WITHIN- AND BETWEEN-PERSON ANALYSES AND POTENTIAL MODERATORS OF THE PHYSICAL ACTIVITY-ALCOHOL CONSUMPTION RELATIONSHIP

by
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DEDICATION/EPIGRAPH

Dedicated to Kai, my beautiful nephew who fought hard before losing his life to Rett syndrome at 14 months of age. Thank you for teaching me resilience, unconditional love, and the value of research to help find treatments and cures for diseases.

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ABSTRACT

Drinking and physical activity behaviors established during college years may extend well into later adulthood. Counterintuitively, ample evidence demonstrates a positive association between physical activity (PA) and alcohol consumption (AC), in that individuals who drink more engage in more physical activity. Prior work has focused mainly on between-person analyses of the PA-AC association, while only a handful of studies have addressed within-person effects, which may yield a different pattern of the PA-AC relation. Because PA is increasingly recommended as an adjunctive treatment for alcohol use disorders, it is important to get a comprehensive understanding of the relationship between PA and drinking. Notably, recent research has revealed that impulsivity (IMP) moderated the between-person PA-AC association, and the literature suggests that religiosity (REL) is inversely related to alcohol intake. To this end, this project evaluated within- and between-person associations between PA and AC, paying particular attention to the potential moderating influences of IMP and REL. Participants, consisting of 250 undergraduate students between the ages of 18 and 25, were recruited from two Southwestern universities and were asked to take part in a 21-day diary study, documenting their daily PA and AC behaviors. PA was also tracked objectively through a smartphone app. Participants also filled out baseline (Day 1) and follow-up (Day 21) self-report measures of PA, AC, IMP and REL. Data analysis evaluated interactions between AC and PA and the influences of IMP and REL at the daily level (within-person) and at the person level (between-person). Results revealed that PA and AC were unassociated at neither within- nor between-person levels across 21 days. Similarly, PA and AC were unassociated at baseline or at follow-up. Further results revealed an inconsistent pattern of

interactions between facets of IMP and PA on drinking outcomes, suggesting differential moderating influences of some of the dimensions of IMP on the PA-AC association. However, no moderating effects of REL on the relationship between PA and AC were found. Findings may help address the challenges behind developing suitable multi-behavior interventions and health guidelines when a health-promoting behavior and a health risk behavior systematically covary among young adults in college.

Keywords: alcohol consumption, physical activity, within-person analyses, between-person analyses, impulsivity, religiosity

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INTRODUCTION

The overarching goal of this research was to examine within- and between-person associations between alcohol consumption (AC) and physical activity (PA) in young adult college students, paying particular attention to the potential moderating influences of the trait variables, impulsivity (IMP) and religiosity (REL). Specifically, the focus is to determine how PA and AC are associated, i.e., do individuals who are more physically active drink more or less on any given day? Do particular variables influence the strength and direction of the PA-AC relation? In recent years, research on the relationship between AC and PA has gained impetus, with consistent findings that individuals who drink more tend to engage in more physical activity than those who drink less (Conroy et al., 2014; French et al., 2009; Leasure & Neighbors, 2014; Piazza-Gardner & Barry, 2012). The vast majority of these studies have focused on between-person analyses of the association between PA and AC; however, within-person effects – possibly overlooked when aggregating variables onto several persons at one point in time - may yield a different pattern of the PA-AC relation. Research on within-person analyses of the PA-AC association is still in its infancy and the currently existing data is inconclusive. Therefore, it is crucial to explore within-person level analyses in addition to between-person analyses to better understand the PA-AC relation.

Alcohol Use and Abuse: Facts And Figures

The production and consumption of alcohol has existed for thousands of years and its prevalence in the United States is high: an estimated 86.3% of people 18 years and over reported drinking in their lifetime, 70% reported drinking in the past year, and 55% reported drinking in the past month (SAMSHA, 2018; as cited in NIAAA, 2020). Among the more popular reasons individuals consume alcohol are celebrating, socializing, and relaxing (NIAAA, 2018b); all rather positive reasons, but ironically, the aftermath of heavy alcohol consumption is often negative.

General consequences of alcohol use and abuse

Numerous years of research have confirmed that the effects of alcohol consumption vary from individual to individual depending on quantity, frequency, age, gender, overall health, and family history (NIAAA, 2018b). A large body of evidence points to the harmful consequences of heavy drinking, and according to the NIAAA (2018b), higher blood alcohol content (BAC) is associated with more severe impairments affecting a range of functions, e.g., decreased self-control, incoherent speech, loss of motor control, confusion, compromised memory, reduced concentration, and in extreme cases, coma, breathing problems, and death. Additionally, longer-term heavy drinking and binge drinking (Gowin et al., 2017) may result in the development of alcohol use disorders (AUD), a heightened risk for certain types of cancer and liver cirrhosis, brain damage (NIAAA, 2018a), and the development of Wernicke-Korsakoff syndrome (NIAAA, 2018b). Non-health related threats include aggressive and violent behavior, increased risk-taking, suicide, and road accidents (NIAAA, 2018b), e.g., in 2014,

alcohol-related driving fatalities resulted in approximately 10,000 deaths in the United States alone (NIAAA, 2020).

Globally, alcohol abuse represented the fifth leading factor for preventable deaths in 2010, and in 2012, 3.3 million deaths (7.6% for men – 4% for women) were attributable to drinking (NIAAA, 2020; WHO, 2018). In the United States, alcohol use currently represents the third leading preventable cause of death, with a likely 88,000 annual deaths. Alcohol dependence poses a public health threat, in that it compromises physical and mental health as well as individuals' perceptions and behaviors (Bjork & Gilman, 2014) leading to substantial societal and personal harms. The economic burdens are significant as well, with $249 billion expended in 2010 on alcohol-related problems, such as, health care, accidents, lack of productivity, and other consequences (Bjork & Gilman, 2014). Notably, three quarters of the total alcohol-related costs were associated with binge drinking (NIAAA, 2020).

Patterns of drinking and related consequences

There are different types of drinkers in the general population: low, moderate, binge and heavy drinkers (French et al., 2009). Patterns of drinking also differ among people, for instance, binge drinking is a pattern of alcohol intake characterized by a blood alcohol content of 0.08 gram % as well as the consumption of 4 or more drinks for adult women and 5 or more drinks for adult men within a 2-hour period, with 1 drink equivalent to 12 ounces of beer, 5 ounces of wine, and 1.5 ounces of spirits (NIAAA, 2020; Silveri et al., 2014). According to the NIAAA (2020), in 2018, nearly 27% of U.S. adults aged 18 years and above reported binge drinking in the past month. Heavy alcohol

use is another pattern of drinking characterized by binge drinking on 5 or more days in the past month (NIAAA, 2020). In the United States alone, 6.6% of people 18 years of age and over reported engaging in heavy alcohol intake in the past month (NIAAA, 2020). Both heavy alcohol use and binge drinking increase the risk of developing an AUD (NIAAA, 2020) and should be controlled effectively. Moreover, brain imaging attests to the damaging neural effects of heavy drinking (Mann et al., 2001; Pfefferbaum et al., 2001; Pfefferbaum et al., 2002; Sullivan & Pfefferbaum, 2005; Zahr et al., 2011).

