

## ABSTRACT

Title of Dissertation:

APPLICATION OF BEHAVIORAL  
ECONOMIC THEORY TO COLLEGE  
STUDENT DRINKERS WITH AND  
WITHOUT ADHD: A DAILY DIARY STUDY

Lauren Elizabeth Oddo, Doctor of Philosophy,  
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Dissertation directed by:

Professor Andrea Chronis-Tuscano, Department  
of Psychology

**Aims:** Young people with ADHD are vulnerable to the initiation and escalation of hazardous alcohol use in college, posing high direct and indirect costs to these individuals and society. Behavioral economic theory proposes key etiological and maintenance factors of hazardous alcohol use that have never been examined at the daily level in connection to ADHD: alcohol demand, substance-free enjoyment and activity engagement, and behavioral activation. **Method:** College student drinkers with ( $n=51$ ) and without ( $n=50$ ) ADHD completed 14 consecutive days of daily diaries ( $n=1,414$ ). We conducted a series of multilevel path models to examine (1) the effect of ADHD on average daily alcohol demand, substance-free enjoyment and activity engagement, and behavioral activation; (2) the effect of average daily alcohol demand, substance-free enjoyment and activity engagement, and behavioral activation on alcohol use and alcohol-related negative consequences; and (3) the moderating effect of ADHD on these same-day associations. **Results:** On average, drinkers with ADHD experienced more daily alcohol-

related negative consequences relative to non-ADHD drinkers. ADHD was also associated with less daily substance-free enjoyment and behavioral activation. Regardless of ADHD status, there were significant associations among each behavioral economic risk factor and alcohol use and alcohol-related negative consequences, though effects differed at the within and between person levels. There were no moderating effects of ADHD on these same-day associations. Conclusion: This is the first study to apply daily diary methodology to examine behavioral economic risk factors among drinkers with versus without ADHD. Results expose areas of daily impairment specific to drinkers with ADHD and meaningfully advance theoretical conceptualizations of ADHD and hazardous alcohol use. Future research identifying daily associations among environmental triggers and alcohol problems in an ecologically valid manner has tremendous potential to inform the development of adaptive interventions delivered to the right people at the right time.

APPLICATION OF BEHAVIORAL ECONOMIC THEORY TO COLLEGE  
STUDENT DRINKERS WITH AND WITHOUT ADHD: A DAILY DIARY  
STUDY

by

Lauren Elizabeth Oddo

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Advisory Committee:

Andrea Chronis-Tuscano, Ph.D., Chair

James Murphy, Ph.D.

Alexander Shackman, Ph.D.

Edward Lemay, Ph.D.

Eric Wish, Ph.D., Dean's Representative

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# Chapter 1: Background

## *Alcohol Use among College Students*

The college years are considered a normative and transient period where many young people experiment with alcohol (Ashenhurst & Fromme, 2018; Staff et al., 2010). According to the 2019 National Survey on Drug Use and Health (SAMHSA, 2019), over half of full-time college students ages 18-22 endorse past-month alcohol consumption, with a substantial minority reporting past-month hazardous use characterized by heavy (i.e., consuming more than 4 drinks on any day or more than 14 drinks per week for males and 7 drinks per week for females) or binge drinking (i.e., consuming 4 or more drinks in about 2 hours for women or 5 or more drinks in about 2 hours for men). Hazardous alcohol use has the potential to interfere with key developmental tasks such as brain maturation, learning, educational attainment, and career development, and increase the risk of progression to alcohol use disorder (AUD; Debenham et al., 2019; Murphy & Dennhardt, 2016). Therefore, it is imperative to characterize those drinkers who are at greatest risk for engaging in hazardous alcohol use in college.

## *The Co-Occurrence of ADHD and Alcohol Problems*

Attention-deficit/hyperactivity disorder (ADHD) can increase risk for alcohol-related problems and disorders in adolescence and adulthood (Luderer et al., 2021). ADHD is a neurodevelopmental disorder and among the earliest emerging of behavioral conditions, with onset in the childhood years well before the majority of other psychopathology to which ADHD



can lead (Nigg et al., 2020). The ADHD phenotype comprises symptoms of inattention and hyperactivity-impulsivity (American Psychiatric Association, 2013). These symptoms are characterized by problems with sustained attention, persistence towards goals, self-monitoring and modulating task-irrelevant thoughts, emotions, and behaviors, and regulating activity levels to contextual demands (Barkley, 2011). In ADHD, these symptoms occur across situations, are age-inappropriate, and directly lead to adverse outcomes and impaired functioning in important life areas (home, community, health, social, school, occupation).

Etiological theories of ADHD suggest core disruptions in behavioral and emotional self-regulation as pathognomonic characteristics (Antshel et al., 2014; Shiels & Hawk, 2010). Self-regulation is a cognitive-motivational phenomenon that refers to self-directed acts sustained over time to alter the likelihood of a desired outcome (Barkley, 2011). Self-regulation is intimately involved in selecting, enacting, modifying, and maintaining appropriate behaviors over time in the context of competing rewards and reinforcers in the environment (Oettingen et al., 2000; Schunk & Zimmerman, 2013). Given their core self-regulation deficits, individuals with ADHD systematically fare worse in situations that require self-motivated behavior towards attaining delayed rewards, compared to situations that inherently rewarding and immediately reinforcing.

The college environment is a large-scale self-regulation task requiring daily self-motivated efforts in planning, organizing, and persisting towards long-term goals in the context of limited structure for adaptive, goal-directed behavior. With widely available and potent psychoactive substances whose effects on the nervous system can be inherently pleasurable and immediately rewarding (Correia et al., 2010), college has the potential to become a “perfect storm” for young people with ADHD. Relative to their peers without ADHD, college students with ADHD are more likely to meet diagnostic criteria for alcohol abuse and dependence (Rooney et al., 2012). In cross-sectional work, students with ADHD report experiencing more difficulties stopping a drinking

episode (Baker et al., 2012) and higher rates of alcohol-related negative consequences (e.g., getting into fights, having memory loss, and being injured), even when students with and without ADHD do not report significantly different levels of past-month/year alcohol consumption (Mochrie et al., 2020; Rooney et al., 2012). Relative to either disorder in isolation, comorbid ADHD and AUD is associated with higher rates of morbidity, disability, and poorer treatment prognosis, posing high direct and indirect costs to these individuals and society (Gupte-Singh et al., 2017; Johann et al., 2003; Sacks et al., 2015). Thus, a critical question facing behavioral and health sciences is why young people with ADHD are vulnerable to impairing alcohol use in college.

### Overview of Behavioral Economic Reinforcer Pathology Model

Normal daily living in college is replete with potentially reinforcing and rewarding stimuli. Whereas some students allocate much of their daily behavior to activities that are productive, valuable, and healthy over the long run, others tend to engage in behaviors, such as hazardous alcohol use, that yield short-term positive effects but can seriously undermine health, functioning, and general wellbeing over time (Correia et al., 2010). Behavioral economics applies foundational principles of microeconomics and behavioral psychology to conceptualize the multiple determinants of these behaviors. This body of work suggests that individuals engaging in hazardous alcohol use display a reinforcer pathology: they tend to overvalue alcohol as a reinforcer and undervalue substance-free activities whose reinforcing properties often occur over time delay (Bickel et al., 2014).

Consistent with this perspective, competing contingencies and rewards in daily living can shape alcohol use (Lamb & Ginsburg, 2018), with addiction characterized by continued use despite

natural constraints and consequences (e.g., negative consequences, competing alternatives to alcohol use). Clinically, individuals with AUD display a maladaptive pattern of behavior allocation towards acquiring and consuming alcohol, at the expense of engaging in rewarding alternatives. That is, they tend to be highly reinforced by their alcohol use (i.e., alcohol demand), engage in minimal substance-free activities and derive less enjoyment from substance-free stimuli (i.e., substance-free reinforcement), and report fewer goal-directed activities bringing pleasure, hope, belonging and purpose (i.e., behavioral activation). Because extended alcohol use exacerbates these factors, via direct physiological effects on the nervous system and indirect effects on psychosocial functioning, addiction is considered a self-perpetuating cycle (Lamb et al., 2016). Such behavioral theories of addiction highlight plausible etiological and maintenance factors of AUD to which drinkers with ADHD may be particularly vulnerable, yet research in this area remains scarce.

### *Alcohol Demand*

Alcohol demand characterizes the incentive value of alcohol and is a proposed etiological and maintenance factor of AUD (Murphy & MacKillop, 2006) but remains wholly unexplored in ADHD. In part, behavioral economic models quantify alcohol demand as the association between alcohol cost and consumption using purchase tasks (Martínez-Loredo et al., 2021). Specifically, associations among cost and consumption are modeled using separate alcohol demand indices quantifying interrelated aspects of a person's motivation to consume alcohol, including consumption at zero cost, maximum money allocated to alcohol use, and sensitivity to escalating costs of alcohol (Acker et al., 2012). As the price of alcohol increases, alcohol purchases and consumption typically decline. Numerous studies show that adults reporting more alcohol consumption at free and escalating prices tend to consume more alcohol, report more alcohol-

related negative consequences, and evidence higher rates of AUD (Amlung et al., 2012; Joyner et al., 2019; Minhas et al., 2020; Murphy et al., 2009). These findings are evident even in hypothetical drinking scenarios (Kaplan et al., 2018).

Importantly, alcohol demand has traditionally been conceptualized as a stable trait that varies across individuals, only. Emerging research supports a complementary state-level component of alcohol demand that changes within individuals over time (Merrill & Aston, 2020; Motschman et al., 2022; Owens et al., 2015). Two known studies have evaluated alcohol demand at the daily level in naturalistic contexts, both showing that demand varies at the individual level, day-to-day (Merrill & Aston, 2020; Motschman et al., 2022). In their intensive longitudinal study, Motschman and colleagues (2022) showed that higher demand on a given day was associated with greater levels of daily alcohol consumption. These findings extend experimental laboratory-based studies of alcohol demand by evaluating the natural course of alcohol demand within daily life and in connection to how much alcohol a person consumes. Preliminary research has also identified key individual difference factors associated with higher levels of alcohol demand. For example, in a large laboratory study of adults, Gray & MacKillop (2014) showed that trait levels of urgency, sensation-seeking, and lack of premeditation (i.e., ADHD-related constructs) were cross-sectionally associated with higher levels of trait alcohol demand.

Although preliminary research suggests that alcohol demand varies within a person and is associated with alcohol use, several questions remain regarding alcohol demand's motivational influence on drinking in the natural (i.e., non-laboratory) environment. No known studies have simultaneously evaluated the same-day associations among alcohol demand and both alcohol use and alcohol-related negative consequences. Consequently, it is unclear whether state-level alcohol demand operates as a proximal motivational driver of both same-day alcohol use and negative consequences. This is an important line of research, given that psychosocial interventions largely

focus on facilitating change within a person's daily life. It is also unknown whether, compared to drinkers without ADHD, those with ADHD experience higher levels of alcohol demand. Alcohol is an easily accessible substance in college with inherently pleasurable and immediately reinforcing properties (Correia et al., 2010). Such properties, combined with the core self-regulation deficits of ADHD (Antshel et al., 2014), may make drinkers with ADHD more likely than their non-ADHD peers to report higher levels of alcohol demand in their daily lives. This line of work has the potential to inform screening efforts and clinical decision making, as alcohol interventions are less efficacious for individuals with high alcohol demand (Murphy et al., 2015).

Additionally, perhaps those drinkers with ADHD who report high alcohol demand are at greatest risk for alcohol use and negative consequences in natural drinking contexts, as they may lack the self-regulation capacity to override a strong motivation to drink even when this is not an adaptive choice in the long run. This possibility is consistent with prior work finding moderating effects of ADHD-related constructs (i.e., impulsivity) on associations among trait-level alcohol demand and alcohol use, though research is mixed (Gray & MacKillop, 2014; Smith et al., 2010). The college environment is uniquely poised to examine the interactive effects of ADHD and alcohol demand on alcohol use and negative consequences, given the uptick in self-regulation demands in the context of high-density social drinking networks, easy access to alcohol, and largely unstructured time with high academic demands.

