with level of positive urgency ($b$ = -.09). Alcohol problems were positively associated with positive urgency ($b$ = .03). Participants who reported experiencing more alcohol problems in the past year also reported higher levels of positive urgency on average. There were no significant interactions between heavy alcohol use or alcohol problems and all contextual factors.

### 3.5.3. Sensation seeking

Neither heavy alcohol use ($b$ = -.15) nor alcohol problems ($b$ = .02) were associated with level of sensation seeking. There were also no significant interactions between either indicator of alcohol use and all contextual factors.

### 3.5.4. Lack of premeditation

There was no main effect of heavy alcohol use ($b$ = .03) or alcohol problems ($b$ = .01) on lack of premeditation. However, there was a significant interaction between heavy alcohol use

and state stress ($b$ = .03). The simple slope at -1 *SD* of heavy alcohol use was not significant ($b$ = .02, $p$ = .33). The simple slopes at the mean of heavy alcohol use ($b$ = .04, $p$ < .01) and at +1 *SD* of heavy alcohol use ($b$ = .07, $p$ < .01) were significant, however. For participants who reported lower levels of alcohol use, there was no association between state stress and state premeditation. For participants who reported average levels of heavy alcohol use, moments characterized by higher than average stress are associated with lower premeditation, or a worse ability to "follow a sensible approach", "think carefully", or "consider the advantages and disadvantages". For participants who reported the highest levels of alcohol use, this association was even stronger. Figure 7 depicts these results. Regions of significance tests suggested that the effect was significant below -32.89 *SD*, which is beyond any data included in the sample, and above -.58 *SD*, which is represented by 66% of the current sample.

**3.5.5. Lack of perseverance**

Neither heavy alcohol use ($b$ = -.04) nor alcohol problems ($b$ = .02) were associated with lack of perseverance. There was a significant interaction between state sedation and alcohol problems ($b$ = .003), as depicted in Figure 8. The simple slope at -1 *SD* of alcohol problems was not significant ($b$ = .002, $p$ = .78). The slopes at the mean ($b$ = .02, $p$ < .01) and +1 *SD* of alcohol problems were significant ($b$ = .03, $p$ < .01). For participants who reported lower levels of alcohol problems, there was no association between state sedation and lack of perseverance. For participants who reported an average number of alcohol problems, when they reported higher than average sedation, or feeling more "sluggish" or having more "slow thoughts", they also reported lower perseverance, or the ability to "concentrate" or "finish what they started". This association was even stronger for participants who reported the highest levels of alcohol problems. Regions of significance testing suggested that this effect was significant below -5.85

*SD* from the mean of alcohol problems, which was not represented in our data. The effect was also significant above -.35 *SD* of alcohol problems, which accounted for 57% of the current sample.

## Chapter 4: Discussion

Impulsivity represents an important risk factor for understanding harmful substance use and substance use disorders (Dick et al., 2010; Stautz & Cooper, 2013). Prior research has focused primarily on impulsivity as a trait and most commonly as a marker of risk. Emerging conceptualizations highlight that individuals vary in the degree to which they behave impulsively across time and situation, and understanding when and why individuals behave more or less impulsively than their average may help explain the mechanisms by which impulsivity confers risk for psychopathology (Fleeson, 2001; Mischel, Shoda, & Mendoza-Denton, 2002). Thus, the current study aimed to examine how variability in facets of impulsivity was related to baseline substance use, how contextual factors influence momentary impulsivity, whether changes in impulsivity explain variation in daily drinking behavior, and whether or not individual differences in reactivity to contextual factors characterizes participants who engage in riskier substance use.

### 4.1. Variability in facets of impulsivity

Given that very little research has explored within-person variability in impulsivity, the first aim of this study was to characterize individual deviations from mean levels of impulsivity. Results indicated that impulsivity does vary among individuals to different degrees, and participants demonstrated different ranges and levels of each facet. These findings are consistent with research that has shown trait measures are poor predictors of any single instance of behavior (Hartshorne & May, 1929; Sharma et al., 2013) and research that has specifically demonstrated that within-person variability in impulsivity exists (Tomko et al., 2013). Furthermore, this study demonstrated within-person variability across all facets of impulsivity, including negative and positive urgency, sensation seeking, lack of premeditation, and lack of perseverance. These

findings further support the need to understand why and when individuals deviate from their mean levels of trait-related behavior.

In characterizing within-person variability in impulsivity, this study also sought to explore how variability was associated with mental health outcomes and specifically alcohol use behaviors. Variability in cognitive facets of impulsivity emerged as an important predictor of past year drunkenness. Across all indicators of variability in lack of premeditation and lack of perseverance, greater variability predicted a greater report of past year drunkenness. This included LT-MSSD, corrected standard deviations, and standard deviations over and above mean levels. This trend was replicated, but to a much lesser degree, in predicting past year binge drinking. Standard deviation and corrected standard deviation of lack of perseverance predicted the likelihood of past year binge drinking, and LT-MSSD of lack of premeditation predicted the count of past year binge drinking. These findings are consistent with a prior theory suggesting that greater variability in trait-related behavior is indicative of greater susceptibility to environmental influences, and in turn at greater risk of psychopathology (Baird et al., 2006). Individuals who show less variability may be more driven by stable, internal values or beliefs. Being more variable, on the other hand, may indicate that peers, mood, stress, or other contextual factors have a stronger influence on behavior. Furthermore, for this sample of drinkers, a greater influence of the environment and contextual factors on facets of impulsivity specifically was shown to lead to increased alcohol use, and specifically drunkenness and binge drinking.

These findings may extend our understanding of the mechanisms by which personality shapes behavior. Person-environment transaction theory argues that traits, including impulsivity, influence behavior by leading individuals to 1) interpret and react to similar environments differently, 2) evoke distinct responses from the environment, and 3) select or create specific

environments (Caspi & Roberts, 2001; Settles et al., 2010). Being higher in trait impulsivity may lead individuals to seek out environments that provide opportunities for and reinforce drinking behavior and may lead individuals to experience greater reinforcement from the same environment. Variability in impulsivity may further exacerbate these effects, as individuals may experience an even stronger influence of environment on their behavior, and may represent an additional risk factor for substance use if the sought environment promotes drinking. Future research should explore how environmental selection and increased variability in impulsivity predict alcohol use and whether or not greater variability in additional trait-related behavior is associated with increased susceptibility to environmental influence and thus increased alcohol use.

Beyond these specific associations, there was little evidence to suggest that variability is an important predictor of substance use above and beyond trait levels. Although the standard deviation of all five facets of impulsivity did predict past year alcohol problems, this effect did not hold over and above mean levels of impulsivity. Given that variability can be mathematically dependent on mean levels and was found to be in this data (Baird et al., 2006), it may be that the predictive value of standard deviation only extends to the degree that it conveys information about someone's trait level. Furthermore, corrected standard deviations, which should account for this mathematical dependence, generally failed to show associations with alcohol use behaviors. Although the corrected standard deviation of sensation seeking was associated with past year alcohol problems, the number of tests run and lack of any other significant prediction by a corrected standard deviation suggest that this may be a spurious effect.

It may be that few associations were found because variability is more important in predicting *when* someone will engage in impulsive behavior as opposed to their overall level of

impulsive behavior or specifically alcohol use. Trait measures are generally very successful at predicting average behavior but are poor at predicting any single instance of behavior (Epstein, 1979). Within-person variability, on the other hand, may tell us more about a different aspect of behavior, such as how the likelihood of drinking varies in a given context or environment. However, all alcohol use outcomes used in these analyses were measuring average past year behavior.

It may also be that the differences in the predictive utility of variability in impulsivity stems from differences in the nature of the constructs. Negative and positive urgency are inherently conditional traits. They are defined as the degree to which a contextual factor, in this case mood, alters one's behavior. Sensation seeking, lack of premeditation, and lack of perseverance do not have a conditional element, rather, participants report on their average level of trait-related behavior across all contexts and situations. While conditional traits are promising in their potential to further our understanding of person by situation interactions, it's not yet clear what the implications of measuring them in traditional trait formats are. For example, while two participants may react in the same way to feeling upset, they may differ greatly in the frequency with which they feel upset and thus the frequency in which they engage in impulsive behavior. However, this aspect is not captured in the measure. Further research is needed to understand how the conditional nature of urgency may influence associations with other constructs, and whether disaggregating emotion from impulse in state measurement improves the measurement of urgency in the moment.

Two separate measures were calculated as indicators of variability: standard deviation and mean-squared successive difference. Beyond what uncorrected standard deviation may tell us about mean levels, it is not clear that either of these indicators of variability in impulsivity

provides more predictive utility in understanding alcohol use behaviors. Mean squared successive difference has the advantage of including information about temporal dependency (Jahng, Wood, & Trull, 2008). It has been argued that this is particularly important in ecological momentary assessment studies that measure variables, such as mood, where subsequent observations are not independent. Future research should explore to what degree temporal dependency is important to variability in impulsivity specifically, and whether or not being higher than your own average in facets of impulsivity in any given moment influences your level of that facet at a subsequent observation.

**4.2. Effect of contextual factors on momentary impulsivity**

The second aim of this study was to explore how stimulation, sedation, stress, and peers may influence momentary deviations from mean levels of impulsivity in real world contexts. As hypothesized, these contextual factors were associated with changes in state impulsivity. However, these associations and the direction of effect varied across different facets of impulsivity.

*Stress*. Stress showed the most associations, and predicted deviations in negative urgency, lack of premeditation, and lack of perseverance. Furthermore, momentary stress was consistently associated with greater impulsivity across all three facets. These findings are consistent with prior research demonstrating that stress was associated with increased risk taking and discounting of delayed rewards as well as decreased response inhibition (Krause-Utz et al., 2013; Lempert et al., 2012; Lighthall et al., 2009; Schepis, McFetridge, Chaplin, Sinha, & Krishnan-Sarin, 2011). That stress was specifically associated with the cognitive facets of impulsivity may also coincide with theories that the influence of stress is biologically mediated through the release of dopamine and cortisol (Gathmann et al., 2014; Pabst et al., 2013). Cortisol is believed

to impair prefrontal cortex and diminish cognitive control, which may be associated with the ability to think rationally, concentrate, or think carefully. The effects of stress may also be mediated by attempts at mood repair, which may explain increases in negative urgency (Reynolds, Schreiber, et al., 2013). Stress was not associated with momentary deviations in positive urgency and sensation seeking, which may be less associated with attempts at mood repair or shifts in cognitive control.

Previous research has also suggested that stress has differential effects depending on the degree of stress experienced, where moderate amounts may motivate participants and decrease impulsivity while very low and very high amounts of stress actually increase impulsivity (Schwabe et al., 2013). Stress was reported to be fairly low on average in the current study. On a scale of 1 (not at all) to 10 (extremely), participants reported an average level of stress since last assessment of 2.02, and no participants reported higher than a 7 on any occasion. Furthermore, 85% of all responses were a 3 or lower. It may be that stress was associated with increased impulsivity because only moderate to low levels of stress were experienced during the study period, and that higher levels of stress would actually be inhibiting. Future research may benefit from exploring a broader range of stress experiences.