The neural effects of binge drinking can be analogous to repetitive withdrawals from alcohol (Duka et al., 2004), resulting in both cognitive and emotional impairments in young adults. Duka and colleagues demonstrated that binge drinkers exhibited compromised cognitive performance and more negative mood states than non-binge drinking moderate social drinkers (Townshend & Duka, 2005; Weissenborn & Duka, 2003). For instance, binge drinkers made more mistakes in a spatial working memory task (Weissenborn & Duka, 2003), and compared with their male counterparts, female binge drinkers exhibited greater impairment on cognitive tasks requiring inhibitory control and sustained attention, suggesting damage to the frontal lobes (Townshend & Duka, 2005).

Moderate drinking, on the other hand, has been linked to some health benefits, such as, reduced risk of cardiovascular disease, types of stroke, diabetes (USDA, 2015), and anxiety and depression (Peele & Brodky, 2000), and is defined as up to 1 drink for women and up to 2 drinks for men per day (USDA and USDHHS, 2015). However, there is mixed research on the health benefits of moderate alcohol use. For instance, Topiwala et al. (2017) indicated that moderate alcohol consumption provided no protective factors

and that no amount of drinking is actually beneficial, whereas Zhang et al. (2020) demonstrated that low to moderate consumption of alcohol was associated with improved cognitive function as well as slower cognitive decline in middle-aged and older adults.

Although college drinking has seen a small decline in recent years (Keyes et al., 2019), heavy alcohol use and binge drinking remain a cause of concern among college students, who may start out as moderate drinkers and subsequently progress to heavier drinking. Therefore, research targeting young and often susceptible college student populations may help control the misuse of alcohol and its deleterious effects.

Why Focus on College Student Populations?

College years: a sensitive time period for establishing health behaviors

Emerging adulthood and the early college years represent an important developmental period met by numerous and rapid changes. With greater autonomy, identity development, and moving out of parents' homes, the years from late adolescence to emerging adulthood appear to be crucial for establishing healthy behaviors that may extend well into adulthood (Nelson et al., 2008).

In particular, the first couple of months of freshman year represent a more delicate time when new incoming students are met with academic and social pressures that may result in an augmented risk of drinking and negative alcohol-related consequences (NIAAA, 2019; Sher & Rutledge, 2007). Notably, studies have indicated that particular lifestyle patterns, e.g., maladaptive drinking, which are fostered in those early college years are likely to extend into later adulthood and become consolidated, thereby leading

to poorer health and, potentially, less successful intervention outcomes (Nelson et al., 2008; Williams et al., 2002).

College drinking and alcohol-related consequences

Historically, young emerging adults who attend college consumed more alcohol than non-college attending adults of the same age group (Slutske, 2005) perhaps because certain characteristics of college life, i.e., the accessibility of alcohol, more freedom and independence, and less interaction with parents, are conducive to increased drinking (NIAAA, 2019); but recently, the figures have changed with college goers aged 18 to 25 consuming less alcohol than their non-college attending peers (Keyes et al., 2019).

College students' patterns of alcohol consumption are typically characterized by binge drinking on weekends and light to no drinking on weekdays (Finlay et al., 2012; Maggs et al., 2011; Neighbors et al., 2011). Furthermore, specific events and holidays, e.g., Spring Break and 4th of July, are marked by increased college drinking and well as higher BACs compared with non-holiday weekends (Neighbors et al., 2011). According to past studies, college students who do not habitually drink heavily, but who abuse alcohol during specific events are more prone to experiencing negative alcohol-related repercussions (Lewis et al., 2009). Thus, understanding patterns of college drinking may help facilitate targeted prevention and intervention strategies geared toward alcohol reduction among college students.

Seemingly, the consequences of alcohol use in college are more dire than is usually perceived by parents, with recent figures demonstrating that college drinking – mainly pertaining to students aged 18 to 24 - is associated with approximately 1500

student fatalities, over 600,000 assaults, 97,000 sexual assaults cases, and date rape on a yearly basis; and this impacts both students who drink and those who do not drink but fall victim to drinkers (NIAAA, 2019). A 2018 report by the National Survey on Drug Use and Health (NSDUH) revealed that approximately 55% of college students between the ages of 18 and 22 reported drinking alcohol in the past month, over a third reported binge drinking in the past month, and 10% reported engaging in heavy drinking in the past month (NIAAA, 2019). Because young adults' prefrontal cortices only complete their development at around 25 years of age, they are particularly at risk of alcohol-induced neural and cognitive dysfunction (Spear, 2018). In a longitudinal study examining neural development of adolescent and emerging adult drinkers and non-drinkers (12-24 years old), Squeglia et al. (2015) performed MRI scans over 6 instances and found that, compared to non-drinkers, binge drinking adolescents deviated from the norm by exhibiting greater decreases in cortical gray matter and smaller increases in white matter in certain neural regions.

Consistent with this finding, student binge drinkers showed disrupted executive functioning relative to their non-drinking peers, suggestive of prefrontal cortex impairment (Parada et al. 2012). Importantly, for some individuals, binge drinking may indicate the development of future AUD. In a pharmacokinetically controlled study, Gowin and colleagues (2017) demonstrated that young adults who possessed certain risk factors, i.e., being male, having higher impulsivity, and a family history of alcoholism, were more likely to engage in binge drinking sessions and develop an AUD.

Therefore, college students' alcohol consumption should be controlled effectively and in a timely manner to prevent, 1- harmful health and societal consequences that may

emerge throughout college years, and, 2- the progression of alcohol abuse into later adulthood.

Physical activity among college students

The health benefits of PA are ample, and weekly engagement in a minimum of 75 minutes of vigorous PA or 150 minutes of moderate PA has been shown to improve health significantly (Kern et al., 2010). Physical activity in young adulthood is associated with improved academic performance (Singh et al., 2012), improved mental health (Chekroud et al., 2018), better sleep (Collings et al., 2015), and a decreased risk of developing obesity (Wareham et al., 2005).

In the transition from high school to college and throughout college years, students' alcohol and PA behaviors undergo significant changes (Calestine et al., 2017; Sher & Rutledge, 2007). A recent meta-analysis by Corder et al. (2019) showed that PA decreases considerably from adolescence to adulthood in individuals aged 13 to 30 years. Specifically, data from studies using self-report measures indicated an average decline of approximately 5 minutes (13%) of daily PA, whereas studies using accelerometers reported a decrease of over 7 minutes (17%) of daily PA (Corder et al., 2019). Furthermore, the literature indicates that college student physical activity exhibits a marked decrease (Bray & Born, 2004; Pinto & Marcus, 1995), with around 40% to 50% of college students engaging in little to no PA (Keating et al., 2005). In addition, it was reported that nearly one third of heavy drinking college students are sedentary (Luo et al., 2015).