### *Substance-Free Reinforcement*

Opportunity costs, or rewarding alternatives to substance use (i.e., substance-free reinforcers) can effectively reduce alcohol use and alcohol-related negative consequences. Various studies show that when substance-free alternatives are immediately and consistently delivered within the

laboratory environment, animals reduce the amount of the drug they self-administer (Lamb et al., 2016). Moreover, heavy alcohol use tends to decrease when engagement in substance-free activities is explicitly and differentially rewarded (e.g., contingency management; Dougherty et al., 2015); when a person acquires alternative, adaptive sources of reward that “compete with” alcohol use (e.g., substance-free hobbies, religious/wellness activities, academics/employment, social interactions; Murphy et al., 2006); and when substance-free behaviors are enhanced in treatment programs (Daughters et al., 2018; Murphy et al., 2019; Oddo, Meinzer, et al., 2021). In naturalistic human studies, less substance-free reinforcement is associated with more alcohol use and negative consequences (Correia et al., 2003; Skidmore & Murphy, 2010). For example, Meshesha et al., (2015) observed negative associations among substance-free reinforcement and past month heavy drinking.

Several questions remain regarding the association among substance-free reinforcement and drinking. Existing work uses aggregate-level data assessing overarching patterns of substance-free reinforcement, typically assessed by combining past-month/year ratings of average frequency of substance-free engagement (e.g., “sometimes”, “often”) and pleasure derived. This foundational body of work tells us that people who report more substance-free reinforcement over time (e.g., past month/year) also drink less and experience fewer negative consequences during that time window, relative to people who report less overall substance-free reinforcement (Acuff et al., 2019). Yet, we do not know the association among substance-free reinforcement and drinking outcomes within a person, at the daily level. Furthermore, given that reinforcement is a multifaceted construct, it is unknown whether certain facets of reinforcement (e.g., substance-free activity engagement versus substance-free enjoyment) show differential effects on alcohol use and negative consequences. As most clinical interventions focus on facilitating individual change

in a person's daily living, it is imperative to directly test whether more granular extensions of prior work reveal similar findings.

Drinkers with ADHD, in particular, may be at risk for deriving limited reinforcement from substance-free activities in college. Indeed, without external contingencies to regulate reward-related behavior, young people with ADHD can present with a host of functional difficulties, including disorganization, procrastination, and a tendency to avoid or not complete important goal-directed tasks (Langberg et al., 2011; Ptacek et al., 2019; Ramsay, 2002; Weiss et al., 2002). In contrast to alcohol use, which is immediately reinforcing and inherently rewarding, many substance-free behaviors recruit effortful, goal-directed, and prosocial approach behaviors – key areas of impairment associated with ADHD. Consequently, drinkers with ADHD may have difficulty engaging in, and deriving pleasure from, substance-free activities that enhance social connection, goal-directed behavior, and health/wellness. Understanding whether drinkers with ADHD allocate their behavior to fewer adaptive substance-free activities in their daily lives, and enjoy these activities less, is an essential step in characterizing risk factors among this vulnerable population. This is especially important given that evidence-based interventions for college drinkers are less efficacious for those with low levels of substance-free reinforcement (Murphy et al., 2005).

ADHD may also moderate the daily effects of substance-free reinforcement on alcohol use and negative consequences. Some theorize that individuals high in ADHD-related traits (e.g., maladaptive behavior allocation towards smaller, immediate rewards) are less likely to constrain their alcohol use in the presence of substance-free alternatives because the reinforcing properties of such alternatives are often delayed, relative to the immediate reinforcement of substance use (Lamb et al., 2016). Youth with ADHD are shown to require full reinforcement contingencies characterized by high doses of consistent and predictable reward to alter behavior (Taylor et al.,

2009; Tripp & Wickens, 2012). Indeed, Nigg et al. (2020) highlight the impact of the environment on individuals with ADHD, and the need to prioritize studies evaluating the degree to which psychosocial context (e.g., environmental demands, rewards) shapes ADHD-related impairments and comorbidities. Identification of moderating effects aligns with this priority and has the potential to directly test questions about “for whom” substance-free reinforcement effectively reduces alcohol use and negative consequences during college, in turn informing personalized interventions.

### *Behavioral Activation*

Behavioral activation is defined as engagement in focused, goal-directed behavior and completion of scheduled activities, as well as minimal avoidance and aversive experiences (Manos et al., 2011). In effect, behavioral activation characterizes a positive reinforcement process for goal-directed behaviors, including the function of behavior (e.g., escape/avoidance). From this perspective, behavioral activation is implicit in behavioral theories of addiction, which conceptualize the development and maintenance of hazardous alcohol use as occurring, in part, within a system of reinforcement contingencies. That is, certain environmental features (e.g., limited presence of adaptive sources of reinforcement, easy access to highly reinforcing substances) and maladaptive behaviors (e.g., avoidance, poor behavioral self-regulation) interfere with deriving reinforcement from adaptive sources (Lamb et al., 2016). Despite theoretical support, we still do not know whether the association among behavioral activation and alcohol use and negative consequences occurs at the individual level, assessed daily within a person’s natural context. Such inquiry is critical to directly testing behavioral economic theory as it



unfolds in a person's life, as generalizing molar patterns of behavior to the daily- and individual-level is a logical facility that can mask important nuance (Curran & Bauer, 2011).

Although unknown, drinkers with ADHD may be at-risk for limited behavioral activation in college, as acquiring behavioral activation requires many cognitive-behavioral skills (e.g., adaptive coping, organization/planning skills) that are impaired in ADHD (Hill et al., 2017; Manos et al., 2011). Individuals with ADHD are shown to experience difficulties persisting towards goals while resisting distractions, tolerating distress and frustration, self-regulating emotions, and attending to and flexibly adjusting cognitions and behaviors contingent on feedback from the natural environment (Christiansen et al., 2019; Ptacek et al., 2019; Seymour et al., 2019; Shiels & Hawk, 2010). Moreover, youth with elevated ADHD symptomatology perceive greater effort and rate tasks as more taxing than those without ADHD symptomatology (Hsu et al., 2017). Such features of ADHD lead to a constellation of impairments that are likely to interfere with planning and executing important, goal-directed activities that may be reinforcing (Harrington, 2011).

In support of this possibility, a recent study of young adult drinkers showed that, out of a suite of reward-related risk factors, the presence of environmental suppressors to reward, including unpleasant and aversive experiences, was the only shared correlate of ADHD and AUD symptoms (Oddo, Acuff, et al., 2021). Further, in the one known study evaluating behavioral activation as a mechanism of change in alcohol intervention for college student drinkers with ADHD, Oddo, Meinzer, et al. (2021) showed that engagement in more adaptive, goal-directed behaviors and less avoidance over the course of treatment predicted greater reductions in alcohol-related negative consequences in the month following intervention. This preliminary body of work is consistent with calls for treatments to go beyond a focus on reducing or eliminating

substance use to enhance engagement in experiences that are functionally meaningful and fulfilling (McKay, 2017).

ADHD may also moderate the effects of behavioral activation on same-day alcohol use and negative consequences. Individuals with ADHD often require external motivators to facilitate adaptive decision-making in the context of competing rewards with more immediately reinforcing properties. Indeed, alcohol use has the potential to enhance the availability of immediate rewards (e.g., social connection, intoxication) and accommodate escape from unpleasant experiences (e.g., engagement in activities requiring sustained effort/attention, persistence towards goals over time delay, involvement in non-preferred activities). Given that individuals with ADHD are especially sensitive to their psychosocial contexts (Nigg et al., 2020), understanding daily associations among environmental triggers and alcohol problems in an ecologically valid manner can inform the development of adaptive interventions on high-risk days (Koch et al., 2021).

### *The Current Study*

Individuals with ADHD experience alcohol-related problems and disorders at higher than chance levels. Unfortunately, recent actuarial data suggest that adults with ADHD have, on average, 11 to 13 years reduced life expectancy compared to neurotypical peers of a similar age and health profile, in part due to higher rates of substance use (Dalsgaard et al., 2015). Behavioral economics articulates a reinforcer pathology model of addiction, with research to date largely focusing on molar patterns over a long timescale (e.g., month/year), with no known work applying this framework to drinkers with ADHD at the daily level. The current study offers a novel and complementary focus on patterns of behavioral risk by extending a reinforcer

pathology model to daily behavior, as well as identifying differential patterns of risk between college drinkers with and without ADHD.

Technological advancements supporting streamlined and less burdensome intensive longitudinal data collection have tremendous potential in this area. Unlike retrospective reports, which ask a person to abstract their behavior to “typical” levels (e.g., average alcohol use, typical substance-free functioning), proximal reports of behaviors in the form of daily diaries can reduce biased estimates. Gathering proximal and granular data is especially useful in the context of ADHD, as inattentive symptoms may interfere with accurate recall over time delay. Moreover, intensive longitudinal data collection allows for the use of statistical methodology parceling effects that occur across individuals (i.e., between persons) and at the individual level (i.e., within persons). Disaggregating these effects is especially important in refining theory, as generalizing associations observed across individuals to the individual level is an error of inference that limits a complete understanding of the true nature of hypothesized relations (Curran & Bauer, 2011).

In the current daily diary study, we investigated three aims. First, we examined if drinkers with and without ADHD differed in daily reports of alcohol demand, substance-free enjoyment and activity engagement (i.e., two substance-free reinforcement indices), and behavioral activation – all theoretically linked to ADHD and AUD pathogenesis but largely unexamined to date. We hypothesized that drinkers with ADHD would report more daily alcohol demand, less daily substance-free activity enjoyment and engagement, and less daily behavioral activation than drinkers without ADHD. Second, we aimed to evaluate the effect of daily alcohol demand, substance-free activity enjoyment and engagement, and behavioral activation on alcohol use and alcohol-related negative consequences, both across participants and at the individual level. Consistent with a reinforcer pathology framework, we hypothesized that higher daily alcohol demand, lower daily substance-free activity enjoyment and engagement, and lower daily

behavioral activation would be associated with higher levels of daily alcohol use and alcohol-related negative consequences. Third, we aimed to evaluate the moderating effects of ADHD on these same-day associations. We hypothesized that those drinkers with ADHD who reported more daily alcohol demand, less daily substance-free activity enjoyment and engagement, and less daily behavioral activation, would report the highest levels of daily alcohol use and alcohol-related negative consequences.

## Chapter 2: Method

### Participants

Participants were 101 college students with (n=51) and without (n=50) ADHD from a large public university in the Mid-Atlantic region of the United States. See Table 1 for sample demographic and descriptive information. All participants were enrolled as full-time students and, of note, 89.10% of participants (n=90) completed the study protocol during the coronavirus pandemic (September 2020 – May 2021). 86.10% of participants (n=87) reported living fully independent of their caregivers during their participation in the study.

Participants were eligible if they were: full-time college students between the ages of 18-22, reported drinking at least 3 times per week in the past two weeks, reported at least 1 heavy drinking episode in the past two weeks (i.e., consuming 4+/5+ drinks in 2 hours or less for females/males, respectively), and exceeded young adult hazardous drinking cut-offs on the Alcohol Use Disorder Identification Test (AUDIT; scores of 5+/7+ for females/males, respectively; DeMartini & Carey, 2012). Students in the non-ADHD comparison group (i.e., “controls”) were eligible for study inclusion if they: (1) had < 3 current DSM-5 symptoms of ADHD, (2) reported no history of ADHD in childhood, and (3) had never been prescribed medication to treat ADHD. Participants assigned to the ADHD group were additionally required to meet full DSM-V diagnostic criteria for ADHD, defined as clinically significant ADHD symptoms and multi-domain impairment evidenced by age 12 and persisting currently based on rating scales and diagnostic interviews (described below). Approximately 67% of students (n=34) in the ADHD group reported a prior diagnosis of ADHD, diagnosed by either a medical or mental

health provider. Across both groups, students were ineligible if they were currently in alcohol/drug use treatment, reported a psychotic disorder, reported eminent suicide or homicide risk, or were not fluent in English language. All participants were treated in accordance with American Psychological Association ethical guidelines for research conduct, and the institutional review board approved all study procedures prior to participant recruitment.