*Stimulation and Sedation.* Momentary stimulation was associated with increased sensation seeking (more impulsivity) but decreased lack of perseverance (less impulsivity). These findings are difficult to connect to prior research on the effects of mood on impulsivity because very few studies have included arousal dimensions of mood. Some emotion theories suggest that both valence and arousal are important dimensions of mood and may have unique contributions to behavior (Russell, 1980). Stimulation is characterized by how “up”, “excited”, and “energized” an individual reported feeling, and may best map onto an arousal dimension.

This is in contrast to more commonly used measures of mood valence, that assess to what degree a participant may feel sad, mad, angry, scared or happy, for example (Watson, Clark, & Tellegen, 1988). Most prior studies have tested valence exclusively. The current finding that stimulation was associated with decreased lack of perseverance is consistent with one prior study suggesting that increased arousal predicted decreased discounting of delayed rewards, or less impulsivity (Weafer et al., 2013). It may be that increased stimulation provides an activating effect that improves cognitive functioning, allowing for increased perseverance, concentration, and the ability to finish what was started.

In contrast, greater stimulation also led to increased sensation seeking and thus greater impulsivity. This contradictory effect is consistent with the overall mixed picture of the effects of mood found in the literature, in which negative and positive moods have been shown to both increase and decrease impulsive behavior (Cyders et al., 2010; de Vries et al., 2008). It could be that increased stimulation provides the energy needed to pursue rewarding and exciting experiences, and thus a minimum amount of stimulation is necessary to feel any level of sensation seeking.

Momentary sedation, however, was only associated with lack of perseverance. Reporting more “slow thoughts” or feeling “sluggish” or “sedated” was associated with greater impulsivity, and specifically greater difficulty “concentrating” or “finishing what was started”. This effect is internally consistent, in that sedation has the opposite effect of stimulation on lack of perseverance. Similar to hypotheses about the effects stimulation, it may be that perseverance requires effort and individuals do not feel they have the resources needed to effectively persevere when sedated.

It is noteworthy that ratings of stimulation and sedation were not associated with the mood-based facets of impulsivity as might be expected. It may be that valence is more important than arousal in influencing negative and positive urgency. However, it is also possible that multiple negative emotions have disparate levels of arousal, and thus provide contradictory influences on negative urgency. For example, feeling sad and feeling angry are likely to have inconsistent stimulation and sedation ratings, and may thus differentially influence state negative urgency. However, both emotions may be averaged in someone's perception of whether or not they can control their emotions when upset. Future research should explore how valence dimensions of mood are associated with state deviations in impulsivity and whether or not specific emotion categories (such as sad vs. angry) are differentially associated with negative urgency, or acting on impulse when upset. Some emotion theory argues that discrete emotions have unique action urges (Linehan, 1993), and future research should explore how disaggregating all negative emotions influences the effect of mood on state impulsivity.

*Peers*. Being in the presence of peers was associated with increased sensation seeking and increased positive urgency. These findings are consistent with research that suggest being around peers can lead to increased risk taking and impulsive behavior (Gardner & Steinberg, 2005; Steinberg, 2008; Weigard et al., 2014). It is particularly noteworthy that this effect emerged in the current study, given the age of the sample. This effect has been shown to be strongest in adolescence, and declines in adults (Gardner & Steinberg, 2005). However, the effect of peers was able to be detected in the current sample of 21-36 year olds. It is also noteworthy that the effect of peers only emerged for sensation seeking and positive urgency and not negative urgency, lack of premeditation, or lack of perseverance. One possible explanation is that participants differentially sought out their peers when they were already experiencing higher

levels of positive urgency or sensation seeking, leading to this association. It may also be that peers influence emotion based facets of impulsivity to a greater degree than cognitive based facets.

The associations found across all contextual factors provide support for the hypothesis that individuals have consistent and stable reactions to situational features, and that these "if-then" associations may represent a characteristic of personality that explains behavior beyond simple mean levels of traits (Shoda & Mischel, 1996). It is also noteworthy that a significant random effect was found for almost all of the associations between contextual factors and state impulsivity. This suggests that while there was an association between stimulation, sedation, stress, and peers and state impulsivity, this association varied across participants. This further supports the theory that these associations are idiographic and may reliably predict behavior over time within an individual, although the associations may still differ between individuals (Mischel & Shoda, 1995).

Furthermore, the variance of these random effects suggested the slopes included both positive and negative values. This indicated that that some participants became more impulsive when stressed, stimulated, or sedated, while others became less impulsive. This may mean that relevant and important moderators were not included in these models. The cognitive affective processing system theorizes that these associations may depend on cognitive-affect units such as expectancies, beliefs, goals, values, or competencies (Mischel & Shoda, 1998). Future research should explore whether these cognitions serve as potential moderators that may explain for whom these associations are stronger and in what direction. It will also be important to understand which features are particularly relevant for each associations.

*Average effect of contextual factors*. The nature of the data also allowed for exploration of how average levels of stress, stimulation, and sedation were associated with impulsivity. Consistent with state associations, average stress was associated with greater average negative urgency, greater positive urgency, and greater lack of perseverance. Greater average stimulation was also associated with greater sensation seeking. These effects essentially duplicate and extend the associations found at the state level and provide further evidence that these contextual factors may influence impulsive behavior. Once again, participants who are more stressed may engage in more impulsive behavior on average in attempts at mood repair. The hypothesized shifts that stress can have on cognitive functioning, potentially mediated by cortisol, may also account for this association.

Several average effects emerged that were not seen in the state associations, however. Although there was little data to suggest that momentary sedation was associated with deviations from mean levels of impulsivity, reporting more sedation across the entire study period was predictive of greater impulsivity on average, including greater negative urgency, greater positive urgency, greater lack of premeditation, and greater lack of perseverance. Additionally, although state stress was not associated with sensation seeking, average stress was. That these findings emerged at the average but not state level may indicatethat these effects are bidirectional or may be caused by third variables that produce higher levels of both. Behaving impulsively may increases subsequent stress and negative emotions, as impulsive behavior often has negative consequences across multiple domains of functioning (Monahan, Steinberg, Cauffman, & Mulvey, 2009; White et al., 1994). In examining state associations, temporal precedence provided some evidence for the proposed direction of effect. However, this still fails to account for positive feedback loops in which negative mood contributes to increased impulsivity, which

in turn creates even greater negative mood. Furthermore, there is no temporal precedence when examining average associations. As such, future studies should explore potential bi-directional effects or potential third variables.

**4.3. Premeditation mediates the association between contextual factors and daily alcohol use**

The third aim of this study was to understand to what degree changes in state facets of impulsivity mediated the association between contextual factors and daily alcohol use. Prior research has found that mood and stress are both associated with daily alcohol use, intoxication, and alcohol related problems (Grzywacz & Almeida, 2008b; Park et al., 2004; Simons et al., 2005, 2014; Todd et al., 2009). Our findings partially replicated these associations. Daily sedation was associated with the likelihood of drinking as well as number of drinks consumed daily. Daily stimulation was also associated with the number of drinks consumed daily. These findings suggest that mood and arousal may be important determinates of daily drinking decisions and further support the argument that within-person variation is an important predictor of behavior.

As before, it is somewhat difficult to connect these findings using an arousal dimension of mood with research specifically testing valence dimensions of mood. Prior research found that higher anxiety, sadness, hostility, and overall negative affect was associated with increased drinking and intoxication (Rankin & Maggs, 2006; Simons et al., 2010). In the current study, stimulation predicted increased drinking, while sedation was associated with a decrease in drinking. As before, it may be that some level of stimulation or activation is required to be in settings or situations where there is easy opportunity or encouragement to drink, such as going to a bar or a restaurant or being around peers. Future research should seek to include valence

dimensions of mood as well as disaggregated emotional categories or dimensions in addition to arousal to further inform our understanding of this pathway. It may be that happiness, sadness, anger, anxiety, and fear would differentially influence daily drinking behavior. Some prior research has also found that variability in mood, and not level of mood, predicts daily drinking (Gottfredson & Hussong, 2013). Future research should extend this finding and explore whether or not variability in arousal dimensions of mood such as stimulation and sedation are associated with daily drinking.

In contrast to prior research, our results failed to find evidence of an association between daily stress and both likelihood of drinking as well as the number of drinks consumed. It may be that more nuanced measure of stress would have elucidated stronger associations, as some prior research has focused on interpersonal and work-related stress specifically, while the current study relied on a single item of undifferentiated stress (Armeli et al., 2007; Carney et al., 2000; Todd et al., 2009). It may also be that we failed to find this association because of the generally low levels of stress reported in the current study.

I hypothesized that stimulation, sedation, stress, and peers may influence state impulsivity, which in turn may be associated with daily alcohol use. This hypothesis was only partially supported. There were no significant indirect effects when predicting the number of drinks consumed daily across all facets of impulsivity. When predicting whether any drinking occurred, however, lack of premeditation emerged as significant mediator of the association between both stress and sedation and the likelihood of drinking on a given day. These findings suggest that participants may be more likely to drink on days that arousal and stress influence their level of premeditation. In other words, stress and arousal may be important determinates of

daily drinking behavior because they decrease one's ability to follow a rational approach, think carefully before doing anything, or consider advantages and disadvantages.

Null findings for the mediated effects through negative urgency, positive urgency, sensation seeking, and lack of perseverance may be due to the limited timeframe of the EMA period and subsequent low variability in alcohol use. Specifically, whether or not it was a weekend accounted for a lot of the variance in daily drinking behavior. While the study intentionally spanned two weekends to maximize likely drinking days, it may be that this time frame still does not include enough drinking days to fully capture how impulsivity contributes to variability in drinking behavior among Fridays and Saturdays, for example. Future studies seeking to examine variability in daily drinking behavior may benefit from sampling more weekend days.

Null findings may also be a result of the overall low levels of drinking that occurred in the study. In the current study participants reported drinking four or more drinks on only 7% of all days. However, not all alcohol use is impulsive. Rather, some alcohol consumption is quite intentional and planned. It may be that changes in state impulsivity are more related to breaking one's own drinking limits or drinking more than expected in a given day. Indeed, one prior study found that daily ratings of participants' efforts to regulate their mood, control their thoughts, dealt with stress, and felt overwhelmed predicted whether or not they violated their own drinking limits that day (Muraven, Collins, Shiffman, & Paty, 2005). It may be that the effect of state impulsivity would emerge among heavier drinking or in personal limit violations.

**4.4. Heavy alcohol use and problems as a moderator**

The fourth aim of this study was to explore whether or not participants who experience greater associations between contextual factors and state impulsivity are also characterized by

greater alcohol use and problems. This hypothesis was partially supported. There were three significant interactions between heavy alcohol use and problems and contextual factors in predicting state negative urgency, lack of premeditation, and lack of perseverance. These findings support the hypothesis that the degree to which individuals are influenced by context may be a risk factor for alcohol use and problems. This is consistent with prior research that has found that reactivity to stress and therapeutic intervention may be a marker for other psychopathology (Cohen et al., 2008, 2005). In the current study, participants who experienced more deviations from their mean level of impulsivity due to environment or prior experiences were also more susceptible to using alcohol at heavy or problematic levels. This provides specificity to the findings from aim 1, suggesting that not just variability, but specific associations between contextual factors and impulsivity may be associated with increase alcohol use.