Therefore, it is important to investigate both the behaviors of PA and AC and the association between them among college students to inform intervention methods geared toward improving health by decreasing drinking and increasing PA.

Clarifying Nomenclature: Definitions and Distinction between Physical Activity and Exercise

Throughout this project, physical activity (PA) was defined as a set of unstructured activities performed by an individual, resulting in energy expenditure that exceeds that individual's baseline; while exercise was characterized by a set of planned and structured physical activities executed purposely to improve fitness levels (Koeneman et al., 2011; Leasure et al., 2015). For the sake of clarity and accuracy, the term 'physical activity (PA)' was used in reference to all research undertaken in this current project, and 'exercise' was used when referring to either PA or exercise mentioned in other studies, keeping in mind that other studies often used both terms interchangeably. In animal research, for instance, the terms PA and exercise are generally used interchangeably because it is hard to say whether rodents that voluntarily choose running wheels and seem to 'enjoy' it are doing it with the intention of improving their fitness levels!

PA is a health behavior typically assessed using several methods, such as, self-report measures, diaries (which commonly include duration, intensity, and frequency of exercise (Caspersen et al., 1985)), and wireless-enabled wearable devices which objectively measure number of steps taken, calories expended, and total distance traveled. PA can comprise numerous distinct types ranging from light to vigorous activity,

including walking, aerobic exercise, and gym-based workouts (Asmundson et al., 2013). Norton et al. (2010) suggested a clear categorization of physical activity exertion by dividing PA into 5 intensity levels and placing types of activities that exert similar relative physiological stress on the body in the same level/category. Intensity levels with their corresponding objective and descriptive measures are displayed in Table 2. The metabolic equivalent (MET) values corresponding to these PA intensities were shown to be suitable for the majority of healthy adults aged 18 to 30 years (Norton et al., 2010), and are, thereby, applicable to this project's sample population. METs are typically used to estimate energy expenditure (Ainsworth et al., 2000; Colley et al., 2011), with 1 MET equal to 3.5 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$ and any activity that exceeds resting or being sedentary is then multiplied by 1 (Wagner, 2005). In the current project, we will focus primarily on moderate and vigorous PA levels.

Physical Activity and Its Neural Benefits

Studies on the neural benefits of PA indicate that overall quantity of PA, either in the form of a physically active lifestyle or specific types of exercise, plays a key role in determining the positive effects of PA on the brain (West et al., 2019). The many benefits of exercise span multiple systems in both animals and humans. In fact, research on both humans and animals attests to the widespread benefits of PA on overall brain and cognitive health. Regular exercise increases neurogenesis in the adult hippocampus and supports the survival of the nascent neurons (Snyder et al., 2009), therefore boosting cognition and, in particular, learning and memory. For instance, animal studies have shown that wheel running prompts hippocampal neurogenesis throughout all stages of

development (Hillman et al., 2008). In addition, developing animals that are physically active display better hippocampal functioning in adulthood (Gomes da Silva et al., 2012). Exercise also decreases inflammation and stress (Cotman et al., 2007; Stranahan et al., 2008), enhances learning and memory and executive functions, promotes the rapid production of glial cells (Mandyam et al., 2007), and allows the brain to recover more effectively post disease and injury (Lees & Hopkins, 2013; Li et al., 2013; Vaynman & Gomez-Pinilla, 2006; West et al., 2019). Imaging studies have shown a higher proportion of gray matter in the prefrontal cortex and temporal areas of physically active people, indicating enhanced executive functioning and learning and memory (Hillman et al., 2008). It was previously thought that aerobic exercise was unique in providing health benefits, but, more recently, other exercise regimens, such as resistance training and high-intensity interval training (HIIT, i.e., intermittent brief bouts of high intensity activity with periods of rest) have been associated with improved executive functioning (Tsukamoto et al., 2016) and spatial learning (Cassilhas et al., 2012).

The Rewarding Properties of Exercise and Drinking

In spite of alcohol having noxious effects on the brain, and in contrast, PA offering only neural advantages, both have overlapping effects on the neurobiological mechanism of reward (Leasure et al., 2015). Alcohol and exercise share common neurobiological mechanisms of reward (Werme et al., 2002). Both exercise, a substance-free activity, and alcohol, present as rewarding stimuli that activate the mesolimbic dopaminergic pathway leading to a cascade of events involving the projection of dopaminergic neurons from the ventral tegmental area to the nucleus accumbens and to

other forebrain regions implicated in reward (Ehringer et al., 2009; Greenwood et al., 2011). Greenwood et al. (2011) found that voluntary wheel-running in rats was rewarding, and consequently, exercised rats demonstrated a heightened interest in more exercise. On a neurobiological level, long-term (over six weeks) wheel-running elicited neuroplasticity, specifically, changes in gene transcription of mechanisms of reward and dopaminergic transmission (Greenwood et al., 2011). Long-term exercise also resulted in a significant rise in dopamine levels in various brain regions involved in reward (Greenwood et al., 2011). Similarly, Brené et al. (2007) reviewed the rewarding properties of exercise on the human brain and reported that as a result of running, a number of neurochemical changes took place in the neural reward system, namely a rise in dopamine, commonly known as the 'happy hormone'. Consequently, individuals who engaged in regular exercise were better equipped to fight depression and anxiety (Brené, et al., 2007; Brocardo et al., 2012).

Similarly, vast literatures attest to the reinforcing effects of alcohol on the brain's reward system, and in fact, alcohol shares the exact same mechanism used by exercise (Berridge, 2007; Robinson & Berridge, 1993; Spreckelmeyer et al., 2011; Yoder et al., 2009). In humans, PET studies have demonstrated a significant increase in dopamine levels in the nucleus accumbens following alcohol consumption (Spreckelmeyer et al., 2011). Interestingly, Berridge and colleagues (Berridge, 2007; Robinson & Berridge, 1993) showed that alcohol-related cues, as well, triggered the activation of dopaminergic neurons in the nucleus accumbens. In the same vein, in an fMRI study, Yoder et al. (2009) reported that reward regions in human brains were activated by stimuli that trigger

cravings, thereby demonstrating that in heavy alcohol users, the mere odor of an alcoholic beverage activated the nucleus accumbens.

With PA being a health behavior that almost exclusively offers benefits to the brain and body, and alcohol being a health risk behavior that rather damages both, especially if consumed in excess, the fact that PA and AC have consistently displayed a positive association is paradoxical and worth further examination.