### Procedures

Participants were recruited through campus listservs, the undergraduate research participation system, and flyers posted at University Counseling, Accessibility and Disability support services, and in the proximity of campus. Recruitment materials included a brief description of the study: “to examine college student drinking behaviors and lifestyle choices.” Interested students participated in a two-step screening process to determine eligibility for the baseline session. They first completed an online screener assessing alcohol use frequency, heavy drinking episodes, and ADHD status (i.e., prior diagnosis) and symptoms. Students meeting initial eligibility criteria were scheduled to speak with study personnel over the phone where they were provided with information on the purpose and procedures of the study. Students who consented also completed a brief phone assessment of current drinking behaviors, prior diagnoses, medication status, and student status.

Eligible students on the phone assessment were invited for a two-hour baseline session in a university-based research laboratory ( $n=11$ ) or via secure online videoconference platform ( $n=90$ ), due to physical distancing precautions during the coronavirus pandemic. Of note, these baseline visits did not occur during major academic calendar events, such as final exam week or prolonged academic breaks to capture typical drinking patterns in the college environment. Master’s- and doctoral-level assessors administered structured and semi-structured clinical interviews assessing ADHD and AUD under the supervision of a licensed psychologist, and

participants completed measures assessing demographics, alcohol and drug use, and psychosocial risk and protective factors. If it was discovered that a participant did not meet eligibility criteria during the baseline assessment, the participant was compensated, provided with appropriate referrals, and excluded from further participation ( $n=4$ ).<sup>1</sup>

At the end of their baseline study visit, eligible participants confirmed their phone number. Participants were trained to properly operate the mobile daily diary features as well as to understand the meaning of all questions and response choices and the procedures for responding to alerts.<sup>2</sup> A practice diary (in response to a text prompt) was completed with the assessor to confirm understanding. Participants were instructed that compliance would be regularly monitored by the research team and they would receive messages from a staff member throughout the study to check-in on their progress. The assessor explicitly instructed participants not to respond to text prompts received at inappropriate moments (e.g., while driving, during class). Participants were instructed to go about their day-to-day routines and were not asked to change any behavior due to study participation. Participants were provided with the full payment schedule for their participation: \$25 for the baseline assessment, \$45 for completion of 10 of 14 daily diaries, and \$45 for completion of 12 of 14 daily diaries. They also received the study phone number and email address for contact related to any issues with the daily surveys. Participants were notified that these were not crisis contacts and if they experienced a crisis during the dairy period to call 911/university police or report to Student Health, Counseling Services, or their local emergency department. Participants were provided with this information in the form of an index card and a follow-up text message.

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<sup>1</sup> Four participants were excluded at baseline due to elevated ADHD symptoms not at full diagnostic threshold.

<sup>2</sup> One participant received diaries via email, as requested, due to poor mobile service.

The next day, eligible participants started the mobile daily diary protocol where they reported on prior day's alcohol and drug use and psychosocial risk and protective factors for 14 consecutive days. A two-week surveying period balances the need to obtain a sufficient number of reports per participant to characterize typical experiences with the need to minimize participant burden (Eisele et al., 2022; Goodman et al., 2022). Surveys were sent via text messages that contained individualized links, with up to 5 reminders per day. The first text message arrived at 8:50 AM ET and the last text message arrived at 3:45 PM ET.<sup>3</sup> Surveys took between 5 and 10 minutes to complete.

### Measures

**Demographics.** Demographic characteristics were collected via self-report during the baseline session. Participants reported on assigned sex at birth (male/female), race and ethnic identity, and socioeconomic status (SES; defined to participants as “Low-income or poor” “Working-class” “Middle-class” “Upper-middle or professional-middle” “Wealthy”).

**Alcohol Use Screener.** The Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993) was administered on the phone assessment to determine hazardous drinking behaviors, consistent with study eligibility criteria. See Appendix A for all items. The AUDIT is a 10-item brief screening instrument designed to assess high-risk drinking and related impairments in the past year (Bohn et al., 1995). A higher total score indicates more alcohol-related problems and higher risk of AUD. All participants in the current study met or exceeded developmentally

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<sup>3</sup> To optimize recall and compliance, we designed the daily diary surveys to open before the start of most university classes and to close before the start of most local happy hours.



appropriate cut-off scores for identifying high-risk college drinkers (i.e., 7+ for males and 5+ for females; DeMartini & Carey, 2012).

**Semi-Structured Adult ADHD Interview.** The Adult ADHD Clinical Diagnostic Scale (ACDS; Kessler et al., 2010) was used to assess clinically significant current (i.e., past 12 months) and childhood (i.e., prior to 12 years of age) ADHD symptoms. See Appendix B for all items. The ACDS is a semi-structured interview administered by rigorously trained and supervised master's- and doctoral-level assessors ( $n = 3$ ), supervised by a licensed clinical psychologist. Assessors met reliability criterion on the ACDS ( $k > 0.80$ ). Cases were reviewed by both an advanced clinical psychology doctoral student and a licensed clinical psychologist with extensive experience in the assessment and treatment of ADHD. ADHD diagnostic status, derived from the ACDS, was used to determine group membership (i.e., ADHD versus control), in line with inclusion/exclusion criteria described previously.

**Daily Alcohol Demand.** We used 3 indices of daily alcohol demand, derived from a hypothetical Alcohol Purchase Task (APT; Kaplan et al., 2018; Murphy et al., 2009) and modified from prior work (Merrill & Aston, 2020), to capture key aspects of alcohol demand. Intensity was measured by the item: "If drinks were free today/tonight, how many would you have?" (response options from 0-10+, in single drink increments). Omax was measured by the item: "What is the maximum total amount you would spend on drinking today/tonight?" (response options from \$0 to \$140+, in \$4 increments). Breakpoint was measured with the item: "What is the maximum you would pay for a single drink today/tonight?" (response options from \$0 to over \$20, in \$2 increments). Higher scores on each item reflect greater state-level alcohol demand. See Appendix C for items.

**Daily Substance-Free Activity Engagement.** Substance-free activity engagement was measured using a series of daily time allocation questions. See Appendix C for all items. Each day, participants were asked to approximate how much time they spent the prior day engaging in a

pre-populated series of activities, while not under the influence of drugs or alcohol. Participants were instructed to round to the closest half an hour time increment, with 15 minutes rounded up to 30 minutes. To prompt recall, participants viewed an initial prompt stating: “Now we’re going to get a little more detailed about some of the things you did yesterday while you were not drinking or using drugs, or under the influence of alcohol or drugs.” Following the recall prompt, participants were presented with the instructions: “Yesterday, about how many hours did you spend engaging in the following activities without alcohol, drugs, or being under the influence of alcohol or drugs?” Participants reported time allocation across a series of substance-free activity domains, with each domain including multiple developmentally appropriate examples to support item clarity. In each prompt, participants were allowed to indicate that they did not do that activity. They were also reminded of the desired reporting period, “Yesterday = between waking up and going to bed.”

In the current study, we derived two subscales of daily substance-free engagement based on prior research showing specific substance-free activities to be associated with lower rates of substance use and hazardous drinking among young adults (Murphy et al., 2006; Murphy & MacKillop, 2006) and to be impaired among individuals with ADHD (Garcia et al., 2012; Knouse et al., 2008; Langberg et al., 2011; Merrill et al., 2020; Nigg et al., 2020). First, given the well-documented salience of close social relationships in adolescent and emerging adult development (Giletta et al., 2021), we derived a social substance-free connection variable, comprised exclusively of hours spent connecting with close relational partners (“Yesterday, about how many hours did you spend connecting with close people in your life, like hanging out with friends, romantic partners, family members, without drinking, using drugs, or being under the influence of drugs or alcohol?”). Second, we derived a substance-free activity engagement variable, comprised of time spent in substance-free activities supporting social connection, goal-directed behavior, and health/wellness: substance-free social (e.g., “having a meal with friends, dating, going to a

party, asking for help/advice, talking about daily activities”), academic (e.g., “studying, going to class, doing homework, volunteering in a research lab”), hobby (e.g., “painting, crafts, playing an instrument, photography”), wellness/religious (e.g., “mindfulness, yoga, meditation, religious service, time in nature, hiking”), and intimacy (e.g., “kissing, hooking up, having sex”) activities. Of note, the substance-free activity engagement variable is not equivalent to total hours spent not under the influence of alcohol or drugs, as one can engage in other substance-free activities (e.g., commuting, social media, watching TV alone) that are not necessarily considered to promote positive reinforcement for adaptive behaviors.

**Daily Substance-Free Enjoyment.** Substance-free enjoyment was assessed via daily ratings using a 5-point Likert scale of 0 (unpleasant or neutral) to 4 (extremely pleasant), adapted from the Adolescent Reinforcement Survey Schedule (ARSS; Hallgren et al., 2016). See Appendix C for all items. We created a total substance-free enjoyment variable, comprised of daily responses to the prompt: “Yesterday, how much did you enjoy the time you spent without being under the influence of drugs or alcohol?” We also created a social substance-free enjoyment variable, given the large body of work supporting social network influences on drinking across diverse adolescent and young adult populations (Acuff et al., 2020; Cheong et al., 2021; Henneberger et al., 2021; Murphy & MacKillop, 2006). Participants rated their social substance-free enjoyment on the following item: “Yesterday, about how much did you enjoy connecting with close people in your life, like hanging out with friend(s)/romantic partner/family, without being under the influence of drugs or alcohol?” Higher scores indicate more daily substance-free enjoyment.

**Behavioral Activation.** Behavioral activation was assessed using a modified version of the Behavioral Activation for Depression Scale – Short Form (BADSF; Manos et al., 2011). See Appendix C for the full measure. This is a 9-item questionnaire intended to measure engagement in approach behaviors that increase the likelihood of adaptive sources of response contingent

positive reinforcement from the environment. Importantly, this measure includes key components of behavioral activation: 1) engaging in focused, goal-directed behavior and completion of scheduled activities and 2) experiencing aversive controlling stimuli and engaging in escape and avoidant behavior (Manos et al., 2011). Item prompts were modified slightly for daily use such that each prompt began with “Yesterday...” (e.g., “yesterday, I made good decisions about what types of activities and/or situations I put myself in”), as the original measure assesses changes in past-week behaviors (Kanter et al., 2007). All items were rated using a 7-point Likert scale from 0 (Not at all) to 6 (Completely), with a higher total score indicating more daily behavioral activation.

Daily Alcohol Use. Quantity of alcohol consumed was measured with the item: “How many standard drinks in total did you have yesterday?” The item also contained a note with standard drink quantities to facilitate accurate reporting: “(1 drink = 12 fl oz/can of regular beer = 8-9 fl oz of malt liquor = 5 fl oz of wine = 1.5 fl oz shot of liquor).” Participants were reminded of the desired reporting period: “Yesterday = between waking up and going to bed.” A total score was created for each day representing the total number of standard drinks consumed that day. See Appendix C for item.

Daily Alcohol-related Negative Consequences. Alcohol-related negative consequences were assessed daily using select items derived from the Brief Young Adult Alcohol Consequences Questionnaire (BYAACQ; Kahler et al., 2005). See Appendix C for all items. Items were modified for daily use and were presented as a checklist that began with: “Please check all that apply to your drinking yesterday.” Items selected for inclusion were among the highest frequency items reported in a prior study on college student drinkers with ADHD (Meinzer et al., 2021) and theoretically linked to hypothesized impairments in ADHD (e.g., “I took foolish risks while drinking”, “I failed to do something that was expected of me because of drinking”). Consistent

with standard measurement of alcohol-related negative consequences (Kahler et al., 2005), a total score was created for each day by summing the number of endorsed items, with higher scores indicating more daily alcohol-related negative consequences.