One theory to explain the association between susceptibility to stress or negative mood and alcohol use suggests that impulsive behavior in response to these contexts may be associated with ineffective coping strategies (Berg et al., 2015). When an individual is upset and does not have skills for reducing negative feelings, they may turn to distraction or extreme attempts at eliciting a contrasting emotion, which in turn can lead to impulsive action and specifically alcohol use. Participants who have effective coping skills, in contrast, are able to regulate their responses to environmental stimuli without leading to impulsive behavior. However, further research is needed to clarify these mechanisms, and should explore how coping styles and choice may predict who has greater changes in impulsivity in response to contextual factors.

Consistent with prior research, heavy alcohol use and problems were not consistently associated with all facets of impulsivity. In this study, alcohol problems were associated with

negative and positive urgency. Similarly, a prior meta-analysis also found that negative and positive urgency were the strongest predictors of problematic alcohol consumption (Coskunpinar et al., 2013; Cyders & Smith, 2007; Stautz & Cooper, 2013). Interestingly, this study found that heavy alcohol use was only associated with negative urgency and lack of premeditation, and these associations emerged only at certain levels of state stress and stimulation. Heavy alcohol use was not associated with any other facet of impulsivity. Conversely, prior research has found that all facets of impulsivity have a moderate association with drinking quantity and frequency, and lack of perseverance is even more strongly associated with drinking frequency (Coskunpinar et al., 2013). The heavy alcohol use measure included in this study was a composite of both quantity and frequency, and combining these indicators into one composite may explain why different and fewer associations emerged here.

The difference between averaging ecological momentary assessments and baseline trait measures may also explain differences between the findings of this study and prior research. In this study, correlations between baseline assessments and EMA averages for the five facets of impulsivity ranged between .34 and .67, clearly demonstrating that while these measures overlap, they are also capture something unique (see table 3.1). Given that most trait measures ask participants to reflect on a much broader timeframe or how they are in general, it may be that a longer time frame is needed to sufficiently capture the range of trait-related behavior that would correspond to a participant's report. It may also be that participants are biased in their self-perception of their own trait-related behavior or vary in how they interpret the questions, and these methods of measuring impulsivity would never fully overlap regardless of time frame. Future research using EMA should continue to explore these possibilities.

### 4.5. Clinical Implications

There are several important clinical implications from these findings. First, evidence that state impulsivity partially mediates the association between contextual factors and likelihood of drinking provides an additional target of intervention and suggests that strategies aimed at impulsivity specifically may be relevant to drinking reduction efforts. Shaping the environment to limit access (Steinberg, 2008) and mindfulness-based interventions (Barnert, Himelstein, Herbert, Garcia-Romeu, & Chamberlain, 2013; Bögels, Hoogstad, van Dun, de Schutter, & Restifo, 2008) are two interventions that may be efficacious in this regard and should continue to be explored in research.

Our findings also support the use of the cognitive affect processing model to explore idiographic associations that may explain who becomes more impulsive in response to specific situations or contextual factors. Our findings suggest that although stimulation, sedation, stress, and peers have an average effect on state impulsivity, this effect varies widely and often in opposite directions. Research has found that tracking and integrating unique "if-then" behavioral associations can increase clinical efficacy (Shoda, Wilson, Chen, Gilmore, & Smith, 2013). Understanding these stable within-person contingencies may help shape interventions targeted at reducing impulsive behavior by identifying and managing unique and idiographic antecedents and associations.

### 4.6. Limitations

This study has several limitations that should be acknowledged. First, it is important to understand how the sample used may influence the current findings. In order to be eligible for this study, participants had to endorse at least some drinking in the past month. There were also no participants who reported abstaining from all alcohol use during the study period. As such, it

is not clear if the current findings would generalize to non-drinkers. Furthermore, it may be that recruiting only participants who endorse some alcohol use leads to a restricted range of other variables. Given the strong association between trait impulsivity and alcohol use (Dick et al., 2010), it may be that a sample including participants who endorse a broader range of alcohol use would also report a broader range of both trait and state impulsivity. It is possible that a restricted range of any study variable may contribute to attenuated associations and provide an underestimate of actual effects.

The sample may also influence current findings given the lack of gender variability and age range captured. The sample was 92% male, and this may explain why additional gender effects were not found. As previously discussed, specific hypotheses about the effects of peers on state impulsivity are age dependent, with effects peaking in adolescence, declining in early adulthood, and having no effect in later adulthood (Smith, Steinberg, Strang, & Chein, 2015). It may be that a younger sample would demonstrate more robust effects of peer presence on state impulsivity.

This study is further limited by the timing of assessments. Even with as many as six assessments each day, it is not clear that timeframe of the proposed mechanisms was appropriately captured. It is feasible that mood, stress, peer presence, or state impulsivity fluctuates within a two-hour span, and would thus not be captured in the current design. It would also be beneficial to capture to these variables over a longer timeframe including more weekend days. However, this needs to be balanced with the burden on participants, as length of time in the study was seen to predict some responses.

Finally, the current study is limited in its conclusions because it only tested effects in the hypothesized direction. It is also plausible that engaging in impulsive behavior leads to increased

stress and negative emotion. Although many of the effects tested in the current study had temporal precedence, effects that were averaged across the entire day are the most confounded by this limitation. Future studies should explore the bi-directionality of this effect.

**4.7. Strengths**

This study also had many strengths. This is one of very few studies to examine within person variability in trait-related behavior and specifically impulsivity using ecological momentary assessment. Few studies are able to examine these processes beyond survey measures and assumed average levels. Furthermore, this is the one of the first studies to expand the literature examining the role of mood, peers, and stress on impulsive responding to real world contexts and across multiple trials within the same participant. Toward this end, this study also utilized multilevel modeling to fully take advantage of the data provided by an ecological momentary assessment study.

Second, this study also advances the literature on how contextual factors influence impulsive behavior by using a novel measure of state impulsivity. As previously highlighted, impulsivity is not a unitary construct and instead represents a range of lower order traits that are only moderately correlated (Whiteside & Lynam, 2001). This study was able to extend factor analytic work identifying five facets of trait impulsivity to momentary measures, allowing examination of the differential effects of contextual factors on these facets.

Third, while previous literature often collapses across substance use outcomes, this study examined past year consequences, frequency of drunkenness, and frequency of binge drinking as unique outcomes. Previous research has raised concern about the practice of combining indicators, especially quantity and frequency of alcohol use (McGinley & Curran, 2014), which was thus avoided.

### 4.8. Conclusions

This study is one of the first to use ecological momentary assessment to explore how contextual factors influence within-person variability in facets of impulsivity and how this relates to substance use behavior. This study provided strong evidence for the importance of considering within-person variability in trait-related behavior and situational factors that demonstrate consistent deviations from mean levels of behaviors. Specifically, within-person variability provides two important contributions to our understanding of the association between impulsivity and substance use. First, within-person variability may provide additional information in identifying *who* is at greatest risk of developing problematic or harmful levels of substance use. Demonstrating more variability may be an additional marker of risk. Furthermore, this prediction may be improved by including information about stable, within-person associations between contextual factors and deviations in impulsivity that characterize heavy alcohol users. Second, exploring within-person variation in impulsivity may provide additional information about *when* individuals are most likely to engage in alcohol use and what factors are associated with increased likelihood of use. Together, these contributions have important implications for understanding how impulsivity confers risk for substance use and problems and may inform intervention efforts. Continuing to explore the factors that increase the likelihood of impulsive behavior and problematic substance abuse will be an important avenue to further understand how impulsivity contributes to psychopathology.

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## Tables

Table 2.1. Means and standard deviations of study variables.

| | *Ecological Momentary Assessment* | | *Daily Averages* | | *Baseline* | |
|---|---|---|---|---|---|---|
| *Variable* | Mean | SD | Mean | SD | Mean | SD |
| Negative Urgency | 1.52 | 0.68 | 1.54 | 0.63 | 2.15 | 0.68 |
| Positive Urgency | 1.41 | 0.62 | 1.43 | 0.59 | 1.83 | 0.67 |
| Premeditation | 1.80 | 0.72 | 1.83 | 0.67 | 1.96 | 0.56 |
| Perseverance | 1.72 | 0.64 | 1.74 | 0.59 | 1.92 | 0.56 |
| Sensation Seeking | 1.74 | 0.71 | 1.77 | 0.68 | 2.91 | 0.55 |
| Sedation | 2.46 | 1.68 | 2.46 | 1.45 | -- | -- |
| Stimulation | 4.63 | 2.00 | 4.65 | 1.76 | -- | -- |
| Peer Presence | 0.36 | 0.48 | 0.36 | 0.36 | -- | -- |
| Stress | 2.02 | 1.42 | 2.07 | 1.28 | -- | -- |
| Alcohol Use | -- | -- | 0.84 | 1.57 | 26.93 | 17.80 |
| Alcohol Problems | -- | -- | -- | -- | 20.09 | 18.61 |

Table 2.2. Bivariate correlations between facets of impulsivity, contextual factors, and alcohol use and consequences.

| *Average Levels Across Assessments* | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Negative Urgency | **0.94** | **0.64** | **0.58** | **0.66** | 0.04 | **0.49** | 0.00 | **0.45** | **0.09** | **0.32** |
| 2. Positive Urgency | | **0.65** | **0.47** | **0.57** | **0.07** | **0.39** | 0.00 | **0.40** | **0.09** | **0.26** |
| 3. Sensation Seeking | | | **0.28** | **0.31** | **0.22** | **0.24** | **0.19** | **0.32** | **-0.08** | **0.10** |
| 4. Premeditation | | | | **0.89** | 0.00 | **0.42** | **-0.18** | **0.30** | **0.19** | **0.22** |
| 5. Perseverance | | | | | **-0.05** | **0.48** | **-0.12** | **0.38** | **0.13** | **0.24** |
| 6. Stimulation | | | | | | **0.14** | **0.24** | **0.07** | **-0.17** | -0.05 |
| 7. Sedation | | | | | | | 0.04 | **0.40** | **0.07** | **0.23** |
| 8. Peer Presence | | | | | | | | 0.02 | **-0.06** | **0.07** |
| 9. Stress | | | | | | | | | 0.03 | **0.22** |
| 10. Alcohol Use | | | | | | | | | | **0.53** |
| 11. Alcohol Problems | | | | | | | | | | |

| *Ecological Momentary Assessments* | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. |
|---|---|---|---|---|---|---|---|---|---|
| 1. Negative Urgency | **0.83** | **0.54** | **0.42** | **0.50** | 0.01 | **0.31** | 0.02 | **0.34** | 0.01 |
| 2. Positive Urgency | | **0.56** | **0.37** | **0.44** | **0.05** | **0.26** | 0.02 | **0.28** | -0.02 |
| 3. Sensation Seeking | | | **0.19** | **0.18** | **0.19** | **0.10** | **0.11** | **0.19** | 0.00 |
| 4. Premeditation | | | | **0.76** | -0.02 | **0.27** | **-0.04** | **0.19** | **0.05** |
| 5. Perseverance | | | | | **-0.08** | **0.34** | **-0.04** | **0.26** | 0.02 |
| 6. Stimulation | | | | | | **-0.10** | **0.14** | 0.01 | **0.09** |
| 7. Sedation | | | | | | | **0.04** | **0.21** | **-0.05** |
| 8. Peer Presence | | | | | | | | -0.02 | **0.11** |
| 9. Stress | | | | | | | | | -0.01 |
| 10. Alcohol Use | | | | | | | | | |