The Relationship between Physical Activity and Alcohol Use

Between-person studies

A positive association between physical activity and alcohol consumption has been well-established, i.e., individuals who drink more tend to exercise more (Buscemi, 2011; Conroy et al., 2014; French et al., 2009; Leichliter et al., 1998; Lisha et al., 2011; Piazza-Gardner & Barry, 2012), and has been consistently observed among college students (Dunn & Wang, 2003; Kokotailo et al., 1996; Leichliter et al., 1998; Nattiv & Puffer, 1991). The first to identify a positive association between AC and PA in non-athletic collegiate sports were Smothers and Bertolucci (2001). The National Health Interview Survey they administered to several thousand U.S. adults revealed that persons who consumed alcohol moderately were twice as likely to engage in leisurely physical activity compared with non-drinkers (Smothers & Bertolucci, 2001). Excluding studies comprising persons with AUD in their samples, Dodge et al. (2017) systematically reviewed the direction of the PA-AC relationship among college students and non-student adults. They found that 7 of 8 studies with college student samples and 6 of 8 studies with non-student samples reported a positive association between PA and AC. In

the case of heavy and problematic drinking, some have reported a curvilinear association between PA and AC whereby PA peaks for moderate drinking. For instance, Lisha et al. (2013) found that PA is positively associated with less severe forms of AUD, but exhibits a curvilinear relationship with more severe forms of the disorder, possibly because severe AUD patients are incapacitated and unable to engage in any PA (Lisha et al., 2013).

In more recent years, the nature of the PA-AC relation at between-subject levels has been disputed, with some studies finding no association between PA and AC at between-person levels. For instance, in a two-week-long diary study, Henderson et al. (2020) investigated the association between moderate-to-vigorous PA, which was recorded objectively using accelerometers, and daily alcohol consumption among college students. Henderson et al. (2020) observed no between-person coupling of PA and AC, suggesting that, overall, individuals who engaged in more PA did not consume more alcohol. However, they did find that the between-person PA-AC relation was significantly moderated by social drinking motives, and negative and positive affect (Henderson et al., 2020), indicating the importance of including key explanatory variables when examining the PA-AC relationship. Indeed, the two health behaviors seem to be psychosocially linked in that several moderators and motives tend to influence their co-occurrence. For instance, Lisha et al. (2011) found that both age and gender acted as moderators of the PA-alcohol use relation, and they specifically demonstrated that the association was strongest in younger males in their twenties and weaker in adults over the age of fifty. In addition, motives such as sensation-seeking, guilt, and counterbalancing negative health effects have been suggested to influence the association (French et al., 2009; Leasure et al., 2015). And, in fact, Leasure and Neighbors (2014)

revealed a more robust relation between alcohol use and PA in individuals with greater sensation-seeking tendencies. Compensatory motives, in particular, appear to be frequent among emerging adults (Abrantes et al., 2017; Buchholz & Crowther, 2014), e.g., Abrantes et al. (2017) found that the between-person relationship between alcohol intake and exercise was significant only when factoring in the motive to burn off the extra calories consumed from alcohol. The focus of ongoing research by Neighbors, Henderson, Leasure, and Young (National Institute on Alcohol Abuse and Alcoholism Grant# R21AA026380) is on other possible motives, e.g., body image, guilt, stress, and the 'work hard, play hard' ethic, that may help explicate the relationship between PA and AC. Importantly, prior work has focused on between-individual associations of PA and AC, and only recently have considerations of within-individual effects been expanding, with relevant research outlined subsequently.

Within-person studies: gaps in the literature

Findings by Conroy et al. (2014) provided preliminary evidence for a positive within-subject association between AC and PA, indicating that on days when individuals were more physically active, they also consumed higher amounts of alcohol. In particular, day of the week (weekday versus weekend) had an effect on the link between daily drinking and PA; specifically, daily drinking was positively related to previous day drinking, but not to previous day PA (Conroy et al., 2014). Conversely, research by Abrantes et al. (2017) revealed a negative within-person association between PA and drinking, i.e., on days when individuals exercised more, they drank less. Their participants, young emerging adults who attend college, were asked to self-report their

PA and drinking behaviors using Timeline Follow-back (TLFB) for exercise and drinking. The authors also noted that, over the 90-day period, increased weekday PA was associated with diminished alcohol use over the weekend (Abrantes et al., 2017). More recently, two other studies also ventured into the within-person evaluation of the PA-AC relation. In a 30-day online diary study, Cho et al. (2018) found a weak positive within-person PA-AC association among college students, which no longer applied when day of the week was factored into the model; particularly, on weekdays only, daily alcohol use was negatively associated with next day PA, indicating that students who drank more during the week were less physically active the following day. Graupensperger et al. (2018) explored the longitudinal relationship and bi-directionality of PA and AC over one school year among college students. Their findings revealed that a rise in alcohol consumption significantly predicted a rise in vigorous PA, however, engaging in more vigorous PA did not significantly predict subsequent alcohol use (Graupensperger et al., 2018). Contrary to the majority of previous findings, Henderson et al. (2020) reported no significant within-person relationship between PA and AC.

In addition to these studies yielding contradictory findings, the following collective limitations should be noted: 1- Conroy et al.'s (2014) sample consisted of community dwellers of a broad age range (19-89 years); 2- only one of these studies used an objective measure of PA and self-reported daily activity; and 3- distinct PA intensity levels (light, moderate, vigorous) were not reported in some of these studies; 4- Abrantes et al. (2017) required participants to self-report on their exercise and alcohol activities using TLFB, which involves retrospective recall over the preceding 90 days, and that may have potentially resulted in inaccurate reporting of AC and PA. The current study

circumvents some of these issues by, 1- focusing on a narrower age range (18-25 years) that is more representative of young emerging college-attending adults, 2- looking at daily associations between PA and AC as well as lagged effects of previous day PA on AC and previous day AC on AC (i.e., does PA on day 1 affect AC on day 2, does AC on day 1 affect AC on day 2?), 3- using an objective measure of PA in order to systematically examine the data, and 4- distinguishing different PA intensity levels which have been demonstrated to differentially influence the PA-AC relation.

Distinguishing between within- and between-person analyses

Within-person effects provide information on the daily co-occurrence of PA and AC, i.e., each individual's patterns of daily drinking and PA, while between-person effects provide information on the average co-occurrence of PA and AC between participants. In comparisons of intraindividual (within-person) with interindividual (between-person) difference data, it has been demonstrated that results from interindividual modeling do not typically generalize to the level of the person, and thus, individual effects may remain unobserved in large sample modeling techniques (Adolf et al., 2014). Notably, the functional association between PA and AC is person-specific, in that it varies systematically across persons, and the strength of the PA-AC association carries substantial information about the individual. For instance, if the between-person relation varies significantly across individuals, then it is likely that, in some individuals, PA and AC are positively associated, while in others the two are negatively associated. Such variability in the PA-AC relationship would suggest that some individuals tend to drink more on days when they engage in PA whereas others may drink less on the days

they engage in PA. Therefore, in order to take into account population heterogeneity, it is important to not only examine between- but also within-person associations of PA and AC. In fact, a handful of studies that have evaluated both between- and within (daily)-person associations of PA and AC among college students have reported that the nature of the relation differed at within- and between-levels (Abrantes et al., 2017; Cho et al., 2018; Graupensperger et al., 2018). Further, due to the heterogeneity detected in daily engagement of PA and drinking among student populations (Conroy et al., 2014), such as higher rates of drinking on weekends (Finlay et al., 2012; Maggs et al., 2011), drawing a parallel between within- and between-subject analyses may help better explain the PA-AC relation among college students (Abrantes et al., 2017), which is essential to inform who in the population may be more susceptible to consuming larger amounts of alcohol if given exercise regimens, and who might use exercise to mitigate the desire to drink.