## Chapter 3: Results

### Analytic Overview

Following examination of descriptive statistics, a series of multilevel path models were conducted in Mplus (version 8), with day at Level 1 nested within person at Level 2. Multilevel path models accommodate the hierarchical data structure, incorporate a sandwich estimator to help adjust for non-normality in the data, and simultaneously model dependent variables (Heck & Thomas, 2020). In this approach, there is an implicit parcellation of variation between and within clusters as latent-type constructs. That is, observed variables are assumed to be jointly caused by both within- and between-person cluster variations, which are each modeled as latent variables (Sadikaj et al., 2021).

We included theoretically relevant covariates in all statistical models. Given documented sex differences in alcohol use and substance-free reinforcement indices (Becker & Chartoff, 2019; Salvatore et al., 2017), self-identified sex was modeled as a Level 2 covariate in all analytic models. Recognizing that current SES contributes to accessibility and availability of environmental rewards (Leventhal et al., 2015), self-reported SES was also modeled as a Level 2 covariate in all analytic models. At the daily level, day in study (i.e., 1-14) and a dummy variable representing weekend (i.e., Friday or Saturday) were included as Level 1 covariates in all models given documented differences in alcohol use on weekends versus weekdays (Finlay et al., 2012). In all analytic models, Level 1 continuous predictors (e.g., alcohol demand, substance-free reinforcement indices, behavioral activation), were person-centered. This allowed us to test whether deviations above or below a given person's average daily levels of alcohol demand,

substance-free reinforcement, and behavioral activation corresponded to individual-level changes in average daily alcohol use and alcohol-related negative consequences.

To test the first research question, ADHD was regressed on daily diary reports of alcohol demand, substance-free activity engagement, substance-free enjoyment, and behavioral activation in separate models. To test the second research question, daily diary reports of alcohol demand, substance-free activity engagement, substance-free enjoyment, and behavioral activation were modeled as independent predictors of same-day alcohol use and alcohol-related negative consequences in separate models, with alcohol use and negative consequences modeled as simultaneous outcome variables. In these models, we included random intercepts and fixed slopes. To test the third research question, we specified random intercepts and random slopes, such that within cluster variation in the strength of associations among predictor and outcomes comprised latent variables at the between-person level, with each latent variable regressed on ADHD (Sadikaj et al., 2021). This allowed us to evaluate in separate models whether ADHD moderated the within-person effect of daily alcohol demand, substance-free activity engagement, substance-free enjoyment, and behavioral activation (person-centered) on alcohol use and alcohol-related negative consequences. All models were just identified where the number of free parameters exactly equaled the number of variances and unique covariances; thus, models were all perfectly fit to the data.

### Descriptive Statistics

See Table 1 for demographic and descriptive statistics. On average, drinkers with ADHD were younger than non-ADHD controls, though the average age of all drinkers with below 21 years. Compliance was outstanding, with participants completing 98.20% ( $n=1,388$ ) of all possible daily diaries (i.e., out of 1,414). The minimum number of daily diary surveys completed was 12 of 14 days. There were no significant differences in completion rates between participants with and

without ADHD (ADHD: 97.90% completed; Controls: 98.40% completed;  $r=-0.02$ ,  $p=0.50$ ).

Bivariate correlations at the within and between person levels and intraclass correlation coefficients (ICC) were calculated for daily diary variables (Table 2). ICCs ranged from 0.09-0.57, meaning that much of the variability in study variables was attributable to change at the individual level (i.e., between 43% – 91% of the variance was due to within-person change).

Approximately 43% ( $n=607$ ) of days were drinking days, with participants reporting between 1-14 drinking days over the two-week period ( $M=6.12$ ,  $SD=2.75$ ). Participants with ADHD reported significantly more drinking days than participants without ADHD ( $M=6.76$ ,  $SD=3.23$ ; Controls:  $M=5.52$ ,  $SD=2.10$ ;  $p=0.03$ ). Participants reported consuming between 1 and 30 drinks per drinking day, with an average of 5 drinks per drinking day ( $M=5.50$ ,  $SD=4.19$ ; ADHD:  $M=5.35$ ,  $SD=4.37$ ; Controls:  $M=5.68$ ,  $SD=3.94$ ). Alcohol-related negative consequences ranged from 0-10, with approximately 44% (ADHD) and 38% (Controls) of drinking days resulting in one or more proximal negative consequence. Results from a descriptive multilevel path model evaluating the effect of ADHD on average daily alcohol use and alcohol-related negative consequences (modeled as simultaneous outcome variables) showed that, on average, ADHD was associated with more alcohol-related negative consequences ( $b=0.37$ ,  $SE=0.16$ ,  $p=0.02$ ), with no significant association among ADHD and average daily alcohol use ( $b=0.28$ ,  $SE=0.27$ ,  $p=0.30$ ), controlling for sex, current SES, weekend, and day in study.<sup>4</sup>

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<sup>4</sup> Males reported higher average daily alcohol use ( $b=1.24$ ,  $SE=2.60$ ,  $p<0.001$ ) but females reported more average daily alcohol-related negative consequences ( $b=-0.38$ ,  $SE=.17$ ,  $p=0.02$ ). Current SES was associated with alcohol-related negative consequences ( $b=-0.22$ ,  $SE=1.17$ ,  $p=0.10$ ), such that participants with lower SES endorsed more alcohol-related negative consequences but did not significantly differ in average daily alcohol use. Within person, weekend (Friday and Saturday) was associated with higher average alcohol use ( $b=3.94$ ,  $SE=0.33$ ,  $p<0.001$ ) and more alcohol-related negative consequences ( $b=0.55$ ,  $SE=0.10$ ,  $p<0.001$ ).



*Aim 1: Associations among ADHD and Alcohol Demand, Substance-Free Reinforcement, and Behavioral Activation*

See Table 3 for model results. There were no significant associations among ADHD and average daily alcohol demand (Intensity:  $b=0.18$ ,  $SE=0.31$ ,  $p=0.55$ ;  $O_{\max}$ :  $b=-0.76$ ,  $SE=1.03$ ,  $p=0.46$ ; Breakpoint:  $b=-0.31$ ,  $SE=0.38$ ,  $p=0.41$ ) or average daily hours spent in substance-free social, academic, hobby, wellness/religious, and intimacy activities ( $b=-0.34$ ,  $SE=0.54$ ,  $p=0.53$ ). Relative to controls, participants with ADHD reported significantly less enjoyment from substance-free activities ( $b=-0.40$ ,  $SE=0.14$ ,  $p=0.003$ ) and substance-free social connection ( $b=-0.41$ ,  $SE=0.16$ ,  $p=0.01$ ). Participants with ADHD also reported lower levels of behavioral activation than did controls ( $b=-5.08$ ,  $SE=1.33$ ,  $p<0.001$ ).<sup>5</sup>

*Aim 2: Same Day Effects of Alcohol Demand, Substance-Free Reinforcement, and Behavioral Activation on Alcohol Use and Negative Consequences*

See Table 4 for model results. Within person, greater alcohol demand was associated with more alcohol use (Intensity:  $b=0.69$ ,  $SE=0.06$ ,  $p<0.001$ ;  $O_{\max}$ :  $b=0.16$ ,  $SE=0.02$ ,  $p<0.001$ ; Breakpoint:  $b=0.33$ ,  $SE=0.05$ ,  $p<0.001$ ). In other words, when an individual reported that they would consume

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<sup>5</sup> Males reported higher average daily alcohol demand intensity ( $b=1.00$ ,  $SE=0.31$ ,  $p=0.001$ ) whereas females reported more average daily substance-free activity engagement ( $b=-1.42$ ,  $SE=0.52$ ,  $p=0.01$ ) and substance-free social engagement ( $b=-1.18$ ,  $SE=0.35$ ,  $p=0.001$ ). Males reported more average daily behavioral activation ( $b=0.41$ ,  $SE=0.19$ ,  $p=0.03$ ). There were no significant differences among males and females in average daily  $O_{\max}$ , breakpoint, or substance-free enjoyment indices. Current SES was not significantly associated with any behavioral economic variables (i.e.,  $ps > 0.05$ ). Within person, weekend (Friday and Saturday) was significantly associated with higher average alcohol demand intensity ( $b=3.20$ ,  $SE=0.26$ ,  $p<0.001$ ),  $O_{\max}$  ( $b=7.76$ ,  $SE=0.66$ ,  $p<0.001$ ), breakpoint ( $b=2.41$ ,  $SE=0.22$ ,  $p<0.001$ ), substance-free social activity engagement ( $b=0.52$ ,  $SE=0.17$ ,  $p<0.01$ ), substance-free enjoyment ( $b=0.15$ ,  $SE=0.06$ ,  $p=0.01$ ), substance-free social enjoyment ( $b=0.11$ ,  $SE=0.05$ ,  $p=0.03$ ), and behavioral activation ( $b=0.24$ ,  $SE=0.07$ ,  $p<0.001$ ), but less average substance-free activity engagement ( $b=-1.19$ ,  $SE=0.20$ ,  $p<0.001$ ). Time in study was significantly associated with alcohol demand intensity ( $b=-0.06$ ,  $SE=0.02$ ,  $p=0.003$ ),  $O_{\max}$  ( $b=-0.07$ ,  $SE=0.03$ ,  $p=0.04$ ), breakpoint ( $b=-0.08$ ,  $SE=0.03$ ,  $p=0.01$ ), substance-free social engagement ( $b=-0.05$ ,  $SE=0.02$ ,  $p=0.01$ ) but not with substance-free activity engagement, substance-free activity enjoyment, or behavioral activation ( $ps > 0.05$ ).

more drinks that day if drinks were free (intensity), spend more money on alcohol ( $O_{\max}$ ), and pay more for a single drink (breakpoint) than they typically did, they reported consuming more alcohol. Additionally, within person, greater demand intensity and  $O_{\max}$ , but not breakpoint, corresponded to more alcohol-related negative consequences (Intensity:  $b=0.07$ ,  $SE=0.03$ ,  $p=0.01$ ;  $O_{\max}$ :  $b=0.02$ ,  $SE=0.01$ ,  $p=0.02$ ; Breakpoint:  $b=0.02$ ,  $SE=0.03$ ,  $p=0.48$ ). Across persons, average daily intensity and  $O_{\max}$ , but not breakpoint, were positively associated with alcohol use (Intensity:  $b=0.58$ ,  $SE=0.10$ ,  $p<0.001$ ;  $O_{\max}$ :  $b=0.06$ ,  $SE=0.03$ ,  $p=0.03$ ; Breakpoint:  $b=0.04$ ,  $SE=0.07$ ,  $p=0.63$ ). On average, participants who reported that they would consume more drinks if drinks were free (intensity) and spend more money on alcohol ( $O_{\max}$ ) also reported consuming more alcohol, compared to those who reported lower levels of intensity and  $O_{\max}$ , respectively. There were no significant associations among average daily alcohol demand and alcohol-related negative consequences between persons (Intensity:  $b=0.04$ ,  $SE=0.06$ ,  $p=0.44$ ;  $O_{\max}$ :  $b=0.01$ ,  $SE=0.02$ ,  $p=0.64$ ; Breakpoint:  $b=0.05$ ,  $SE=0.06$ ,  $p=0.43$ ).