*Note.* Correlations significant at $p < .05$ are indicated in **bold.**

Table 2.3. -2 Log likelihood, AIC, and BIC values for distributions modeling past year binge drinking, drunkenness, and alcohol consequences.

| | Gaussian | Poisson | Zero-Inflated Poisson | Negative Binomial | Zero-Inflated Negative Binomial | Negative Binomial Hurdle |
|---|---|---|---|---|---|---|
| *Alcohol Consequences* | | | | | | |
| Log Likelihood | -446.674 | -559.585 | -448.300 | **-379.237** | -371.786 | -371.395 |
| AIC | 903.349 | 1127.171 | 912.600 | **768.546** | 761.573 | 760.790 |
| BIC | 918.369 | 1139.186 | 936.631 | **783.565** | 788.608 | 787.825 |
| *Past Year Binge Drinking* | | | | | | |
| Log Likelihood | -350.524 | -365.785 | -329.231 | -335.790 | **-325.055** | -325.660 |
| AIC | 711.047 | 739.570 | 674.462 | 681.581 | **668.111** | 669.319 |
| BIC | 726.067 | 751.585 | 698.493 | 696.600 | **695.146** | 696.355 |
| *Past Year Drunkenness* | | | | | | |
| Log Likelihood | -342.039 | -346.585 | -322.162 | **-314.801** | -309.232 | -308.639 |
| AIC | 694.078 | 701.171 | 660.324 | **639.602** | 636.463 | 635.278 |
| BIC | 709.098 | 713.186 | 684.356 | **654.622** | 663.499 | 662.314 |

*Note.* Values in **bold** indicate models selected for each outcome. AIC = Akaike Information Criteria. BIC = Bayesian Information Criteria. There was an error estimating the zero-inflated negative binomial model for past year drunkenness, which was thus not considered for the final model.

Table 2.4. -2 Log likelihood, AIC, and BIC values for distributions modeling daily alcohol use.

| | Gaussian | Poisson | Zero-Inflated Poisson | Negative Binomial | Zero-Inflated Negative Binomial | Negative Binomial Hurdle |
|---|---|---|---|---|---|---|
| *Daily Alcohol Use* | | | | | | |
| Log Likelihood | -1842.09 | -1474.72 | -1271.549 | **-1203.914** | -1203.914 | -1205.029 |
| AIC | 3694.181 | 2957.439 | 2553.098 | **2417.829** | 2419.829 | 2422.057 |
| BIC | 3718.664 | 2977.026 | 2577.582 | **2442.312** | 2449.209 | 2451.381 |

*Note.* Values in **bold** indicate models selected for the outcome. AIC = Akaike Information Criteria. BIC = Bayesian Information Criteria. There was an error estimating the zero-inflated negative binomial model for daily alcohol use, which was thus not considered for the final model.

Table 3.1. Bivariate correlations between baseline measures, average EMA levels and total standard deviations of facets of impulsivity and alcohol use and consequences.

| | | *Negative Urgency* | | *Positive Urgency* | | | *Sensation Seeking* | | | *Premeditation* | | | *Perseverance* | | | *Alc. Use* | *Alc. Prob.* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | EMA | SD | Base | EMA | SD | Base | EMA | SD | Base | EMA | SD | Base | EMA | SD | | |
| Negative Urgency | Baseline | **.605** | **.452** | **.757** | **.478** | **.379** | .051 | **.343** | **.186** | **.507** | **.455** | **.189** | **.611** | **.489** | **.268** | .039 | **.322** |
| | EMA | | **.602** | **.704** | **.935** | **.618** | -.007 | **.642** | **.343** | **.457** | **.583** | **.217** | **.568** | **.664** | **.243** | .094 | **.320** |
| | SD | | | **.412** | **.477** | **.863** | -.136 | **.334** | **.724** | **.233** | **.568** | **.549** | **.424** | **.594** | **.557** | -.004 | **.235** |
| Positive Urgency | Baseline | | | | **.665** | **.456** | .036 | **.505** | **.214** | **.472** | **.427** | .142 | **.512** | **.444** | .149 | .035 | **.234** |
| | EMA | | | | | **.576** | -.006 | **.651** | **.268** | **.381** | **.468** | .146 | **.423** | **.572** | .123 | .092 | **.259** |
| | SD | | | | | | -.115 | **.439** | **.708** | **.232** | **.529** | **.523** | **.359** | **.558** | **.494** | -.010 | **.188** |
| Sensation Seeking | Baseline | | | | | | | **.343** | .098 | .028 | -.092 | -.145 | **-.217** | -.147 | .018 | .028 | .025 |
| | EMA | | | | | | | | **.364** | **.292** | **.280** | -.045 | **.256** | **.309** | .074 | -.080 | .101 |
| | SD | | | | | | | | | .153 | **.395** | **.483** | **.239** | **.375** | **.475** | -.040 | .144 |
| Premed. | Baseline | | | | | | | | | | **.536** | .138 | **.599** | **.455** | .146 | .093 | **.261** |
| | EMA | | | | | | | | | | | **.467** | **.508** | **.894** | **.472** | **.193** | **.217** |
| | SD | | | | | | | | | | | | **.168** | **.390** | **.761** | **.208** | **.162** |
| Pers. | Baseline | | | | | | | | | | | | | **.613** | **.244** | -.042 | **.265** |
| | EMA | | | | | | | | | | | | | | **.442** | .130 | **.240** |
| | SD | | | | | | | | | | | | | | | **.282** | **.200** |

*Note.* Correlations significant at $p < .05$ are indicated in **bold**. Grey highlights indicate correlations between baseline measures and average EMA levels for each facet of impulsivity. *EMA* = Average level across all ecological momentary assessments during the study period. *SD* = total standard deviation across all ecological momentary assessments during the study period. *Alc. Use* = Alcohol use. *Alc. Prob.* = Alcohol problems.

Table 3.2. Intraclass correlations for momentary measures of facets of impulsivity.

| Construct | Residual | Intercept | Total Variance | ICC |
|---|---|---|---|---|
| Negative Urgency | 0.142 | 0.324 | 0.466 | 0.696 |
| Positive Urgency | 0.094 | 0.293 | 0.387 | 0.756 |
| Sensation Seeking | 0.138 | 0.398 | 0.536 | 0.742 |
| Premeditation | 0.178 | 0.383 | 0.562 | 0.683 |
| Perseverance | 0.178 | 0.383 | 0.562 | 0.683 |

Table 3.3. Means and standard deviations of indicators of variability.

| | Daily Standard Deviation | | Total Standard Deviation | | ST-MSSD | | LT-MSSD | |
|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Negative Urgency | 0.22 | 0.26 | 0.32 | 0.23 | 0.18 | 0.38 | 0.12 | 0.27 |
| Positive Urgency | 0.16 | 0.22 | 0.25 | 0.22 | 0.12 | 0.27 | 0.10 | 0.25 |
| Sensation Seeking | 0.23 | 0.23 | 0.33 | 0.20 | 0.17 | 0.33 | 0.12 | 0.24 |
| Premeditation | 0.27 | 0.29 | 0.38 | 0.23 | 0.28 | 0.56 | 0.13 | 0.25 |
| Perseverance | 0.24 | 0.23 | 0.34 | 0.16 | 0.21 | 0.34 | 0.10 | 0.16 |

Table 3.4. Bivariate correlations between measures of variability.

| *Variable* | Daily SD & Total SD | ST-MSSD & LT-MSSD | Daily SD & ST-MSSD | Total SD & LT-MSSD |
|---|---|---|---|---|
| Negative Urgency | 0.62 | 0.23 | 0.78 | 0.71 |
| Positive Urgency | 0.59 | 0.23 | 0.81 | 0.75 |
| Sensation Seeking | 0.55 | 0.21 | 0.76 | 0.75 |
| Premeditation | 0.55 | 0.28 | 0.79 | 0.76 |
| Perseverance | 0.54 | 0.30 | 0.80 | 0.71 |

*Note.* All correlations were significant at $p < .05$.

Table 3.5. Models predicting past year alcohol problems from indicators of variability in facets of impulsivity.

| | **Negative Urgency** | | | | **Positive Urgency** | | | |
|---|---|---|---|---|---|---|---|---|
| | *b* | *SE* | *RR* | *95% CI* | *b* | *SE* | *RR* | *95% CI* |
| Total SD | **1.06** | **0.37** | **2.90** | **[1.40, 6.01]** | **1.02** | **0.38** | **2.78** | **[1.33, 5.83]** |
| Total SD (w/Mean) | 0.46 | 0.47 | 1.58 | [0.62, 3.99] | 0.52 | 0.46 | 1.68 | [0.68, 4.15] |
| Corrected SD | 0.74 | 0.52 | 2.10 | [0.76, 5.82] | 0.63 | 0.52 | 1.88 | [0.68, 5.22] |
| LT-MSSD | 0.44 | 0.42 | 1.55 | [0.68, 3.51] | 0.54 | 0.26 | 1.72 | [0.68, 4.34] |

| | **Sensation Seeking** | | | | **Lack of Premeditation** | | | |
|---|---|---|---|---|---|---|---|---|
| | *b* | *SE* | *RR* | *95% CI* | *b* | *SE* | *RR* | *95% CI* |
| Total SD | **0.85** | **0.42** | **2.35** | **[1.03, 5.36]** | 0.75 | 0.40 | 2.12 | [0.97, 4.62] |
| Total SD (w/Mean) | 0.91 | 0.47 | 2.48 | [0.99, 6.23] | 0.34 | 0.40 | 1.41 | [0.65, 3.06] |
| Corrected SD | **1.00** | **0.51** | **2.73** | **[1.01, 7.40]** | 0.24 | 0.44 | 1.27 | [0.54, 2.98] |
| LT-MSSD | 0.44 | 0.40 | 1.55 | [0.70, 3.40] | 0.40 | 0.39 | 1.49 | [0.70, 3.17] |

| | **Lack of Perseverance** | | | |
|---|---|---|---|---|
| | *b* | *SE* | *RR* | *95% CI* |
| Total SD | **1.27** | **0.55** | **3.57** | **[1.21, 10.58]** |
| Total SD (w/Mean) | 0.68 | 0.56 | 1.98 | [0.66, 5.97] |
| Corrected SD | 0.71 | 0.59 | 2.04 | [0.64, 6.46] |
| LT-MSSD | 0.87 | 0.60 | 2.38 | [0.73, 7.72] |

*Note.* SD = standard deviation. Coefficients significant at $p < .05$ are indicated in **bold**. Models included age, gender, and ethnicity as covariates. Models were run separately for each facet of impulsivity and each indicator of variability. Past year alcohol problems was modeled as a negative binomial distribution.