Exercise-Type Interventions as Adjunct Treatment for AUD: Conflicting Findings

AUD, a debilitating syndrome characterized by excessive drinking, alcohol dependence, tolerance, and adverse effects on health, social and professional life, is the most common of all psychiatric disorders (Hallgren et al., 2018). Worldwide, an estimated 16% of individuals are at risk of developing AUD in their lifetime (NIAAA, 2020) but, to date, few effective treatments are available. In the United States, a 2018 report by the NSDUH revealed that an estimated 15 million individuals aged 18 and above (4% women and 7.5% men) suffered from AUD (NIAAA, 2020) and only 8% of those afflicted received appropriate treatment in the past year. In the United Kingdom, nearly 1 in 20 individuals who met the criteria for AUD were left untreated (Hallgren et

al., 2017). Overall, treatment for AUD has proven difficult, because, afflicted individuals do not typically ask for help and/or common treatment methods, i.e., pharmacological and counseling, seem to be unappealing due to the perceived stigma they hold (Hallgren et al., 2018). A recent systematic review by Palpacuer et al. (2018) comparing the efficacy of various pharmacological treatments including naltrexone, revealed that none of the pharmacological treatments developed to date are efficacious enough to significantly reduce drinking and result in beneficial health outcomes. Furthermore, it is not uncommon to become abstinent posttreatment, however relapse rates are high (Hallgren et al., 2017), thereby indicating little to no long-term treatment effectiveness.

Evidence indicates that rates of physical inactivity are high among individuals who suffer from AUD (Hallgren et al., 2017). Although, recognizing the widespread benefits of PA and exercise, studies investigating physical activity-type interventions for substance use disorders, including AUD, have expanded in recent years (Brown et al., 2009; Brown et al., 2014; Giesen et al., 2015; Weinstock, 2010; Weinstock et al., 2016). They do, however, typically involve clinical populations and the focus on college student AUD and the potential effectiveness of PA remains scarce.

Clinical populations

In clinical populations, studies using exercise as an adjunctive treatment for alcohol-dependent individuals have yielded conflicting findings. Some demonstrate a reduction in alcohol intake following exercise-based interventions while others report no significant effects of exercise on drinking. A recent review by Giesen et al. (2015) showed that while exercise seems to improve certain components of AUD, such as

depression and physical fitness levels, its effectiveness in full remission of AUD remains limited. Similarly, a review by Hallgren et al. (2017) more recently showed that exercise was unsuccessful in reducing alcohol intake in the long-term, which is in line with Roessler et al. (2017) who found no direct effects of exercise on drinking reduction, but reported that moderate PA appeared to offer some protection against excessive drinking. Conversely, Weinstock et al. (2008) showed that, following an exercise regimen, patients' alcohol intake decreased and their fitness levels improved while still in treatment. Similarly, Ussher et al. (2004) reported that one single bout of exercise reduced the urge to drink in alcohol dependence patients undergoing detoxification. Long-term abstinence post treatment, however, is questionable.

Non-treatment-seeking college students

Growing evidence suggests that exercise-based interventions may help control hazardous alcohol use among college students. However, findings are mixed and inconclusive. For instance, Murphy et al. (1986) demonstrated that male college students decreased their drinking following an exercise intervention. However, their study is over three decades old and excluded women, thereby not entirely representing present college populations. Correia et al. (2005) reported an association between exercise programs and reduced drinking among college students, however, they also indicated low exercise adherence and high dropout rates, which could be problematic when opting to use PA interventions for AUD (Weinstock, 2010). Aiming to control high attrition and low adherence to exercise, Weinstock and colleagues (2016) introduced exercise-based interventions along with contingency management and motivational enhancement therapy

to help reduce college students' heavy drinking. In contrast to simply instructing participants what to do, contingency management and motivational enhancement therapy help boost motivations to exercise (Weinstock et al., 2016). In particular, their findings revealed that students who adhered to exercise regimens and increased their PA levels at follow-up assessments indeed saw an improvement in their fitness levels, however, the target goal which was to decrease alcohol consumption rates, was not met (Weinstock, 2010; Weinstock et al., 2016). These mixed findings can potentially be explained by two separate events: 1- given the positive relation between PA and AC, using exercise as an intervention strategy to help minimize drinking may not work, and, in certain cases may even increase drinking, whereas, 2- exercise and alcohol tap the same neural reward circuitry, and so the reward provided by exercise may help satisfy alcohol cravings. From a behavioral economics standpoint, substance-free activities, i.e., PA, may be sufficiently reinforcing and capable of partially competing with drinking, thereby acting as a substitute for alcohol (Correia et al.; 2005; Leasure et al., 2015).

A review by Stoutenberg et al. (2016) suggested that exercise may be quite beneficial in addressing AUD, but, the extent of its effectiveness was contingent on personal and social influences. Therefore, it is essential to examine characteristics that may moderate the PA-AC relation to inform who may be more susceptible to drinking when higher rates of PA are undertaken.

Potential Moderators of the Physical Activity-Alcohol Consumption Relationship

The role of impulsivity

Impulsivity (IMP) is a heterogeneous construct that can be defined as an individual trait characterized by rash actions and a disregard to possible consequences of

one's behaviors (Cyders & Smith, 2007; Freimuth et al., 2011; Moeller et al., 2001). In the literature, there has been a distinction between IMP as a stable personality trait, typically measured in self-report questionnaires, and IMP as decisions and actions, typically measured through behavioral tasks (Dick et al., 2010; Herman & Duka, 2019). In addition, multiple sub facets make up the construct of IMP, which should be taken into account when examining IMP in relation to outcomes of interest (Dick et al., 2010) and especially health behaviors (Cyders et al., 2007; LaBrie et al., 2019; Stamates & Barraco, 2017; Tran et al.; 2018). The following five facets of subjective, trait-like IMP, evaluated using the UPPS-P self-report scale (Cyders & Smith; 2007; Cyders et al., 2007), have been developed, validated, and examined in the context of health behaviors: sensation-seeking (SS), which is the pursuit of novel and exhilarating experiences (Whiteside & Lynam, 2001), negative urgency (NU), an inclination to act rashly in response to a negative mood state (Cyders et al., 2009, Whiteside & Lynam, 2001), positive urgency (PU), the inclination to act rashly in response to a positive mood state (Cyders et al., 2007), lack of premeditation (PREM), the tendency to engage in behaviors without pondering the possible consequences, and lack of perseverance (PERS), characterized by an inability to stay concentrated on and complete a task (Whiteside & Lynam, 2001).