Within person, more time spent in substance-free activities was associated with less alcohol use ( $b=-0.20$ ,  $SE=0.04$ ,  $p<0.001$ ) and fewer alcohol-related negative consequences ( $b=-0.06$ ,  $SE=0.02$ ,  $p<0.01$ ). That is, when an individual reported spending more time in substance-free social, academic, hobby, wellness/religious, and intimacy activities than they typically did, they reported consuming less alcohol and experiencing fewer negative consequences. Similarly, within person, more time engaged in substance-free social connection coincided with less alcohol use ( $b=-0.14$ ,  $SE=0.05$ ,  $p<0.01$ ) and fewer alcohol-related negative consequences ( $b=-0.06$ ,  $SE=0.02$ ,  $p<0.01$ ). In other words, when an individual reported spending more substance-free time connecting with close others than they typically did, they reported consuming less alcohol and experiencing fewer negative consequences. Across persons, there were no significant associations among average daily substance-free activity engagement and alcohol use (Total:  $b=0.02$ ,

$SE=0.04, p=0.59$ ; Social Connection:  $b=0.08, SE=0.07, p=0.26$ ) or alcohol-related negative consequences (Total:  $b=-0.02, SE=0.04, p=0.54$ ; Social Connection:  $b=-0.01, SE=0.04, p=0.85$ ).

Within person, there were no significant associations among substance-free enjoyment and alcohol use (Total:  $b=-0.05, SE=0.14, p=0.72$ ; Social:  $b=-0.08, SE=0.12, p=0.48$ ) or alcohol-related negative consequences (Total:  $b=-0.10, SE=0.09, p=0.45$ ; Social:  $b=0.003, SE=0.07, p=0.96$ ). Across persons, substance-free enjoyment was significantly negatively associated with alcohol-related negative consequences ( $b=-0.30, SE=0.12, p<0.01$ ), but not with alcohol use ( $b=0.10, SE=0.15, p=0.49$ ). On average, participants who derived more daily enjoyment from their substance-free activities also reported fewer alcohol-related negative consequences, compared to those who reported lower levels of substance-free enjoyment. Across persons, there were no significant associations among average daily substance-free social enjoyment and alcohol use ( $b=-0.08, SE=0.12, p=0.48$ ) or alcohol-related negative consequences ( $b=-0.18, SE=0.12, p=0.12$ ).

Within person, higher average daily behavioral activation was associated with more alcohol use ( $b=0.04, SE=0.02, p=0.03$ ) but fewer alcohol-related negative consequences ( $b=-0.02, SE=0.01, p=0.01$ ). In other words, when an individual reported more behavioral activation than they typically did, they reported consuming more alcohol but experiencing fewer negative consequences. Across persons, average daily behavioral activation was negatively associated with alcohol-related negative consequences ( $b=-0.04, SE=0.01, p<0.001$ ) but not with alcohol use ( $b=0.003, SE=0.02, p=0.85$ ). On average, participants who reported more daily behavioral activation also reported fewer negative consequences, compared to those who reported less behavioral activation.

### *Aim 3: Moderating Effect of ADHD*

There were no significant moderating effects of ADHD on within-person daily associations among (1) alcohol demand and alcohol use and alcohol-related negative consequences, (2) either substance-free reinforcement indices (i.e., engagement and enjoyment) and alcohol use and alcohol-related negative consequences, (3) or behavioral activation and alcohol use and alcohol-related negative consequences. See Table 5 for model results.

## Chapter 4: Discussion

### Overview and Descriptives

There is a pressing need for novel, theoretically sound approaches to inform prevention and intervention of AUD among college student drinkers with ADHD. Behavioral economic theory articulates a reinforcer pathology model whereby individuals engaging in hazardous alcohol use tend to overvalue alcohol as a reinforcer and undervalue substance-free activities whose reinforcing properties often occur over time delay (Bickel et al., 2014). Under this umbrella, key etiological and maintenance factors of AUD include alcohol demand, substance-free reinforcement indices (i.e., enjoyment and engagement), and behavioral activation. The current study is the first to map the influence of these factors onto alcohol use and alcohol-related negative consequences within a person's daily life, as well as among drinkers with versus without ADHD. Results expose areas of daily impairment specific to drinkers with ADHD that have the potential to directly inform AUD prevention and intervention.

Descriptive models showed that, on average, drinkers with ADHD experienced more alcohol-related negative consequences than drinkers without ADHD. Although this finding is consistent with prior work (e.g., Rooney et al., 2012), this is the first study to use robust daily diary methodology, include a control group engaging in hazardous drinking, and simultaneously account for average daily alcohol use in modeling negative consequences. In so doing, we fill a meaningful literature gap, as all known prior work on alcohol use among college students with ADHD has relied on cross-sectional designs, included lighter drinking samples, and/or asked participants to abstract their drinking to "typical" levels over time delay (e.g., past month/year; Baker et al., 2012; Mochrie et al., 2020; Rooney et al., 2012) – an approach that is subject to

reporting bias in populations characterized by ADHD features (e.g., forgetfulness). While speculative, it is possible that drinkers with ADHD, relative to neurotypical peers, are more likely to combine drugs and alcohol, employ fewer harm reduction strategies, or attribute more problems to their drinking than those without ADHD. Research on co-occurring alcohol and drug use among drinkers with ADHD in addition to work specifying highest frequency negative consequences can directly map onto interventions aimed at reducing harm. Of note, although not the focus of the current study, we also found that drinkers with ADHD reported more weekday drinking episodes (Sunday – Thursday) than non-ADHD controls. Future work should directly evaluate timing of drinking episodes and next-day responsibilities, which will further develop a complete understanding of how and why drinkers with ADHD experience negative consequences. Finally, our high compliance rates provide proof-of-concept support for utilizing daily diary methodology among populations with characteristic difficulties with follow-through (e.g., young people with ADHD). Such methodology has tremendous potential in providing timely insights that inform theory as well as interventions delivered to the right people at the right time (NOT-DA-23-006).

### *Behavioral Activation*

On average, drinkers with ADHD reported less daily behavioral activation than non-ADHD controls, defined as more daily avoidance and aversive experiences and lower levels of engagement in focused, goal-directed behavior and completion of scheduled activities (Manos et al., 2011). Perhaps drinkers with ADHD perceive efforts to engage in important, goal-directed approach behaviors as burdensome and effortful or are less confident in their ability to deploy cognitive-behavioral strategies to achieve effortful rewards. This possibility is consistent with prior work showing that individuals with ADHD demonstrate more avoidant coping and difficulties in task persistence, effort regulation, and social skills compared to their neurotypical

peers (Barkley, 1997; Knouse & Mitchell, 2015). Relatedly, prior work shows that ADHD-related impairments in social and academic domains can limit a person's perceptions of their life options, potential, and sense of achievement and direction (Meaux et al., 2009; Ramsay, 2002). Future research should directly test whether behavioral activation is a mechanism contributing to alcohol-related negative consequences among college drinkers with ADHD. Furthermore, drinkers with ADHD may require a repertoire of compensatory strategies to support behavioral activation (e.g., organizational skills, planning, time management, technology supports) and to effectively reduce alcohol-related harm (Oddo, Meinzer, et al., 2021).

Regardless of ADHD status, participants who reported less daily behavioral activation experienced more alcohol-related negative consequences, compared to those who reported more behavioral activation. Within person, when an individual reported more behavioral activation than they typically did, they also reported consuming more alcohol, but experienced fewer alcohol-related negative consequences. These findings are the first to directly link behavioral activation to alcohol-related negative consequences both across participants and at the individual level. Of note, our within-person finding that more behavioral activation was associated with more alcohol use, but fewer negative consequences is somewhat counterintuitive. However, the behavioral activation measure used in the current study (BADs) did not specify substance-free behaviors; thus, it is possible that we also captured substance-related activities. In fact, some adaptive and goal-directed activities in college can involve drinking, for example social dinners, happy hours, celebrations. Alcohol use in these settings may be moderated by norms and expectancies that constrain drinking to non-impairing levels. Future research should examine what, specifically, characterizes drinking episodes on days with high levels of behavioral activation.

### Substance-Free Reinforcement

Substance-Free Enjoyment. On average, drinkers with ADHD reported deriving less enjoyment from their daily substance-free experiences compared to non-ADHD counterparts. The constellation of ADHD symptoms and impairment may interfere with deriving enjoyment from substance-free experiences, as substance-free activities often involve effortful, goal-directed, and prosocial behaviors. These are likely to be aversive conditions for college students with ADHD, given the pathognomonic characteristics of ADHD (e.g., poor frustration tolerance, emotion dysregulation, avoidance/procrastination) interacting with college demands (e.g., unstructured time, minimal adult oversight and scaffolding, high academic and self-regulation demands). Our findings extend those of Knouse and colleagues (2008), who showed in an ecological momentary assessment study that community adults with elevated ADHD symptoms reported more general distress, higher levels of negative affect, and less satisfaction in daily living. It is possible that drinkers with ADHD experience more negative affect and stressors in daily life, which in turn limits their substance-free reward.

Regardless of ADHD status, participants who derived less enjoyment from their daily substance-free activities also reported more alcohol-related negative consequences, compared to those who reported higher levels of daily substance-free enjoyment. This between-person finding suggests that those who tended to derive less enjoyment from substance-free activities also tended to experience more negative consequences, relative to those who tended to derive more enjoyment from substance-free activities. Although speculative, drinkers who derive less daily enjoyment from substance-free experiences may be less concerned about the negative impact of their drinking on substance-free functioning. In a recursive cycle, experiences of alcohol-related negative consequences may also interfere with substance-free enjoyment and ultimately reinforce problematic drinking (Fazzino et al., 2019). Future research should evaluate the magnitude and



direction of associations among substance-free enjoyment, alcohol use, and alcohol-related negative consequences. Additionally, interventions for drinkers with ADHD should identify and scaffold substance-free experiences that are inherently rewarding and pleasurable (Oddo, Meinzer, et al., 2021).

**Substance-Free Activity Engagement.** Contrary to predictions, college drinkers with ADHD did not differ from non-ADHD controls in the amount of time spent in substance-free social, academic, hobby, wellness/religious, and intimacy activities. Although engaging in the same average daily amount of time in these substance-free activities, it is possible that drinkers with ADHD in our study engaged in these substance-free activities at aversive, stressful, and/or otherwise inopportune times (e.g., selecting to go to dinner with friends [substance-free social activity] instead of completing an important assignment [substance-free academic activity]). Two people may engage in the same substance-free behaviors (e.g., going to dinner with friends), but the function of those behaviors could be adaptive (e.g., unwinding after completing important schoolwork) or maladaptive (e.g., avoidance of difficult schoolwork). Ultimately, it is imperative that research combines multiple facets of reward and reinforcement to fully refine our understanding of areas of impairment that directly map onto nodes of intervention.

Regardless of ADHD status, participants who reported spending more time in these substance-free activities than they typically did also reported consuming less alcohol and experiencing fewer negative consequences. In the current study, we specifically asked about substance-free activities theorized to reinforce social connection, goal-directed behavior, and health/wellness. Therefore, our results extend prior research that has evaluated aggregate levels of substance-free behavior, abstracted to typical frequency of substance-free activity engagement (e.g., “sometimes” “often”) over longer timescale (Acuff et al., 2019). Findings are consistent with the idea that substance-free activities have the potential to effectively “compete with” alcohol use

(Murphy et al., 2006), yet our findings specify that this is only evident within a person. Our results directly map onto intervention strategies that facilitate change within a person by enhancing person-level substance-free activity engagement (Murphy et al., 2019). Therefore, the current study is strengthened by the use of analytic tools parceling effects across persons and at the individual level, which is an essential step in appropriately generalizing findings to interventions whose mechanisms of action occur within a person in their daily lives.

### *Alcohol Demand*

Contrary to predictions, we did not find significant differences among drinkers with and without ADHD in average daily alcohol demand (intensity, Omax, and breakpoint). There are several explanations for these findings, warranting additional investigation. Drinkers with ADHD in the current study were slightly younger, on average, than their non-ADHD peers. Perhaps alcohol demand, which is assessed via hypothetical expenditure, is less developmentally appropriate for younger students who are under the United States legal drinking age (Aston & Merrill, 2021). It may also be that drinkers with ADHD endorse elevated alcohol demand in certain situations, only. For example, drinkers with ADHD may experience more alcohol demand than their non-ADHD peers when involved in drinking contexts that are accompanied by salient reinforcers (e.g., stimulating drinking games, romantic partners, other social reinforcers) or minimal environmental constraints (e.g., alternative substance-free reinforcers, next-day responsibilities). Therefore, future research should identify contextual correlates of alcohol demand among college student drinkers with ADHD.