Table 3.6. Models predicting past year drunkenness from indicators of variability in impulsivity.

| | **Negative Urgency** | | | | **Positive Urgency** | | | |
|---|---|---|---|---|---|---|---|---|
| | *b* | *SE* | *RR* | *95% CI* | *b* | *SE* | *RR* | *95% CI* |
| Total SD | 0.29 | 0.35 | 1.33 | [0.67, 2.65] | 0.11 | 0.39 | 1.12 | [0.53, 2.38] |
| Total SD (w/Mean) | 0.39 | 0.43 | 1.47 | [0.63, 3.42] | 0.18 | 0.47 | 1.20 | [0.48, 2.97] |
| Corrected SD | 0.40 | 0.47 | 1.48 | [0.69, 4.93] | 0.15 | 0.49 | 1.17 | [0.45, 3.02] |
| LT-MSSD | 0.22 | 0.37 | 1.25 | [0.60, 2.58] | 0.06 | 0.41 | 1.06 | [0.47, 2.38] |

| | **Sensation Seeking** | | | | **Lack of Premeditation** | | | |
|---|---|---|---|---|---|---|---|---|
| | *b* | *SE* | *RR* | *95% CI* | *b* | *SE* | *RR* | *95% CI* |
| Total SD | 0.26 | 0.41 | 1.29 | [0.58, 2.90] | **1.08** | **0.27** | **2.95** | **[1.75, 4.98]** |
| Total SD (w/Mean) | 0.58 | 0.40 | 1.79 | [0.82, 3.92] | **0.93** | **0.29** | **2.54** | **[1.45, 4.45]** |
| Corrected SD | 0.64 | 0.39 | 1.90 | [0.88, 4.12] | **0.83** | **0.35** | **2.30** | **[1.16, 4.56]** |
| LT-MSSD | 0.16 | 0.40 | 1.17 | [0.54, 2.54] | **0.55** | **0.24** | **1.73** | **[1.09, 2.76]** |

| | **Lack of Perseverance** | | | |
|---|---|---|---|---|
| | *b* | *SE* | *RR* | *95% CI* |
| Total SD | **1.71** | **0.40** | **5.54** | **[2.51, 12.23]** |
| Total SD (w/Mean) | **1.73** | **0.41** | **5.62** | **[2.51, 12.58]** |
| Corrected SD | **1.76** | **0.43** | **5.79** | **[2.51, 13.34]** |
| LT-MSSD | **1.10** | **0.55** | **3.01** | **[1.02, 8.86]** |

*Note.* SD = standard deviation. Coefficients significant at $p < .05$ are indicated in **bold**. Models were run separately for each facet of impulsivity and each indicator of variability. All models included age, gender, and ethnicity as covariates. Past year drunkenness was modeled as a negative binomial distribution.

Table 3.7. Models predicting past year binge drinking from indicators of variability in facets of impulsivity.

| | **Likelihood** | | | | **Binge Drinking Count** | | | |
|---|---|---|---|---|---|---|---|---|
| | *b* | *SE* | *OR* | *95% CI* | *b* | *SE* | *RR* | *95% CI* |
| *Negative Urgency* | | | | | | | | |
| Total SD | -1.21 | 1.55 | 0.30 | [0.01, 6.28] | 0.13 | 0.29 | 1.14 | [0.65, 1.99] |
| Total SD (w/Mean) | -0.58 | 1.70 | 0.56 | [0.02, 15.85] | 0.11 | 0.34 | 1.11 | [0.57, 2.15] |
| Corrected SD | -0.90 | 2.03 | 0.41 | [0.01, 21.67] | 0.23 | 0.38 | 1.25 | [0.59, 2.65] |
| LT-MSSD | -0.13 | 0.95 | 0.88 | [0.14, 5.69] | 0.11 | 0.28 | 1.11 | [0.65, 1.91] |
| *Positive Urgency* | | | | | | | | |
| Total SD | -0.90 | 1.65 | 0.41 | [0.02, 10.38] | 0.04 | 0.30 | 1.04 | [0.57, 1.88] |
| Total SD (w/Mean) | -0.31 | 1.90 | 0.73 | [0.02, 30.6] | -0.04 | 0.37 | 0.96 | [0.47, 1.96] |
| Corrected SD | -0.72 | 2.05 | 0.49 | [0.01, 26.9] | 0.05 | 0.37 | 1.05 | [0.51, 2.19] |
| LT-MSSD | 0.51 | 1.03 | 1.67 | [0.22, 12.53] | 0.11 | 0.30 | 1.11 | [0.62, 2.00] |
| *Sensation Seeking* | | | | | | | | |
| Total SD | 0.27 | 3.74 | 1.31 | [0, 2010.22] | 0.21 | 0.49 | 1.24 | [0.48, 3.20] |
| Total SD (w/Mean) | -0.11 | 1.98 | 0.89 | [0.02, 43.08] | 0.32 | 0.32 | 1.37 | [0.74, 2.55] |
| Corrected SD | -1.09 | 2.28 | 0.34 | [0.00, 29.28] | 0.30 | 0.34 | 1.36 | [0.69, 2.65] |
| LT-MSSD | 0.29 | 0.85 | 1.33 | [0.25, 7.07] | 0.09 | 0.26 | 1.10 | [0.66, 1.82] |
| *Lack of Premeditation* | | | | | | | | |
| Total SD | -3.41 | 0.07 | 0.03 | [0.00, 1.3] | **0.47** | **0.21** | **1.59** | **[1.07, 2.38]** |
| Total SD (w/Mean) | -3.15 | 2.00 | 0.04 | [0.00, 2.16] | 0.33 | 0.24 | 1.40 | [0.88, 2.22] |
| Corrected SD | -2.83 | 1.75 | 0.06 | [0.00, 1.81] | 0.30 | 0.26 | 1.35 | [0.81, 2.26] |
| LT-MSSD | -0.61 | 1.19 | 0.54 | [0.05, 5.55] | **0.35** | **0.14** | **1.42** | **[1.09, 1.85]** |
| *Lack of Perseverance* | | | | | | | | |
| Total SD | **-5.22** | **1.94** | **0.01** | **[0.00, 0.24]** | **0.66** | **0.31** | **1.94** | **[1.05, 3.58]** |
| Total SD (w/Mean) | **-5.38** | **2.26** | **0.00** | **[0.00, 0.38]** | 0.58 | 0.32 | 1.78 | [0.95, 3.35] |
| Corrected SD | **-4.79** | **1.94** | **0.01** | **[0.00, 0.37]** | 0.58 | 0.33 | 1.79 | [0.94, 3.42] |
| LT-MSSD | -2.39 | 2.92 | 0.09 | [0.00, 28.13] | 0.48 | 0.35 | 1.62 | [0.82, 3.21] |

*Note.* SD = standard deviation. Coefficients significant at $p < .05$ are indicated in **bold**. Models included age, gender, and ethnicity as covariates. Models were run separately for each facet of impulsivity and each indicator of variability. Binge drinking was modeled as a zero-inflated negative binomial distribution.

Table 3.8. Effects of stimulation, sedation, stress, and peer presence on state levels of negative urgency.

| | *Fixed Effects* | | | *Random Effects* | | |
|---|---|---|---|---|---|---|
| | ***Estimate*** | ***SE*** | ***95% CI*** | ***Estimate*** | ***SE*** | ***95% CI*** |
| Intercept | **1.96** | **0.30** | **[1.36, 2.55]** | **0.23** | **0.03** | **[0.17, 0.29]** |
| Study day | 0.00 | 0.00 | [-0.00, 0.00] | **0.001** | **0.000** | **[0.001, 0.002]** |
| Age | -0.02 | 0.01 | [-0.03, 0.00] | | | |
| Stimulation | | | | | | |
| *State* | 0.00 | 0.01 | [-0.01, 0.00] | **0.001** | **0.000** | **[0.001, 0.002]** |
| *Average* | -0.03 | 0.02 | [-0.08, 0.01] | | | |
| Sedation | | | | | | |
| *State* | -0.01 | 0.01 | [-0.01, 0.00] | **0.001** | **0.000** | **[0.00, 0.001]** |
| *Average* | **0.16** | **0.03** | **[0.09, 0.21]** | | | |
| Stress | | | | | | |
| *State* | **0.06** | **0.01** | **[0.04, 0.08]** | **0.010** | **0.002** | **[0.007, 0.01]** |
| *Average* | **0.17** | **0.04** | **[0.09, 0.23]** | | | |
| Peer Presence | | | | | | |
| *State* | 0.02 | 0.02 | [-0.01, 0.04] | **0.011** | **0.004** | **[0.005, 0.02]** |

*Note*. Coefficients in bold are significant at $p < .05$.

Table 3.9. Effects of stimulation, sedation, stress, and peer presence on state levels of positive urgency.

| | *Fixed Effects* | | | *Random Effects* | | |
|---|---|---|---|---|---|---|
| | ***Estimate*** | ***SE*** | ***95% CI*** | ***Estimate*** | ***SE*** | ***95% CI*** |
| Intercept | **1.43** | **0.05** | **[1.34, 1.52]** | **0.311** | **0.001** | **[0.242, 0.398]** |
| Study day | 0.00 | 0.00 | [-0.01, 0] | **0.002** | **0.003** | **[0.001, 0.002]** |
| Stimulation | | | | | | |
| *State* | 0.00 | 0.00 | [-0.01, 0.01] | **0.001** | **0.000** | **[0.000, 0.002]** |
| *Average* | 0.01 | 0.03 | [-0.05, 0.06] | | | |
| Sedation | | | | | | |
| *State* | -0.01 | 0.00 | [-0.01, 0] | | | |
| *Average* | **0.12** | **0.03** | **[0.05, 0.18]** | | | |
| Stress | | | | | | |
| *State* | 0.01 | 0.01 | [-0.01, 0.03] | **0.001** | **0.001** | **[0.003, 0.008]** |
| *Average* | **0.13** | **0.04** | **[0.05, 0.2]** | | | |
| Peer Presence | | | | | | |
| *State* | **0.03** | **0.01** | **[0, 0.05]** | **0.01** | **0.003** | **[0.004, 0.016]** |

*Note*. Coefficients in bold are significant at $p < .05$.

Table 3.10. Effects of stimulation, sedation, stress, and peer presence on state levels of sensation seeking.

| | *Fixed Effects* | | | *Random Effects* | | |
|---|---|---|---|---|---|---|
| | ***Estimate*** | ***SE*** | ***95% CI*** | ***Estimate*** | ***SE*** | ***95% CI*** |
| Intercept | **2.72** | **0.38** | **[1.98, 3.46]** | **0.360** | **0.046** | **[0.28, 0.46]** |
| Study day | -0.01 | 0.00 | [-0.02, 0] | **0.002** | **0.000** | **[0.001, 0.003]** |
| Age | **-0.03** | **0.01** | **[-0.06, -0.01]** | | | |
| Stimulation | | | | | | |
| *State* | **0.02** | **0.01** | **[0.01, 0.04]** | **0.003** | **0.001** | **[0.002, 0.01]** |
| *Average* | **0.07** | **0.03** | **[0.01, 0.13]** | | | |
| Sedation | | | | | | |
| *State* | 0.00 | 0.01 | [-0.01, 0.01] | **0.001** | **0.001** | **[.00, .00]** |
| *Average* | 0.03 | 0.04 | [-0.05, 0.11] | | | |
| Stress | | | | | | |
| *State* | 0.00 | 0.01 | [-0.02, 0.02] | **0.007** | **0.002** | **[0.005, 0.01]** |
| *Average* | **0.11** | **0.05** | **[0.02, 0.2]** | | | |
| Peer Presence | | | | | | |
| *State* | **0.07** | **0.02** | **[0.04, 0.1]** | **0.012** | **0.004** | **[0.01, 0.02]** |

*Note*. Coefficients in bold are significant at $p < .05$.