Notably, a lack of correlation has been found between self-report measures, typically measuring subjective/trait IMP, and behavioral measures, however, numerous studies have consistently demonstrated that subjective/trait IMP is strongly associated with heavy AC and the development of AUD in young adults (Bø et al., 2016; de Wit, 2008; DiNicola et al., 2015; Shin et al., 2012). In fact, IMP in adolescence predicts future

initiation and increase of alcohol consumption (Spear, 2018) and, can therefore, serve as a marker for risk of developing AUD.

Excluding age and gender, moderating factors of the PA-AC relation have not been sufficiently researched (Lisha et al., 2011). However, IMP was shown to influence the association between PA and AC (Leasure & Neighbors, 2014; Reilly et al., 2015), in that individuals higher on IMP tend to exercise and drink more than those lower on IMP. Because impulsivity is composed of multiple facets, assessing both trait/subjective and behavioral IMP by using both self-report measures and behavioral tasks may potentially offer a more comprehensive understanding of impulsivity's involvement in the PA-AC association.

Prior work on the role of IMP in PA-AC associations has focused on between-person effects, but within-person variations between PA and AC may look different depending on distinct levels of IMP. Although Cho et al. (2018) found no main effects of trait IMP on the within-person PA-AC relation, other research focusing on between-individual associations has. Therefore, IMP merits further exploring as a variable that may moderate daily deviations between PA and AC.

Impulsivity, religiosity, and self-regulation

Self-regulation is defined as an automatic and effortless process by which individuals adjust their current state or behavior in order to attain a preferred state or behavior (McCullough & Carter, 2013; McCullough & Willoughby, 2009). Impulsivity and religiosity are involved in self-regulation in inverse ways. While people high on impulsivity exhibit poorer self-regulation (Pearson et al., 2013), those high on religiosity

seem to be good self-regulators (Watterson & Giesler, 2012). According to the 'muscle model', self-regulation resources originating in the prefrontal cortex (Lazarus et al., 2019) are finite, which means that just like a muscle fails to contract when over-exerted, self-regulation can also be depleted (McCullough & Carter, 2013; McCullough & Willoughby, 2009), thereby leading to an undesirable state or behavior, such as impulsive urges and acts. Further, when self-regulation reserves decline due to fatigue or other effects, impulsive urges emerging from subcortical regions are poorly controlled leading to a failure to effectively self-regulate (Lazarus et al., 2019).

A study on self-control and self-regulation demonstrated that following two weeks of exercising self-control, self-regulatory abilities increased significantly (Muraven et al., 1999), which is the proposed mechanism underlying religious people's better abilities to self-regulate. Self-control is characterized by an effortful desire to achieve a goal deemed to be more beneficial, while suppressing an undesirable state or behavior. Self-regulation, as defined above, is more of an effortless process whereby people change their current state in order to attain a preferred state or behavior (McCullough & Carter, 2013; McCullough & Willoughby, 2009). While self-control is a more specific construct than self-regulation (McCullough & Carter, 2013; McCullough & Willoughby, 2009), the two are often used in tandem.

A large body of evidence indicated that religiosity and self-regulation are positively associated, which is likely due to the fact that religious individuals build up their self-regulatory capacity by engaging in tasks requiring self-control, i.e., attending religious services, engaging in long prayers (McCullough & Willoughby, 2009). Watterson and Giesler (2012) gave participants a puzzling task that diminished self-

regulatory resources and subsequently administered another task that required persistence, and found that individuals high on religiosity had larger reserves of self-regulation than those low on religiosity.

An inverse relationship between religiosity and drinking

Religiosity displays an inverse relationship with AC (Cochran et al., 1992). Findings from a meta-analysis assessing over 20 studies from 1995 to 2007 demonstrated that religiosity was related to less alcohol use among the youth (Yeung et al., 2009). Additionally, college students who identified with a particular religious affiliation consumed less alcohol than students with no religious affiliation (Patock-Peckham et al., 1998). Consistently, in a study comparing AC between students enrolled in a religious college and those in a secular college, Wells (2010) found that the least religious students were over 25 times more likely to drink heavily and 9 times more likely to drink moderately compared to the most religious students. Further, Lucchetti et al. (2012) demonstrated a robust negative correlation between organizational religiosity, including more frequent religious attendance, and alcohol use. Notably, addiction therapy groups, i.e., Alcoholics Anonymous, have tailored their treatments for individuals with problem drinking around belief in a higher power (Steigerwald & Stone, 1999).

As mentioned in the section above, religious individuals are better self-regulators, perhaps because they participate in activities that help improve self-control. Indeed, studies have shown that people who engage in religious practices exhibit higher self-control than those who do not (McCullough & Carter, 2013). For instance, McCullough and Willoughby (2009) reviewed 11 out of 12 studies which reported a positive

association between self-control and REL. In Addition, there is strong evidence suggesting that self-control is inversely proportional to drinking (Sun & Longazel, 2008), of which the proposed underlying mechanism is that self-control recruits cortical areas to accomplish a top-down suppression of undesirable emotions and behaviors (Jensen-Campbell et al., 2007), e.g., the impulse to drink. Therefore, individuals who report higher religiosity may exhibit higher levels of self-control that, in turn, may alter the PA-AC relation. Indeed, religiosity in the context of alcohol use and abuse has been widely examined (Edlund et al., 2010; Michalak et al., 2007; Yeung et al., 2009), and consistent research on religion suggests that religious involvement offers a protective factor against risky behaviors, including alcohol use and misuse (Chawla et al., 2007; Cochran et al., 1992; Wells, 2010). Therefore, as religiosity influences alcohol intake, it may also influence the nature of the AC-PA relation.

To date, no study has explored the potential moderating effects of religiosity on the PA-AC relationship. Taken together, these findings provide a groundwork for looking into both IMP and REL as characteristics that may moderate the PA-AC relation.

Overview and Current Study Aims

Consistent evidence points to the prominence of heavy college drinking across the United States, with 55% of students having consumed alcoholic beverages in the past month, 20% who met the criteria for an AUD, and an estimated 25% who experience academic problems due to drinking, such as performing poorly on exams and skipping classes (NIAAA, 2020). Because health behaviors that are fostered in adolescence and young adulthood seem to continue into later adulthood (Nelson et al., 2008; Williams et al., 2002), a crucial goal of this study is to help tease out young emerging college

students for whom an exercise program tailored toward drinking reduction may prove iatrogenic. In an effort to control maladaptive alcohol use and prevent alcohol-related consequences affecting students intellectually and socially, this research is in line with a key focus of NIAAA's College Drinking Research Program, which involves contributing to the development of suitable prevention and intervention strategies for college student populations. As an innovative extension to previous work, the current research examined and compared within- and between-individual associations of PA and AC, while focusing on the moderating influences of IMP and REL among college students.

Aims and hypotheses

Aim 1. Characterize within-person associations between physical activity and alcohol consumption. A negative association between PA and AC at within-participant levels was expected, in that higher daily PA levels would predict lower daily AC levels.