Regardless of ADHD status, participants who reported that they would consume more drinks that day if drinks were free (intensity), spend more money on alcohol (Omax), and pay more for a single drink (breakpoint) than they typically did also reported consuming more alcohol.

Additionally, across-persons, those with more average daily demand intensity and Omax, only, reported more average daily alcohol use compared those with less intensity and Omax. A similar pattern was observed with alcohol-related negative consequences at the individual level, only, with higher demand intensity and Omax associated with more negative consequences. Our results generally align with Motschman and colleagues (2022), who found at both the day- and event-levels that higher intensity, Omax, and breakpoint were associated with more total alcohol use, yet they did not evaluate negative consequences. The current study supports the utility of evaluating both alcohol use and negative consequences in models of daily alcohol demand, as each demand metric is theoretically distinct and can be used in daily analyses to refine theoretical accounts of addiction.

Indeed, cross-sectional principal component analyses have shown that alcohol demand consists of a two-factor structure, with one factor indexing a pure metric of drug value under no/minimal cost and the other factor indexing sensitivity to escalating drug price. The intensity metric loads onto the value factor whereas breakpoint loads onto the cost sensitivity factor; Omax is shown to load onto both factors (Hardy et al., 2021; MacKillop et al., 2009). These two-factor structures are considered to map onto theoretical accounts of addiction: a compulsion-based account whereby individuals do not incorporate the costs of alcohol into their decisions to drink, versus a value-based choice account whereby individuals place extremely high value on alcohol, which effectively overrides any alcohol-related cost consideration (Hardy et al., 2021). Interestingly, our findings are mostly strongly associated with the value-based choice account, as intensity and Omax evidenced the strongest and most consistent relations with alcohol use and alcohol-related negative consequences.

Of note, it is also possible that sensitivity to monetary costs for a single drink (i.e., breakpoint) is less developmentally appropriate for college students who are not fully employed and who

purchase alcohol in bulk. While we accounted for current SES in all models, future work should evaluate the unique effects of demand metrics on alcohol use and alcohol-related negative consequences, accounting for discretionary spending/allowance and typical purchase behavior. Moreover, perhaps there are social and contextual determinants of a person's willingness to spend more money on a single drink (i.e., breakpoint). For example, a person attending a concert with high drink prices may pay more for a single drink (breakpoint) but only purchase one drink – in this scenario, breakpoint is unlikely to meaningfully predict impairing alcohol use. Additional research should evaluate the unique contribution of daily alcohol demand on drinking behavior, above and beyond the effects of drinking environment, plans to drink, and drinking experiences (e.g., social reinforcers that augment alcohol's value).

### *Moderating Effects of ADHD*

Finally, results from our series of moderation analyses showed no significant moderating effects of ADHD. That is, drinkers with and without ADHD did not appear to differ in the magnitude of daily within-person associations between (1) alcohol demand and alcohol use and negative consequences, (2) substance-free reinforcement indices and alcohol use and negative consequences, or (3) behavioral activation and alcohol use and negative consequences. Instead, our findings suggest “upstream effects” of ADHD on select behavioral economic risk factors, such that ADHD contributes to impairment in domains of substance-free reinforcement and behavioral activation. Taken together, these significant main effects and non-significant moderating effects support future research identifying the specific ways in which a person's ADHD interferes with deriving substance-free enjoyment and behavioral activation. Such work has the potential to refine interventions, which remain largely undereffective for those with ADHD-related features (e.g., poor self-regulation, low future time orientation; Carey et al., 2007;

Soltis et al., 2018) and for those with elevated alcohol demand and low levels of substance-free reinforcement (Murphy et al., 2005, 2015).

### Limitations

Some limitations are important to consider. First, although we included weekend in all statistical models, we did not include specific next-day contingencies (e.g., academic or work obligations) that could shape drinking behavior, activity engagement, and alcohol demand. Second, our sample was largely collected during the coronavirus pandemic, though most students still lived independently of their caregivers and all students met drinking criteria for inclusion in the study. It is probably the case that individuals experienced a marked decline in environmental rewards during data collection and acquiring substance-free rewards required more effort than ever before. We therefore caution against generalizing findings to non-pandemic times, with the current findings requiring replication. Third, we did not include a full suite of alcohol-related negative consequences on the daily diaries due to our desire to keep surveys brief; thus, we may have failed to fully capture the frequency of negative consequences in the current sample. Finally, our sample contained a large group of male- and female-identified students who were White, non-Latina/o/e, and who attended a four-year institution in a large, metropolitan area. Replication efforts are imperative in order to understand these processes in additional samples with broader gender, racial, geographic, and economic representation.

### Conclusion

There is a pressing need for novel, theoretically sound approaches to inform prevention and intervention of AUD among college student drinkers with ADHD. The present study supports the

application of daily diary methodology to evaluating a behavioral economic reinforcer pathology model of alcohol use and alcohol-related negative consequences in college student drinkers with and without ADHD. On average, drinkers with ADHD experienced more daily alcohol-related negative consequences and less daily substance-free enjoyment and behavioral activation. Daily substance-free enjoyment and behavioral activation were each negatively associated with more alcohol-related negative consequences, regardless of ADHD status. Findings also highlight daily substance-free activity engagement and alcohol demand as relevant correlates of alcohol use and alcohol-related negative consequences within naturalistic contexts. Taken together, the current study is the first to identify upstream effects of ADHD on daily behavioral economic risk factors, with clear implications for AUD prevention and intervention. Future research identifying daily associations among environmental triggers and alcohol problems in an ecologically valid manner has tremendous potential to inform the development of adaptive interventions delivered to the right people at the right time.

# Appendices

## Appendix A: Screener Measure

### 1. Alcohol Use Disorders Identification Test (AUDIT)

- a. *How often do you have a drink containing alcohol?*
  - Never
  - Monthly or less
  - 2-4 times a month
  - 2-3 times a week
  - 4 or more times a week
- b. *How many standard drinks containing alcohol do you have on a typical day when drinking?*
  - 1 or 2
  - 3 or 4
  - 5 or 6
  - 7 to 9
  - 10 or more
- c. *How often do you have six or more drinks on one occasion?*
  - Never
  - Less than monthly
  - Monthly
  - Weekly
  - Daily or almost daily
- d. *During the past year, how often have you found that you were not able to stop drinking once you had started?*
  - Never
  - Less than monthly
  - Monthly
  - Weekly
  - Daily or almost daily
- e. *During the past year, how often have you failed to do what was normally expected of you because of drinking?*
  - Never
  - Less than monthly
  - Monthly
  - Weekly
  - Daily or almost daily

- f. *During the past year, how often have you needed a drink in the morning to get yourself going after a heavy drinking session?*
- Never
  - Less than monthly
  - Monthly
  - Weekly
  - Daily or almost daily
- g. *During the past year, how often have you had a feeling of guilt or remorse after drinking?*
- Never
  - Less than monthly
  - Monthly
  - Weekly
  - Daily or almost daily
- h. *During the past year, how often have you been unable to remember what happened the night before because you had been drinking?*
- Never
  - Less than monthly
  - Monthly
  - Weekly
  - Daily or almost daily
- i. *Have you or someone else been injured as a result of your drinking?*
- No
  - Yes, but not in the past year
  - Yes, during the past year
- j. *Has a relative or friend, doctor or other health worker been concerned about your drinking or suggested you cut down?*
- No
  - Yes, but not in the past year
  - Yes, during the past year



## Appendix B: Baseline Measures

### 1. Adult ADHD Clinical Diagnostic Schedule (ACDS) – Childhood

*For the next questions regarding your childhood, we are asking about the period of time before you became a teenager (i.e., prior to age 12), roughly the time corresponding to elementary or primary school.*

a. Makes a lot of careless mistakes

*Did you make a lot of careless mistakes at school? Did you often get problems wrong on tests because you didn't read the instructions right? Did you often leave some questions blank by accident? Forget to do the problems on both sides of a handout? How often did these types of things happen? Did your teacher ever say you should pay more attention to details?*

- Assessor Coding Options: Not present, Moderate: often failed to give close attention to details or made careless mistakes in schoolwork, work or other activities

b. Difficulty sustaining attention on tasks and/or play activities

*Has there ever been a time when you had trouble paying attention in school? Did it affect your schoolwork? Did you get into trouble because of this? When you were working on your homework, did your mind wander? What about when you were playing games? Did you forget to go when it was your turn?*

- Assessor Coding Options: Not present, Moderate: Often had difficulty sustaining attention in tasks or play activities

c. Doesn't listen

*Was it hard for you to remember what your parents and teachers said? Did your parents or teachers complain that you didn't listen to them when they talked to you? Did you "tune people out"? Did you get into trouble for not listening?*

- Assessor Coding Options: Not present, Moderate: Often did not seem to listen when spoken to directly

d. Difficulty following instructions

*Did your teachers complain that you didn't follow instructions? When your parents or your teachers told you to do something, was it sometimes hard for you to remember what they said to do? Did it get you into trouble? Did you lose points on your assignments for not following directions or not completing the work? Did you forget to do your homework or forget to turn it in? Did you get into trouble at home for not finishing your chores or other things your parents asked you to do? How often?*

- Assessor Coding Options: Not present, Moderate: Often did not follow through on instructions and failed to finish schoolwork, chores, or duties at home (not due to oppositional behavior or failure to understand instructions)

e. Difficulty organizing tasks

*Was your desk or locker at school a mess? Did it make it hard for you to find the things you needed? Did your teachers complain that your assignments were messy or disorganized? When you did your worksheets, did you usually start at the beginning and*

*do all the problems in order, or did you like to skip around? Did you often miss problems? Did you have a hard time getting ready for school in the morning?*

- Assessor Coding Options: Not present, Moderate: Often had difficulty organizing tasks and activities
  
- f. Dislikes/avoids tasks requiring sustained attention  
*Were there some kinds of schoolwork you hated doing more than others? Which ones? Why? Did you try to get out of doing your assignments? Did you pretend to forget about your homework to get out of doing it? About how many times a week did you not do your homework? Did your parents or teachers have to sit with you or closely monitor you in order for you to complete your homework?*  
- Assessor Coding Options: Not present, Moderate: Often avoided, disliked, or was reluctant to engage in tasks that required sustained mental effort such as homework
  
- g. Loses things  
*Did you lose things a lot? Your pencils at school? Homework assignments? Things around the house? About how often did that happen?*  
- Assessor Coding Options: Not present, Moderate: Often lost things necessary for tasks or activities (e.g., toys, school assignments, pencils, books, or tools)
  
- h. Easily distracted  
*Was there ever a time when little distractions would make it very hard for you to keep your mind on what you were doing? Like if another kid in class asked the teacher a question while the class was working quietly, was it ever hard for you to keep your mind on your work? When there was an interruption, like when the phone rang, was it hard to get back to what you were doing before the interruption? Were there times when you could keep your mind on what you were doing, and little noises and things didn't bother you? How often were they a problem?*  
- Assessor Coding Options: Not present, Moderate: Was often distracted by extraneous stimuli (e.g., attention often disrupted by minor distractions that other kids would be able to ignore)
  
- i. Forgetful in daily activities  
*Did you often leave your homework at home, or your books or coats on the bus? Did you leave your things outside by accident? Did you forget things in your daily routine, or need frequent reminders (e.g., brush teeth)? How often did these things happen? Did anyone ever complain that you were too forgetful?*  
- Assessor Coding Options: Not present, Moderate: Often was forgetful in daily activities
  
- j. Fidget  
*Did people often tell you to sit still, to stop moving, or stop squirming in your seat? Your teachers? Parents? Did you sometimes get into trouble for squirming in your seat or playing with little things at your desk? Did you have a hard time keeping your arms and legs still? How often?*  
- Assessor Coding Options: Not present, Moderate: Often fidgeted with hands or feet or squirmed in seat