Table 3.11. Effects of stimulation, sedation, stress, and peer presence on state levels of lack of premeditation.

| | *Fixed Effects* | | | *Random Effects* | | |
|---|---|---|---|---|---|---|
| | ***Estimate*** | ***SE*** | ***95% CI*** | ***Estimate*** | ***SE*** | ***95% CI*** |
| Intercept | **1.82** | **0.05** | **[1.73, 1.91]** | **0.27** | **0.03** | **[0.21, 0.35]** |
| Study day | 0.00 | 0.00 | [-0.01, 0.01] | **0.002** | **0.00** | **[0.001, 0.002]** |
| Stimulation | | | | | | |
| *State* | -0.01 | 0.01 | [-0.03, .002] | **0.002** | **0.001** | **[0.001, 0.004]** |
| *Average* | -0.01 | 0.03 | [-0.07, 0.05] | | | |
| Sedation | | | | | | |
| *State* | 0.01 | 0.01 | [-0.003, 0.03] | **0.002** | **0.001** | **[0.001, 0.01]** |
| *Average* | **0.16** | **0.04** | **[0.09, 0.24]** | | | |
| Stress | | | | | | |
| *State* | **0.05** | **0.01** | **[0.02, 0.07]** | **0.009** | **0.002** | **[0.01, 0.01]** |
| *Average* | 0.08 | 0.04 | [-0.004, 0.17] | | | |
| Peer Presence | | | | | | |
| *State* | 0.02 | 0.02 | [-0.01, 0.06] | **0.01** | **0.005** | **[0.004, 0.02]** |

*Note*. Coefficients in bold are significant at $p < .05$.

Table 3.12. Effects of stimulation, sedation, stress, and peer presence on state levels of lack of perseverance.

| | *Fixed Effects* | | | *Random Effects* | | |
|---|---|---|---|---|---|---|
| | ***Estimate*** | ***SE*** | ***95% CI*** | ***Estimate*** | ***SE*** | ***95% CI*** |
| Intercept | **1.74** | **0.04** | **[1.66, 1.81]** | **0.195** | **0.027** | **[0.15, 0.26]** |
| Study day | 0.002 | 0.004 | [-0.01, 0.01] | **0.001** | **0.000** | **[0.001, 0.002]** |
| Stimulation | | | | | | |
| *State* | **-0.01** | **0.005** | **[-0.02, -0.004]** | | | |
| *Average* | -0.04 | 0.02 | [-0.09, 0.01] | | | |
| Sedation | | | | | | |
| *State* | **0.02** | **0.01** | **[0.01, 0.03]** | | | |
| *Average* | **0.18** | **0.03** | **[0.12, 0.24]** | | | |
| Stress | | | | | | |
| *State* | **0.04** | **0.01** | **[0.02, 0.06]** | **0.004** | **0.001** | **[0.002, 0.01]** |
| *Average* | **0.11** | **0.04** | **[0.03, 0.18]** | | | |
| Peer Presence | | | | | | |
| *State* | -0.02 | 0.02 | [-0.05, 0.01] | **0.009** | **0.004** | **[0.004, 0.02]** |

*Note*. Coefficients in bold are significant at $p < .05$.

Table 3.13. Indirect effects of contextual factors on daily alcohol use via facets of impulsivity.

| *Covariates* | ***b*** | ***SE*** | ***RR*** | ***RR 95% CI*** |
|---|---|---|---|---|
| Study Day | 0.04 | 0.02 | 1.04 | [1, 1.08] |
| Weekend | **-0.61** | **0.13** | **0.54** | **[0.43, 0.7]** |
| Ethnicity | -0.03 | 0.13 | 0.98 | [0.76, 1.25] |
| Age | **-0.07** | **0.03** | **0.93** | **[0.88, 0.98]** |
| Gender | -0.15 | 0.26 | 0.86 | [0.52, 1.43] |
| *Contextual Factors* | | | | |
| Stimulation | **0.12** | **0.06** | **1.13** | **[1.01, 1.26]** |
| Sedation | **-0.19** | **0.06** | **0.82** | **[0.73, 0.93]** |
| Stress | -0.04 | 0.08 | 0.96 | [0.82, 1.13] |
| *Impulsivity Facets* | | | | |
| Positive Urgency | -0.25 | 0.28 | 0.78 | [0.45, 1.34] |
| Negative Urgency | 0.40 | 0.30 | 1.49 | [0.82, 2.69] |
| Sensation Seeking | -0.18 | 0.23 | 0.83 | [0.53, 1.31] |
| Premeditation | 0.44 | 0.26 | 1.55 | [0.94, 2.57] |
| Perseverance | -0.16 | 0.31 | 0.85 | [0.46, 1.56] |

| | ***b*** | ***SE*** | ***95% CI*** |
|---|---|---|---|
| *Predicting Negative Urgency* | | | |
| Stimulation | -0.01 | 0.02 | [-0.04, 0.03] |
| Sedation | **0.14** | **0.03** | **[0.08, 0.19]** |
| Stress | **0.13** | **0.04** | **[0.05, 0.2]** |
| *Predicting Positive Urgency* | | | |
| Stimulation | 0.01 | 0.02 | [-0.03, 0.05] |
| Sedation | **0.10** | **0.03** | **[0.04, 0.16]** |
| Stress | **0.11** | **0.04** | **[0.02, 0.19]** |
| *Predicting Sensation Seeking* | | | |
| Stimulation | **0.07** | **0.03** | **[0.02, 0.12]** |
| Sedation | 0.04 | 0.03 | [-0.02, 0.11] |
| Stress | **0.10** | **0.04** | **[0.02, 0.17]** |
| *Predicting Lack of Premeditation* | | | |
| Stimulation | -0.01 | 0.03 | [-0.07, 0.05] |
| Sedation | **0.12** | **0.03** | **[0.07, 0.17]** |
| Stress | **0.09** | **0.04** | **[0.02, 0.16]** |
| *Predicting Lack of Perseverance* | | | |
| Stimulation | -0.03 | 0.02 | [-0.08, 0.01] |
| Sedation | **0.13** | **0.02** | **[0.09, 0.18]** |
| Stress | **0.11** | **0.03** | **[0.06, 0.16]** |

**Coefficients significant at $p < .05$ are indicated in **bold**.*

Table 3.14. Indirect effects of contextual factors on likelihood of any daily drinking via facets of impulsivity.

| *Covariates* | ***b*** | ***SE*** | ***OR*** | ***OR 95% CI*** |
|---|---|---|---|---|
| Study Day | **0.04** | **0.01** | **1.04** | **[1.01, 1.07]** |
| Weekend | **-0.42** | **0.09** | **0.66** | **[0.55, 0.78]** |
| Ethnicity | -0.12 | 0.10 | 0.88 | [0.72, 1.08] |
| Age | **-0.05** | **0.02** | **0.95** | **[0.92, 0.99]** |
| Gender | 0.26 | 0.24 | 1.30 | [0.81, 2.08] |
| *Contextual Factors* | | | | |
| Stimulation | 0.08 | 0.04 | 1.08 | [1, 1.17] |
| Sedation | **-0.16** | **0.06** | **0.85** | **[0.75, 0.96]** |
| Stress | -0.10 | 0.08 | 0.90 | [0.77, 1.06] |
| *Impulsivity Facets* | | | | |
| Positive Urgency | 0.10 | 0.12 | 1.10 | [0.88, 1.38] |
| Negative Urgency | 0.21 | 0.12 | 1.23 | [0.98, 1.55] |
| Sensation Seeking | 0.00 | 0.11 | 1.00 | [0.81, 1.23] |
| Premeditation | **0.28** | **0.11** | **1.32** | **[1.07, 1.62]** |
| Perseverance | 0.19 | 0.13 | 1.21 | [0.93, 1.57] |
| | ***b*** | ***SE*** | | ***95% CI*** |
| *Predicting Negative Urgency* | | | | |
| Stimulation | -0.01 | 0.02 | | [-0.04, 0.03] |
| Sedation | **0.13** | **0.02** | | **[0.09, 0.18]** |
| Stress | **0.13** | **0.02** | | **[0.08, 0.18]** |
| *Predicting Positive Urgency* | | | | |
| Stimulation | 0.01 | 0.02 | | [-0.02, 0.04] |
| Sedation | **0.10** | **0.02** | | **[0.05, 0.15]** |
| Stress | **0.11** | **0.02** | | **[0.07, 0.16]** |
| *Predicting Sensation Seeking* | | | | |
| Stimulation | **0.07** | **0.02** | | **[0.03, 0.11]** |
| Sedation | 0.03 | 0.03 | | [-0.02, 0.08] |
| Stress | **0.10** | **0.03** | | **[0.03, 0.16]** |
| *Predicting Lack of Premeditation* | | | | |
| Stimulation | -0.01 | 0.02 | | [-0.04, 0.03] |
| Sedation | **0.13** | **0.03** | | **[0.08, 0.18]** |
| Stress | **0.09** | **0.03** | | **[0.03, 0.14]** |
| *Predicting Lack of Perseverance* | | | | |
| Stimulation | **-0.03** | **0.02** | | **[-0.06, 0]** |
| Sedation | **0.14** | **0.02** | | **[0.09, 0.18]** |
| Stress | **0.11** | **0.02** | | **[0.07, 0.15]** |

**Coefficients significant at $p < .05$ are indicated in bold.*

Table 3.15. Models testing whether or not heavy alcohol use and alcohol problems moderate the association between contextual factors of stress, stimulation, and sedation on state impulsivity.

| | ***Estimate*** | ***SE*** | ***95% CI*** |
|---|---|---|---|
| *Predicting Negative Urgency* | | | |
| Heavy Alcohol Use | -0.10 | 0.06 | [-0.2, 0.01] |
| Alcohol Problems | **0.04** | **0.01** | **[0.015, 0.05]** |
| Heavy Alcohol Use x State Stimulation | **0.02** | **0.01** | **[0.00, 0.02]** |
| *Predicting Positive Urgency* | | | |
| Heavy Alcohol Use | -0.09 | 0.07 | [-0.22, 0.04] |
| Alcohol Problems | **0.03** | **0.01** | **[0.01, 0.06]** |
| Heavy Alcohol Use x State Stress | -0.02 | 0.01 | [-0.05, 0.001] |
| *Predicting Sensation Seeking* | | | |
| Heavy Alcohol Use | -0.15 | 0.08 | [-0.3, 0.004] |
| Alcohol Problems | 0.02 | 0.01 | [-0.01, 0.04] |
| *Predicting Lack of Premeditation* | | | |
| Heavy Alcohol Use | 0.03 | 0.07 | [-0.11, 0.17] |
| Alcohol Problems | 0.01 | 0.01 | [-0.01, 0.04] |
| Heavy Alcohol Use x State Stress | **0.03** | **0.02** | **[0.001, 0.06]** |
| *Predicting Lack of Perseverance* | | | |
| Heavy Alcohol Use | -0.04 | 0.06 | [-0.15, 0.08] |
| Alcohol Problems | 0.02 | 0.01 | [-0.002, 0.04] |
| Alcohol Problems x State Sedation | **0.00** | **0.00** | **[0.001, 0.005]** |

*Coefficients in bold are significant at $p < .05$. Models were run separately for each facet of impulsivity. Interaction effects that were insignificant and worsened model fit were trimmed from final models. Only the retained interactions are presented here. Main effects of state contextual factors were included in models and are presented in prior tables.