Aim 2. Evaluate the moderating effects of impulsivity and religiosity on the PA-AC relation at the within-subject level.

- Hypothesis 2a. For individuals higher on IMP we expected the within-person PA-AC association would be less negative.
- Hypothesis 2b. For individuals higher on REL we expected the within-person PA-AC association would be more negative.

Aim 3: Evaluate between-person associations between PA and AC at baseline, follow-up, and across 21 days, as well as the potential moderating effects of IMP and REL.

- Hypothesis 3a. We anticipated a positive PA-AC association between participants across 21 days, at baseline (Day 1) and at follow-up (Day 21). AC was expected to increase across individuals as PA increased.
- Hypothesis 3b. IMP was expected to significantly moderate the between-person PA-AC association, making the relation more positive.
- Hypothesis 3c. REL was expected to significantly moderate the between-person PA-AC association, making the relation less positive.

METHOD

Human Subjects and Institutional Review Board (IRB)

All procedures and measures were reviewed and approved by the respective IRBs of the University of Houston (UH) and Sam Houston State University (SHSU). Participants were guided through informed consent procedures by both myself and trained undergraduate research assistants. Participants were provided with written informed consent as well as necessary participation guidelines in the form of an orientation session before the start of the project.

Participants

Participants included 250 undergraduate students (74% female) between the ages of 18 and 25 years (M = 20.3, SD = 1.9) recruited from one large university, UH, and one mid-sized southwestern university, SHSU. As anticipated, the study sample was ethnically diverse, with, 40% Hispanic/Latino and 60% Non-Hispanic, 53% White/Caucasian, 21% Black/African American, 12% Other, 7% Asian, 3% Native American/American Indian, 3% Multi-Ethnic, and less than 1% Native Hawaiian/Pacific

Islander. Inclusion criteria comprised at least 18 and up to 25 years of age and current enrollment in coursework at UH and SHSU. Exclusion criteria were individuals under 18 years or over 25 years of age who typically consumed less than one alcoholic beverage per week, and those who did not own a smartphone. Recruitment was initiated in the Fall semester of 2018 and was completed in Fall 2019. Students were recruited via flyers posted in the Department of Psychology of both universities and the Department of Education at UH, classroom recruitment scripts at UH, and SONA advertisements at UH and PeRP advertisements at SHSU. SONA and PeRP are a research management system through which Psychology studies can be advertised. College students who wish to participate as research subjects to gain extra course credit can create a personal account, sign in and choose which studies they are eligible for and/or would like to partake in.

Students eligible to participate in the current study were asked to record their daily PA through a smartphone app (Pacer) and complete daily AC and PA in an online diary over 21 days. Participants were also asked to provide self-report measures on AC, PA, IMP, and REL. The study was set up in SONA as two parts, with Part 1 consisting of face-to-face fifteen minute long orientation sessions, and Part 2 consisting of completing surveys and daily diaries online. Eligible participants signed up for Parts 1 and 2 in SONA and were asked to schedule a time to come into the laboratory for the orientation session, in which they were briefed about study procedures. Once Part 1 was successfully completed and participants were eligible to participate in the study, they were asked to complete Part 2, i.e., they were sent an email with a link for the baseline survey one day following the orientation session. They were also sent a link by email for the daily diary one day following Part 1 and over 20 consecutive days subsequently. An email

containing a link to the follow-up survey was sent out on Day 21 of the study, which marked the completion of participation.

Compensation for eligible participants consisted of 10 extra course credits (allotted to the chosen courses according to their instructors' allowance for extra credit). Participants who completed the entire assessments received 10 course credits. Specifically, attending orientation sessions granted participants at UH 0.5 extra credit and participants at SHSU 1 extra credit. Completion of baseline assessments granted participants 1 extra credit. Those who completed between 10-15 daily diaries received 2 extra credits and those who completed between 16-21 daily diaries received 7 credits (if enrolled at SHSU) and 7.5 credits (if enrolled at UH). Completion of follow-up self-report assessments granted participants 1 extra credit. Extra course credit incentives have been successfully used in prior studies (Goldenberg et al., 2007; Grady, 2005; including our previous research on AC and PA) and are shown to provide immediate reinforcement for participation.

Measures

Following the orientation session, completion of baseline self-report measures including, demographics, quantity and frequency of drinking, problem drinking, intensity and frequency of physical activity, impulsivity and religiosity were assessed online. All surveys were designed using Qualtrics. Follow-up assessments (at day 21) included the same measures of quantity and frequency of drinking, problem drinking, intensity and frequency of physical activity, impulsivity, and religiosity.

Baseline assessments

Assessments used at baseline included the following self-report measures and behavioral task.

Demographic measures. In this section, participants were first asked 3 screening questions which were also previously printed on the recruitment flyer and asked again at orientation. Then they were asked to report age, sex, height, weight, religious affiliation and denomination, ethnicity, racial background, year in school, class standing, GPA, work and living status, Greek status, relationship status, and number of children – if any.

Alcohol consumption was assessed using the following measures: the Timeline Follow-Back (TLFB) for alcohol use, which represents a monthly calendar and is used to report quantity and frequency of drinking over the past one month (Sobell & Sobell, 2000); and the Alcohol Use Disorders Identification Test (AUDIT; Kokotailo et al., 2004) used to identify problem drinking. In TLFB, participants were asked to report on the number of standard alcoholic drinks they consumed each day over the past month and a graphic and measurements of a standard drink were provided. TLFB has been shown to be a more accurate measure of drinking than quantity-frequency measures in that it better categorizes levels of alcohol intake, i.e., moderate versus heavy drinking (Panza et al., 2012), and even though TLFB requires recall over the past 30 days, the measure is strongly correlated with drinking behaviors, is a widely used assessment of alcohol intake, and has high reliability and validity (Sobell et al., 1996). The AUDIT is composed of 10 items, of which the first 3 assess quantity and frequency of drinking, e.g., "How often do you have a drink containing alcohol?". The following 7 items assess problem

drinking with questions like, "How often during the last year have you found that you were not able to stop drinking once you had started?".

Physical activity was assessed using the International Physical Activity Questionnaire (IPAQ; Craig et al., 2003), which is a comprehensive physical activity questionnaire measuring intensity and frequency of PA in metabolic equivalents (METs) and total time spent in PA. Quantifying PA using METS is among the most commonly used approaches to estimate energy expenditure (Ainsworth et al., 2000; Colley et al., 2011). One MET, i.e., resting metabolic rate, is equal to 3.5 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$ (oxygen consumption) and any activity that exceeds resting or being sedentary is then multiplied by 1 (Wagner, 2005). That being said, the equivalent of 1 MET is not always accurate and depends on individual weight and BMI (Byrne et al., 2005), however, it is widely accepted and commonly used by the American College of Sport Medicine (Wagner, 2005). The IPAQ is divided into 5 sections, with each section providing a specific context for physical activity. The 5 parts are the following: 1- job-related physical activity, 2- transportation physical activity, 3- housework, house maintenance, and caring for family, 4- recreation, sport, and leisure-time physical activity, 5- time spent sitting. Participants were asked to report the number of days they engaged in physical activity and the time spent doing those activities.