- k. Difficulty remaining seated  
*Was there ever a time when you got out of your seat a lot at school? Did you get into trouble for this? Was it hard to stay in your seat at school? What about at dinnertime?*  
 - Assessor Coding Options: Not present, Moderate: Often left seat in classroom or in other situations in which required to be seated
- l. Runs or climbs excessively  
*Did you get into trouble for running down the halls in school? Did your parents often have to remind you to walk instead of run when you were out together? Did your parents or your teachers complain about you climbing things you shouldn't? What kinds of things? How often did this happen?*  
*(IF NECESSARY: When you were an adolescent, did you feel restless a lot? Feel like you had to move around, or that it was very hard to stay in one place?)*  
 - Assessor Coding Options: Not present, Moderate: Often ran about or climbed excessively in situations in which it was inappropriate; NOTE in adolescents, may be limited to a subjective feeling of restlessness
- m. Difficulty playing quietly  
*Did your parents or teachers often tell you to quiet down when you were playing? Did you have a hard time playing quietly?*  
 - Assessor Coding Options: Not present, Moderate: Often had difficulty playing or engaging in leisure activities quietly
- n. On the go/acts like driven by a motor  
*Was it hard for you to slow down? Could you stay in one place for long, or were you always on the go? How long could you sit and watch TV or play a game? Did people tell you to slow down a lot?*  
 - Assessor Coding Options: Not present, Moderate: Was often "on the go" or often acted as if "driven by a motor"
- o. Talks excessively  
*Did people say you talked too much? Did you get into trouble at school for talking when you were not supposed to? Did people in your family complain that you talked too much?*  
 - Assessor Coding Options: Not present, Moderate: Often talked excessively
- p. Blurts out answer  
*At school, did you sometimes call out the answers before you were called on? Did you talk out of turn at home? Answer questions your parents were asking your siblings? How often?*  
 - Assessor Coding Options: Not present, Moderate: Often blurted out answer before questions had been completed
- q. Difficulty waiting turn  
*Was it hard for you to wait your turn in games? What about in line in the cafeteria or at the water fountain*

- Assessor Coding Options: Not present, Moderate: Often had difficulty waiting his/her turn
  
- r. Interrupts or intrudes  
*Did you get into trouble for talking out of turn in school? Did your parents, teachers, or any of the kids you knew complain that you cut them off when they were talking? Did kids complain that you broke in on games? Did this happen a lot?*
- Assessor Coding Options: Not present, Moderate: Often interrupted or intruded on others (e.g., butted into conversations or games)
  
- s. Duration of childhood symptoms
  - Not present
  - Symptoms persisted at least 6 months
  - Other: \_\_\_\_\_
  
- t. Age of onset
  - Not present
  - Some inattentive and/or hyperactivity-impulsive symptoms that caused impairment were present before age 12
  - Other: \_\_\_\_\_
  
- u. Impairment in 2 or more settings (childhood)
  - Not present
  - Moderate: some impairment from the symptoms was present in at least two settings (e.g., at school, with peers, at home)
  - Other: \_\_\_\_\_
  
- v. Assess clinically significant impairment
  - Not present
  - Moderate: There must be clear evidence of clinically significant impairment in social, academic, and/or occupational functioning
  - Other: \_\_\_\_\_

## 2. Adult ADHD Clinical Diagnostic Schedule (ACDS) – Current

*Think about only the past twelve months, that is, since [month, year].*

- a. Makes a lot of careless mistakes  
*In the past 12 months...Do you make a lot of mistakes in school or at work? Is this because you're careless? Do you rush through your work or activities? Do you have trouble with detailed work? Do you not check your work? Do people complain that you're careless? Are you messy or sloppy? Is your desk or workspace so messy that you have difficulty finding things?*
- Assessor Coding Options: Not present, Moderate: often fails to give close attention to details or made careless mistakes in schoolwork, work or other activities

- b. Difficulty sustaining attention on tasks and/or play activities  
*In the past 12 months...Do you have trouble paying attention such as when watching movies, reading or listening to lectures? Or on fun activities such as sports or board games? Is it hard for you to keep your mind on school or work? Do you have unusual trouble staying focused on boring or repetitive tasks? Does it take a lot longer than it should to complete tasks because you can't keep your mind on the task? Is it even harder for you than some others you know? Do you have trouble remembering what you read and do you need to re-read the same passage several times?*
- Assessor Coding Options: Not present, Moderate: Often has difficulty sustaining attention in tasks or play activities
- c. Doesn't listen  
*In the past 12 months....Do people (your spouse, boss, colleagues, friends) complain that you don't seem to listen or respond (or daydream) when spoken to or when asked to do tasks? A lot? Do people have to repeat directions? Do you find that you miss the key parts of conversations because of drifting off in your own thoughts? Does it cause problems?*
- Assessor Coding Options: Not present, Moderate: Often does not seem to listen when spoken to directly
- d. Difficulty following instructions  
*In the past 12 months...Do you have trouble finishing things...work, chores? Do you often leave things half done and start another project? Do you need consequences (such as deadlines) to finish? Do you have trouble following instructions (especially complex, multi-step instructions that have to be done in a certain order with different steps)? Do you need to write down instructions, otherwise you will forget the task at hand?*
- Assessor Coding Options: Not present, Moderate: Often does not follow through on instructions and fails to finish schoolwork, chores, or duties at home (not due to oppositional behavior or failure to understand instructions)
- e. Difficulty organizing tasks  
*In the past 12 months...Do you have trouble organizing things into ordered steps? Is it hard prioritizing work and chores? Do you need others to plan for you? Do you have trouble with time management? Does it cause problems? Do you procrastinate and put off tasks until the last moment possible?*
- Assessor Coding Options: Not present, Moderate: Often has difficulty organizing tasks and activities
- f. Dislikes/avoids tasks requiring sustained attention  
*In the past 12 months...Do you avoid tasks (work, chores, reading, board games) that are challenging or lengthy because it's hard to stay focused on these things for a long time? Do you have to force yourself to do these tasks? How hard is it? Do you procrastinate and put off tasks until the last moment possible?*
- Assessor Coding Options: Not present, Moderate: Often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort such as homework

- g. Loses things  
*In the past 12 months...Do you lose things? (i.e. important work papers, keys, wallet, coats, etc.)? A lot? More than others? Are you constantly looking for important items? Do you get into trouble for this? (At work, home?) Do you need to put items (e.g. glasses, wallet, keys) in the same place each time, otherwise you will lose them?*  
 - Assessor Coding Options: Not present, Moderate: Often loses things necessary for tasks or activities
- h. Easily distracted  
*In the past 12 months...Are you ever very easily distracted by events around you such as noise (conversation, TV, radio), movement, or clutter? Do you need relative isolation to get work done? Can almost anything get your mind off of what you are doing...like work, chores or if you're talking to someone? Is it hard to get back to a task once you stop?*  
 - Assessor Coding Options: Not present, Moderate: Is often distracted by extraneous stimuli (e.g., attention often disrupted by minor distractions that other people would be able to ignore)
- i. Forgetful in daily activities  
*In the past 12 months....Do you forget a lot of things in your daily routine? Like what? Chores? Work? Appointments or obligations? Do you forget to bring things to work such as work materials or assignments due that day? Do you need to write regular reminders to yourself to do most activities or tasks, otherwise you will forget?*  
 - Assessor Coding Options: Not present, Moderate: Often forgetful in daily activities
- j. Fidgets  
*In the past 12 months...Can you still or are you always moving your hands, feet, or squirming in your chair? Do you tap your pencil or your feet? A lot? Do people notice? Do you regularly play with your hair or clothing? Do you consciously resist fidgeting or squirming?*  
 - Assessor Coding Options: Not present, Moderate: Often fidgets with hands or feet or squirmed in seat
- k. Difficulty remaining seated  
*In the past 12 months...Do you have trouble staying in your seat? At work? In class? At home, i.e. watching TV, eating dinner? In church or temple? Do you chose to walk around rather than sit? Do you have to force yourself to remain seated? Is it difficult for you to sit through a long meeting or lecture? Do you try to avoid going to functions that require you to sit still for long periods of time?*  
 - Assessor Coding Options: Not present, Moderate: Often leaves seat in classroom or in other situations in which required to be seated
- l. Restlessness  
*In the past 12 months...Are you physically restless? Do you feel restless inside? A lot? Do you feel more agitated when you cannot exercise on an almost daily basis?*  
 - Assessor Coding Options: Not present, Moderate: Often feels restlessness

- m. Difficulty playing quietly  
*In the past 12 months...Do you have a hard time playing quietly? During leisure activity (non-structured times or on your own such as reading a book, listening to music, playing a board game), are you agitated or dysphoric? Do you always need to be busy while on vacation?*
  - Assessor Coding Options: Not present, Moderate: Often has difficulty playing or engaging in leisure activities quietly
- n. On the go/acts like driven by a motor  
*In the past 12 months...Is it hard for you to slow down? Do you feel like you (often) have a lot of energy and that you always have to be moving, are always "on the go"? Do you feel like you are "driven by a motor"? Do you feel unable to relax?*
  - Assessor Coding Options: Not present, Moderate: Often "on the go" or often acts as if "driven by a motor"
- o. Talks excessively  
*In the past 12 months...Do you talk a lot? All the time? More than other people? Do people complain about your talking? Is it a problem? Are you often louder than the people you are talking to?*
  - Assessor Coding Options: Not present, Moderate: Often talks excessively
- p. Blurts out answer  
*In the past 12 months...Do you give answers to questions before someone finishes asking? Do you say things before it is your turn? Do you say things that don't fit into the conversation? Do you do things without thinking? A lot?*
  - Assessor Coding Options: Not present, Moderate: Often blurts out answer before questions are completed
- q. Difficulty waiting turn  
*In the past 12 months...Is it hard for you to wait your turn in conversation, in lines, while driving? Are you frequently frustrated with delays? Does it cause problems? Do you plan your day around not being in situations where you might have to wait?*
  - Assessor Coding Options: Not present, Moderate: Often has difficulty waiting his/her turn
- r. Interrupts or intrudes  
*In the past 12 months...Do you talk when others are talking without waiting until they're finished? Do you butt into others conversations before being invited? Do you interrupt others activities? Is it hard for you to wait to get your point across in conversations or meetings?*
  - Assessor Coding Options: Not present, Moderate: Often interrupts or intrudes on others (e.g., butted into conversations or games)
- s. Duration of adult symptoms
  - Not present
  - Symptoms persisted at least 6 months

- Other: \_\_\_\_\_
- t. Impairment in 2 or more settings (current)
  - Not present
  - Moderate: some impairment from the symptoms was present in at least two settings (e.g., at school, with peers, at home)
  - Other: \_\_\_\_\_
- u. Assess clinically significant impairment (current)
  - Not present
  - Moderate: There must be clear evidence of clinically significant impairment in social, academic, and/or occupational functioning
  - Other: \_\_\_\_\_



## Appendix C: Daily Diary Variables

### 1. Alcohol Use

*How many standard drinks in total did you have yesterday?*

- Response Options (drop-down menu): 1 – 50+, increments of 1 drink

### 2. Alcohol-Related Negative Consequences

*Please check all that apply to your drinking yesterday.*

- I did not drink alcohol yesterday.
- I have a hangover (e.g., less energy, tired, headache) this morning.
- I didn't go to work or missed class because of drinking or being hungover.
- I said or did embarrassing things while drinking.
- I took foolish risks while drinking.
- I got into sexual situations I later regretted because of drinking.
- I drank more than I planned.
- I was sick to my stomach or vomited because of drinking.
- I don't remember large stretches of time while drinking.
- I drove after drinking.
- I failed to do something that was expected of me because of drinking.
- The quality of my schoolwork suffered because of drinking.
- I got into a verbal argument with someone while under the influence.
- I got into a physical fight with someone while under the influence.
- I got rude, obnoxious, or insulting while drinking.
- I got down about myself after drinking.
- None of the above