## Figures

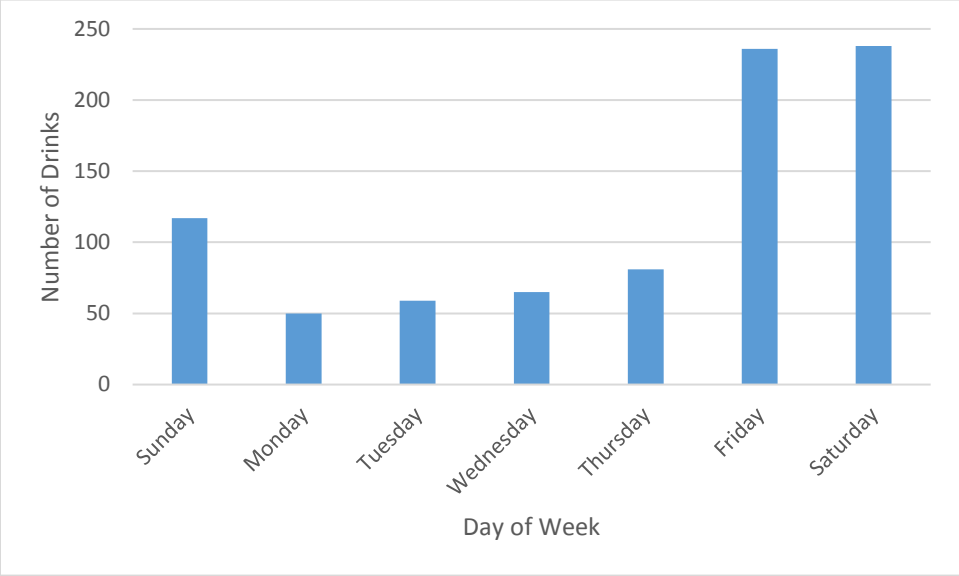


Figure 1. Total number of alcoholic drinks reported during the ecological momentary assessment period by day of week.

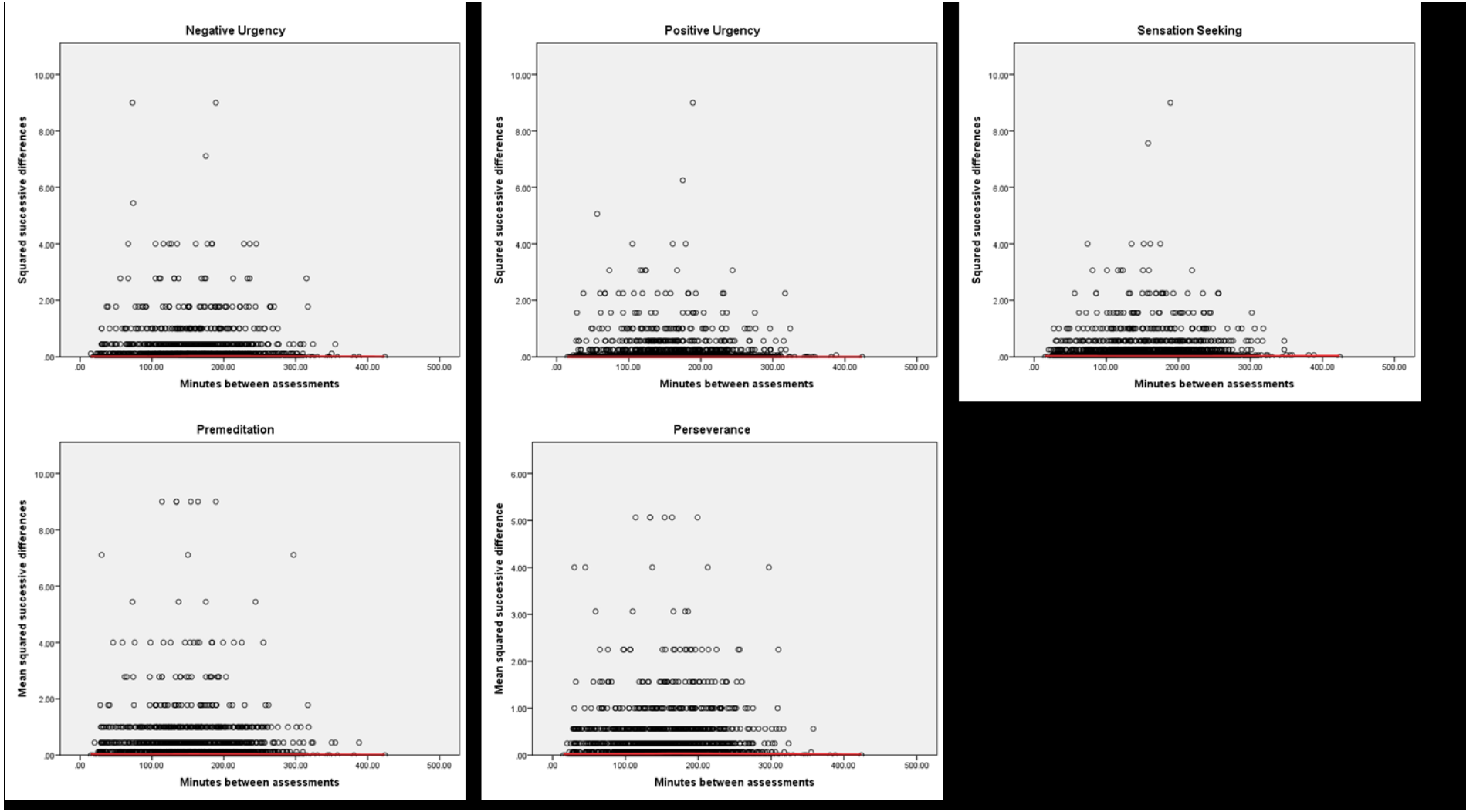


Figure 2. The squared successive differences for each facet of impulsivity plotted against time interval between assessments with loess lines added. A straight line indicates the amount of change between assessments is independent of the length of assessment.

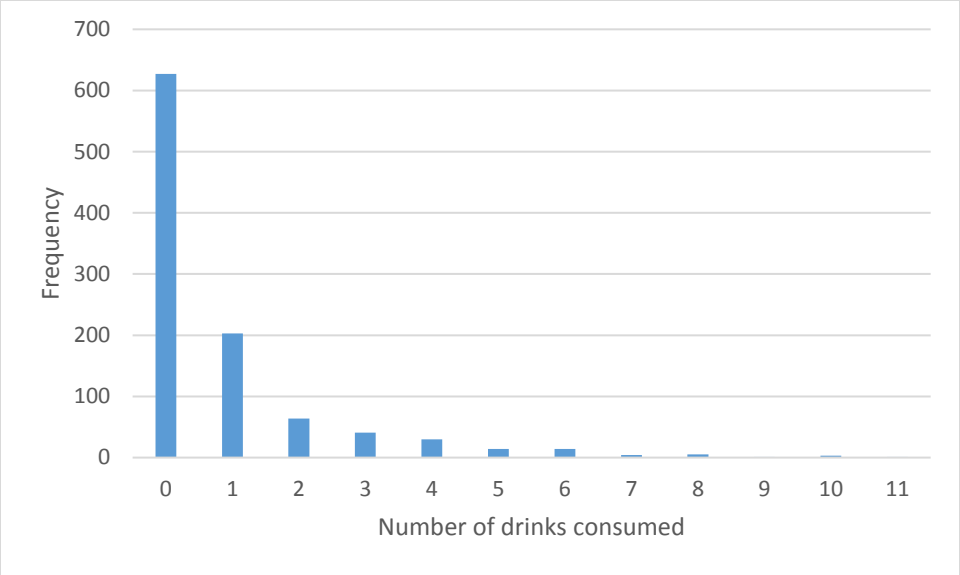


Figure 3. Histogram representing how frequently participants reported consuming all number of drinks during the EMA period.

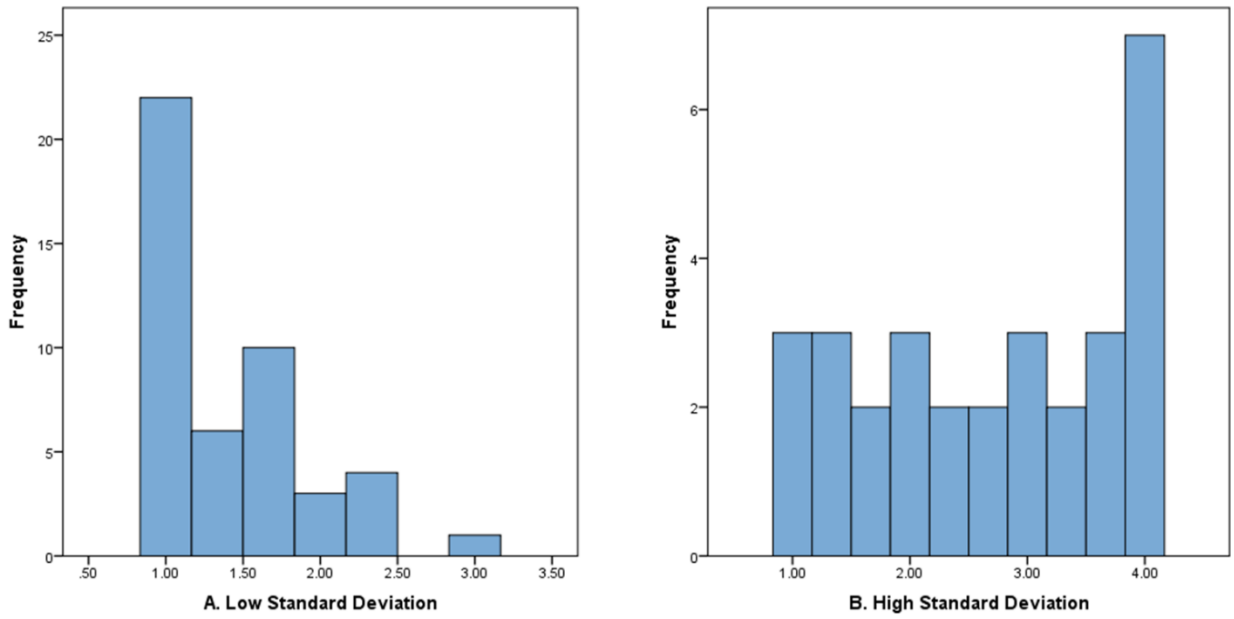


Figure 4. Distributions of two participants' state negative urgency ratings. Panel A depicts a distribution for a participant with a lower standard deviation (SD = .50). Panel B depicts the distribution of state negative urgency for a participants with a higher standard deviation (SD = 1.08).

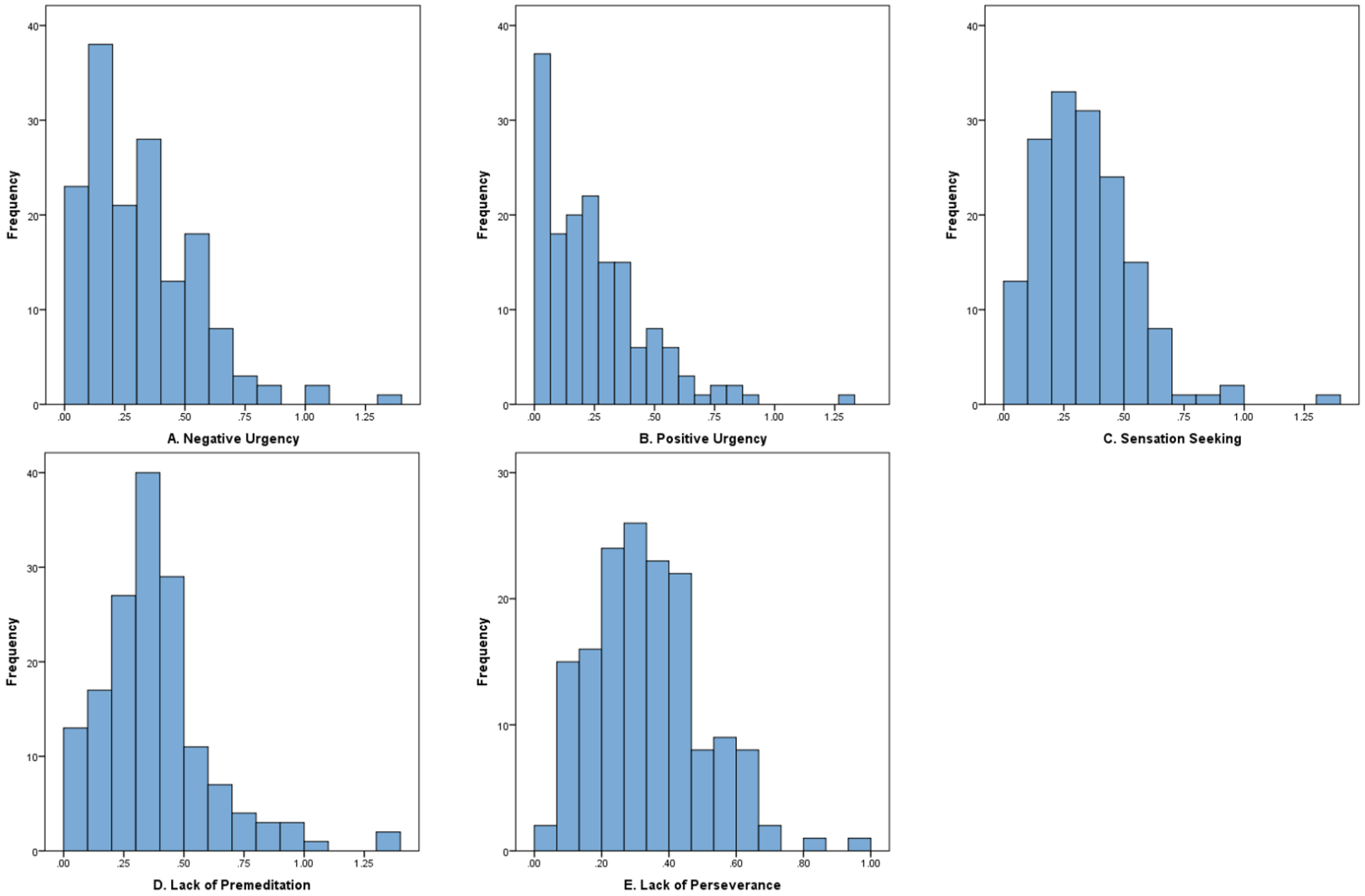


Figure 5. Histogram of the total standard deviation of state negative urgency (panel A), positive urgency (panel B), sensation seeking (panel C), lack of premeditation (panel D), and lack of perseverance (panel E) across participants.

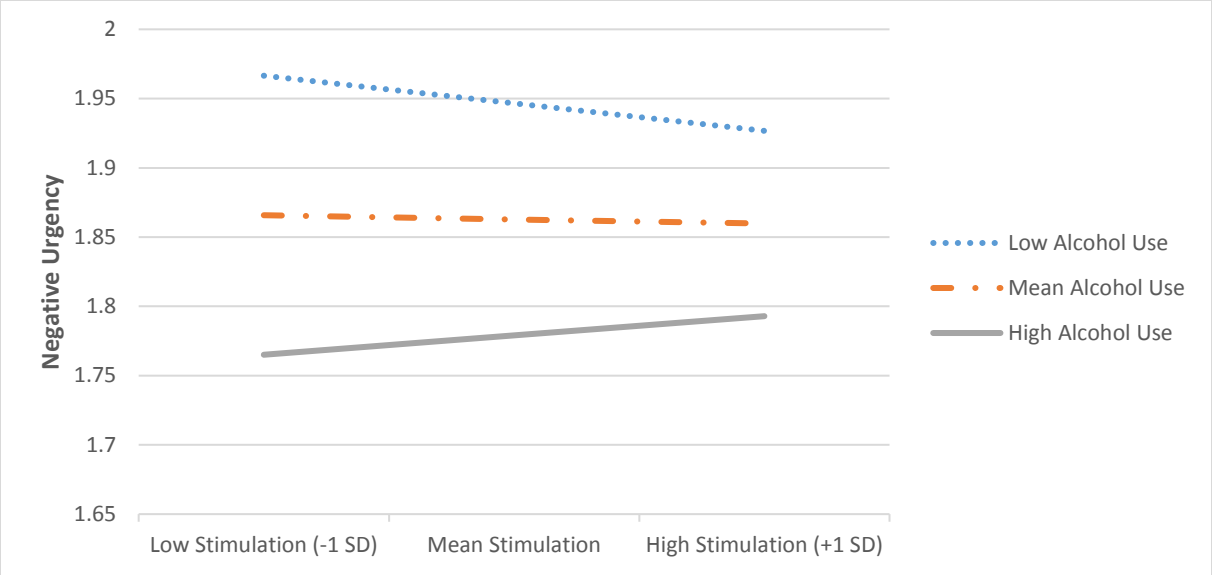


Figure 6. Association between state stimulation and state negative urgency by level of alcohol use.

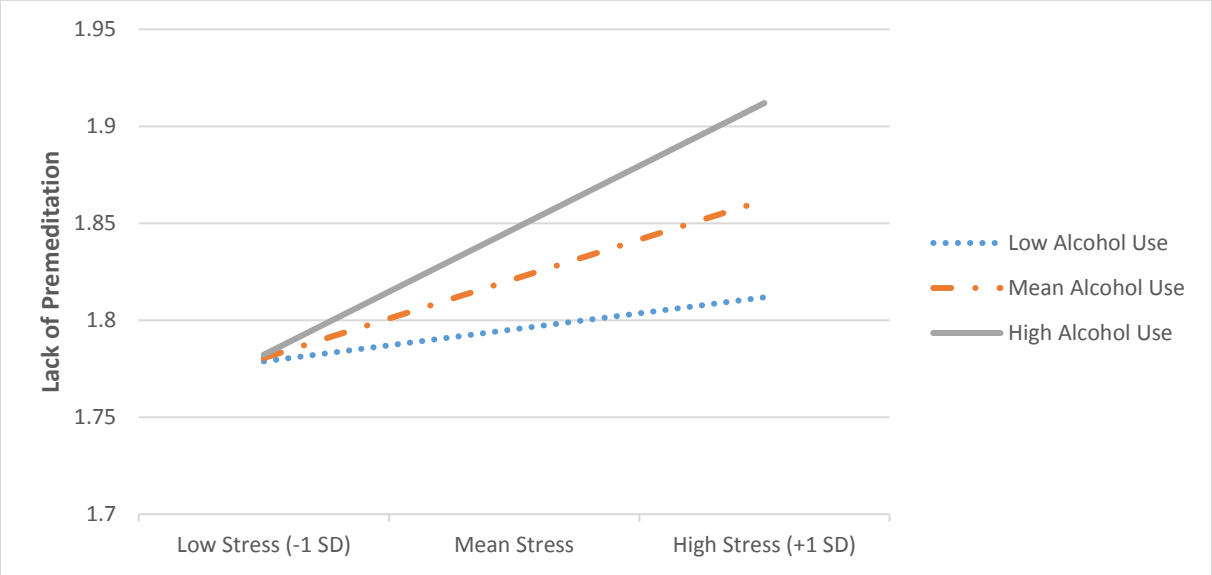


Figure 7. Association between state stress and state lack of premeditation by level of alcohol use.

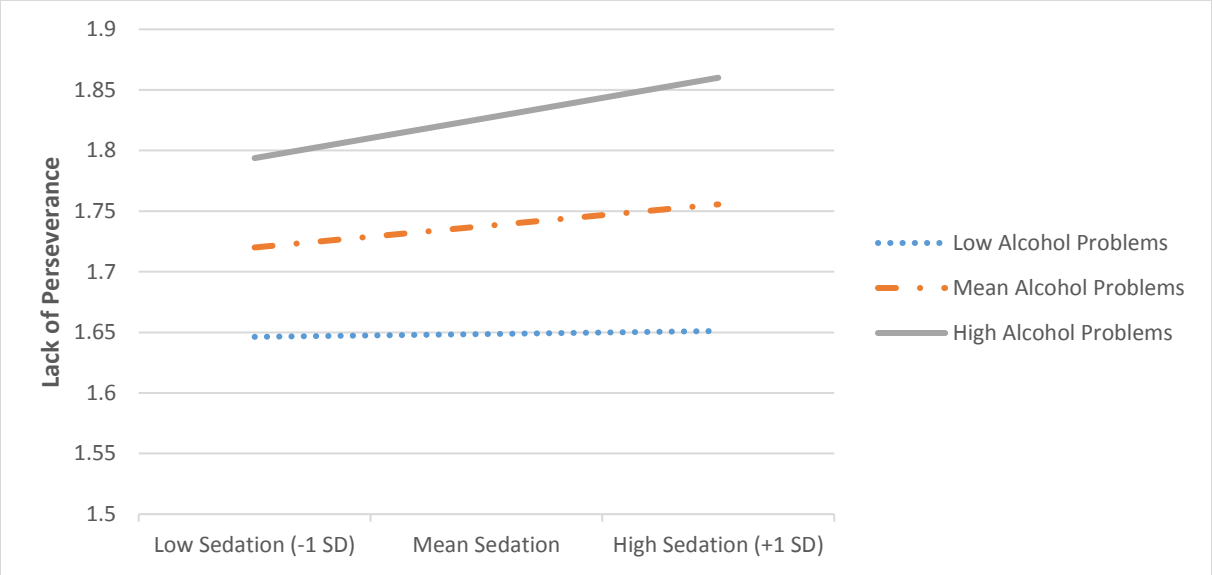


Figure 8. Association between state stress and state lack of perseverance by level of alcohol problems.