### 3. Alcohol Demand

*Intensity: If drinks were free today/tonight, how many would you have?*

- Response Options (drop-down menu): 0 – 10+, in increments of 1 drink

*O<sub>max</sub>: What is the maximum total amount you would spend on drinking today/tonight?*

- Response Options (drop-down menu): \$0 – Over \$40, in increments of \$4

*Breakpoint: What is the maximum you would pay for a single drink today/tonight?*

- Response Options (drop-down menu): \$0 – Over \$20, in increments of \$2

### 4. Substance-Free Activity Engagement

*Yesterday, about how many hours did you spend engaging in the following activities without drugs/alcohol or being under the influence of drugs or alcohol?*

- Response Options (drop-down menu for each item): 0 – 24 hours, in increments of 0.5 (i.e., half an hour)
- Social Activities (e.g., having a meal with friends, dating, going to a party, asking for help/advice, talking about daily activities)
- Academic Activities (e.g., studying, going to class, doing homework, volunteering in a research lab)
- Employment Activities (e.g., on/off campus job, internship)
- Wellness/Religious Activities (e.g., mindfulness, yoga, meditation, religious service, time in nature)

- Performing a Hobby (e.g., painting, crafts, playing an instrument, photography)
- Intimacy Activities (e.g., kissing, hooking up, having sex)

5. Substance-Free Activity Enjoyment

*Yesterday, how much did you enjoy the time you spent without drugs/alcohol or being under the influence of drugs or alcohol?*

- Response Options (select one): I did not spend any time without being under the influence; Unpleasant or neutral; Mildly pleasant; Moderately pleasant; Very pleasant; Extremely pleasant

6. Behavioral Activation

- Response Options (select one for each item): 0 = Not at all, 1, 2 = A little, 3, 4 = A lot, 5, 6 = Completely

*Yesterday, there were certain things I needed to do that I didn't do.*

*Yesterday, I was content with the amount and types of things I did.*

*Yesterday, I engaged in many different activities.*

*Yesterday, I made good decisions about what type of activities and/or situations I put myself in.*

*Yesterday, I was an active person and accomplished the goals I set out to do.*

*Yesterday, most of what I did was to escape from or avoid something unpleasant.*

*Yesterday, I spent a long time thinking over and over about my problems.*

*Yesterday, I engaged in activities that would distract me from feeling bad.*

*Yesterday, I did things that were enjoyable.*

Table 1. Demographic Variables

Variable	ADHD N (%)	Non-ADHD Control N (%)	Full Sample N (%)
Participant Demographics			
Sex			
Female	22 (43.1)	27 (54.0)	49 (48.5)
Male	29 (56.9)	23 (46.0)	52 (51.5)
Racial/Ethnic Identification			
Asian	4 (7.8)	3 (6.0)	7 (6.9)
Black or African American	3 (5.9)	4 (8.0)	7 (6.9)
Hispanic/Latino	7 (13.7)	5 (10.0)	12 (11.9)
White (non-Hispanic/Latino)	36 (70.6)	33 (66.0)	69 (68.3)
> 1 Race	1 (2.0)	5 (10.0)	6 (5.9)
Age			
18	6 (11.8)	5 (10.0)	11 (10.9)
19	14 (27.5)	6 (12.0)	20 (19.8)
20	16 (31.4)	11 (22.0)	27 (26.7)
21	12 (23.5)	24 (48.0)	36 (35.6)
22	3 (5.9)	4 (8.0)	7 (6.9)
Mean Age*	20.39 years	20.88 years	20.64 years
Drinking Day Descriptives			
Mean Drinking Days (SD)*	6.76 (3.23)	5.52 (2.10)	6.12 (2.75)
Weekend Drinking Days	156 (46.0)	150 (56.2)	306 (50.5)
Weekday Drinking Days*	183 (54.0)	117 (43.8)	300 (49.5)

*Note.* \* =  $p < 0.05$ ; Drinking day descriptive values represent average percentages within each group (i.e., ADHD, control, full sample), calculated by number of reported instances divided by total number of reported instances for each variable. Weekend is coded as Friday-Saturday and Monday-Thursday.

Table 2. Intraclass Correlations and Within- and Between-Person Correlations among Average Daily Alcohol Use, Alcohol-Related Negative Consequences, Substance-Free Enjoyment, Substance-Free Activity Engagement, Behavioral Activation, Alcohol Demand

Variable	1	2	3	4	5	6	7	8	9	10
1. Alcohol consumption	-	-0.07	0.04	0.02	-0.04	-0.04	0.08	0.77**	0.12	-0.15
2. Alcohol-related negative consequences	0.48**	-	-0.36*	-0.21	0.02	0.08	-0.47**	0.001	0.03	0.14
3. Substance-free enjoyment	0.03	-0.02	-	0.81**	0.41**	0.35**	0.65**	-0.03	0.02	-0.01
4. Substance-free social enjoyment	0.02	-0.003	0.48**	-	0.42**	0.47**	0.58**	0.01	0.05	0.004
5. Substance-free activity engagement	-0.24**	-0.23**	0.19**	0.24**	-	0.79**	0.15	-0.14	-0.04	-0.06
6. Substance-free social activity engagement	-0.04	-0.10*	0.28**	0.34**	0.65**	-	0.18	-0.13	-0.10	-0.01
7. Behavioral activation	0.13**	-0.10*	0.28**	0.24**	0.11**	0.10**	-	-0.10	-0.04	-0.10
8. Demand intensity	0.62**	0.25**	0.04	0.01	-0.20**	0.05	0.11**	-	0.48*	0.18
9. Demand $O_{\max}$	0.49**	0.21**	0.07*	0.01	-0.15**	0.06	0.12**	0.71**	-	0.84
10. Demand breakpoint	0.40**	0.15**	0.04	0.03	-0.11**	0.09*	0.12**	0.59**	0.81**	-
ICC	0.09	0.28	0.45	0.45	0.40	0.37	0.57	0.23	0.26	0.28

Note. \* $p < 0.05$ , \*\*  $p < 0.01$ ; Upper triangle represents between-person correlations ( $N=101$ ), and lower triangle represents within-person correlations ( $n=1,414$ ). ICC = Intraclass correlation coefficient. All demand indices are lagged one day to reflect same-day associations.

Table 3. Predictors of Average Daily Substance-Free Enjoyment, Substance-Free Activity Engagement, Behavioral Activation, and Alcohol Demand

Predictor	Substance-Free Enjoyment <i>b</i> (S.E.)	Substance-Free Social Enjoyment <i>b</i> (S.E.)	Substance-Free Activity Engagement <i>b</i> (S.E.)	Substance-Free Social Engagement <i>b</i> (S.E.)	Behavioral Activation <i>b</i> (S.E.)	Demand Intensity <i>b</i> (S.E.)	Demand O <sub>max</sub> <i>b</i> (S.E.)	Demand Breakpoint <i>b</i> (S.E.)
Within Level Covariates								
Weekend	0.15 (0.06)*	0.11 (0.05)*	-1.19 (0.20)**	0.52 (0.17)**	1.53 (0.43)**	3.20 (0.23)**	7.76 (0.66)**	2.41 (0.22)**
Study Day	0.002 (0.01)	-0.02 (0.01)*	-0.001 (0.03)	-0.05 (0.02)**	0.001 (0.05)	-0.06 (0.20)**	-0.14 (0.07)*	-0.06 (0.02)*
Between Level Covariates								
Sex	0.01 (0.14)	-0.09 (0.16)	-1.42 (0.52)**	-1.18 (0.35)**	2.89 (1.33)*	1.00 (0.23)**	0.34 (1.04)	-0.33 (0.38)
Current SES	0.12 (0.08)	0.16 (0.10)	0.10 (0.41)	0.13 (0.30)	0.86 (0.76)	-0.09 (0.23)	0.52 (0.79)	-0.10 (0.23)
Between Level Predictor								
ADHD	-0.40 (0.14)**	-0.40 (0.16)**	-0.34 (0.54)	-0.04 (0.36)	-5.08 (1.33)**	0.18 (0.31)	-0.76 (1.03)	-0.31 (0.38)

*Note.* \* $p < 0.05$ , \*\*  $p < 0.01$ ; sex is coded as male=(1) and female=(0); weekend is coded as Friday-Saturday=(1) and Monday-Thursday=(0). All demand indices are lagged one day to reflect same-day associations.

Table 4. Same Day Effects of Alcohol Demand, Substance-Free Enjoyment and Engagement, and Behavioral Activation on Alcohol Use and Alcohol-Related Negative Consequences

Predictor	Alcohol Consumption			Negative Consequences		
	<i>b</i>	<i>SE</i>	<i>p</i> -value	<i>b</i>	<i>SE</i>	<i>p</i> -value
Within Level Predictors						
Substance-free enjoyment	-0.053	0.142	0.71	-0.067	0.086	0.44
Substance-free social enjoyment	-0.085	0.118	0.47	0.003	0.068	0.96
Substance-free activity engagement	-0.190	0.041	0.000	-0.052	0.017	0.002
Substance-free social activity engagement	-0.140	0.046	0.002	-0.056	0.019	0.003
Behavioral activation	0.041	0.018	0.02	-0.021	0.008	0.01
Demand Intensity	0.69	0.06	<0.001	0.07	0.03	0.01
Demand O <sub>max</sub>	0.16	0.02	<0.001	0.02	0.01	0.02
Demand Breakpoint	0.33	0.05	<0.001	0.02	0.03	0.48
Between Level Predictors						
Substance-free enjoyment	0.106	0.145	0.46	-0.300	0.115	0.01
Substance-free social enjoyment	0.102	0.179	0.57	-0.181	0.114	0.11
Substance-free activity engagement	0.019	0.043	0.68	-0.023	0.035	0.52
Substance-free social activity engagement	0.079	0.071	0.26	-0.010	0.038	0.79
Behavioral activation	0.003	0.015	0.84	-0.041	0.012	<0.001
Demand Intensity	0.58	0.10	<0.001	0.04	0.06	0.44
Demand O <sub>max</sub>	0.06	0.03	0.03	0.01	0.02	0.64
Demand Breakpoint	0.04	0.07	0.63	0.05	0.06	0.43

*Note.* For ease of visual presentation, predictors are simultaneously included in one table, but each model was run separately. Covariates are not depicted. All models included covariates sex (male/female), self-reported current socioeconomic status, and weekend versus weekday. All demand indices are lagged one day to reflect same-day associations.

Table 5. Between Level Moderation of ADHD on the Within Level Same-Day Associations Among Behavioral Economic Predictors and Alcohol Consumption and Alcohol-Related Negative Consequences

Interaction Term	Alcohol Consumption			Negative Consequences		
	<i>b</i>	<i>SE</i>	p-value	<i>b</i>	<i>SE</i>	p-value
Substance-free enjoyment*ADHD	0.29	0.30	0.34	-0.11	0.16	0.48
Substance-free social enjoyment*ADHD	-0.12	0.26	0.64	0.004	0.12	0.98
Substance-free activity engagement*ADHD	0.05	0.08	0.55	0.01	0.04	0.73
Substance-free social engagement*ADHD	-0.02	0.09	0.86	-0.03	0.03	0.37
Behavioral activation*ADHD	-0.02	0.04	0.64	-0.02	0.02	0.20
Demand Intensity*ADHD	0.03	0.09	0.73	0.04	0.05	0.40
Demand O <sub>max</sub> *ADHD	0.06	0.03	0.10	0.02	0.01	0.16
Demand Breakpoint*ADHD	0.20	0.12	0.09	0.02	0.04	0.55

*Note.* For ease of visual presentation, predictors are simultaneously included in one table, but each model was run separately. Covariates are not depicted. All models included covariates sex (male/female), self-reported current socioeconomic status, and weekend versus weekday, in addition to each main effect. All demand indices are lagged one day to reflect same-day associations.

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