Impulsivity was measured using a subjective self-report measure as well as an objective behavioral task measure. The subjective measure of IMP was assessed using The UPPS-P Impulsive Behavior Scale (Cyders & Smith, 2007; Lynam et al., 2006), used to identify impulsive traits and consists of 5 facets of impulsivity (negative urgency (NU), positive urgency (PU), lack of premeditation (PREM), lack of perseverance

(PERS), and sensation-seeking (SS)). Because impulsivity is a complex and heterogeneous construct, the literature often separates subjective or trait impulsivity- typically measured through self-report questionnaires- from behavioral impulsivity- typically measured through behavioral tasks (Dick et al., 2010). Here, behavioral impulsivity was assessed using a behavioral task, the Balloon Analogue Risk Task (BART; Lejuez et al., 2002), which typically looks at risk aversion and impulsivity. Instructions on how to complete the task were provided at the start and consisted of 30 trials, where on each trial, participants were asked to pump a balloon by pressing a computer key. The payoff for each pump is $0.05, so the more they pump the balloon, the more money they earn (this was fake money as part of the task – participants were only actually compensated with extra course credit). The caveat is that the balloon is programmed to pop at a different size for each trial, unbeknownst to participants. Because impulsivity is composed of multiple facets, assessing both trait/subjective and behavioral IMP by using both self-report measures and behavioral tasks may potentially offer a more comprehensive understanding of impulsivity's involvement in the PA-AC association. In the present study, subjective (trait) IMP was self-reported through the UPPS-P Impulsive Behavior Scale (Cyders & Smith, 2007), used to evaluate negative and positive urgency, lack of premeditation, lack of perseverance, and sensation-seeking. Behavioral IMP was assessed using the Balloon Analogue Risk Task (BART; Lejuez et al., 2002), a behavioral task primarily used to measure risk aversion as well as impulsivity.

In the current project, IMP was treated as a stable non-time varying variable across the 21 days, since past work has shown a robust correlation between subjective

IMP and alcohol use (Bø et al., 2016; de Wit, 2008; DiNicola et al., 2015; Shin et al., 2012), as well as significant effects of IMP as measured by the UPPS-P on the PA-AC relation (Leasure & Neighbors, 2014).

Because impulsivity is composed of multiple facets, assessing both trait/subjective by using self-report measures and behavioral IMP through behavioral tasks may in some cases offer a more comprehensive understanding of impulsivity's involvement in the PA-AC association. In the present study, subjective (trait) IMP was self-reported through the UPPS-P Impulsive Behavior Scale (Cyders & Smith, 2007), used to evaluate negative and positive urgency, lack of premeditation, lack of perseverance, and sensation-seeking. Behavioral IMP was assessed using the Balloon Analogue Risk Task (BART; Lejuez et al., 2002), a behavioral task primarily used to measure risk aversion and also impulsivity. However, we chose to focus on subjective IMP in the analyses for reasons of parsimony. And, notably, there is a well-established robust association between subjective IMP and hazardous drinking in young adults (Bø et al., 2016; de Wit, 2008; DiNicola et al., 2015; Shin et al., 2012).

Religiosity was assessed using Jessor's Religion Scale (Jessor & Jessor, 1977). This 4-item scale measures devoutness and includes the following statement followed by 4 questions: "How important is it"…, "1- To believe in God", 2- To be able to rely on religious teaching when you have a problem", "3- To be able to turn to prayer when facing a personal problem?" and "4- To rely on your religious beliefs as a guide for day-to-day living?". Participants were asked to choose the most suitable answer on a 4-point scale, e.g., "Not at all important", "A little important", "Pretty important", and "Very important". Religious affiliation and denomination were reported in the 'Demographics'

section. Religiosity was treated as a stable non-time varying variable across the 21 days since prior research has shown religious beliefs tend to be stable throughout emerging adulthood (Barry et al., 2010; Lee, 2002).

Follow-up assessments

Follow-up assessments (at day 21) included Demographics and the same measures of quantity and frequency of drinking, problem drinking, intensity and frequency of physical activity, impulsivity, and religiosity to test for any temporal effects by comparing drinking and PA over time.

Daily assessments

Alcohol consumption. To measure daily alcohol consumption over 21 days, participants completed an online daily diary set up in Qualtrics. A link was sent to them daily at 7:00 PM on weekdays (Sunday to Thursday) and at 9:00 PM on weekends (Friday – Saturday) with an email reminder sent two hours post diary. Text reminders were also sent daily or every other day using an app called Remind. Participants were asked to report type and number of standard drinks consumed 'yesterday' and 'today' (with 1 day defined as the hours between 12am-11:59pm). Pictures and standard measurements of different types of alcoholic beverages were included as an introduction showing a standard drink definition (adapted from Boynton & Richman, 2014). Due to the fact that TLFB requires recall over the past month, it may be susceptible to recall bias (Dulin et al., 2017), therefore, including a daily diary may have helped reduce recall error. Both alcohol quantity and alcohol frequency across all days were investigated.

Drinking quantity was measured as total standard drinks per day per individual, and drinking frequency was characterized as a dichotomous yes/no variable (coded as 1/0 respectively), with 'yes' representing the event of drinking and 'no' the event of no drinking on any particular day.

Physical activity. *Daily Diary:* To measure daily physical activity over 21 days, participants completed an online daily diary set up in Qualtrics. The same diary comprised questions about alcohol intake and physical activity. A link was sent to them daily at 7:00 PM on weekdays (Sunday to Thursday) and at 9:00 PM on weekends (Friday – Saturday) with an email reminder sent two hours post diary. Text reminders were also sent daily or every other day using an app called Remind. Participants were asked to report the time in minutes being physically active, whether they engaged in moderate or vigorous PA and the type of PA they engaged in. Metabolic equivalent (METS) were then calculated based on the intensity of PA reported. Specifically, PA intensity was quantified as follows: light < 3 METS, 3 METS < moderate < 6 METS, and vigorous > 6 METS (Giffuni et al., 2012; Pate et al., 1995) and PA was measured as total time spent engaging in any of these given intensities. *Objective PA*: Objective measures of physical activity were assessed daily using Pacer, a health and fitness app (Pacer Health, 2017). Participants received instructions on how to download Pacer into their smartphones and how to use the app during the orientation session. They were also given a unique username and password generated by me and revealed only to myself and the research assistants. At the end of the study, data from each participant was retrieved by the PI and/or research assistants. Pacer relies on the smartphone's embedded accelerometer to record PA data. Reported parameters by Pacer are steps taken, distance

travelled, calories expended, and total time spent doing PA (Pacer Health, 2017). Throughout the 21-day study period, participants were expected to keep their phones on them throughout waking hours each day, either in hand, pocket, bag, or arm/leg band. A review of 26 studies found that smartphone-based assessments represent a valid and accurate measure of objective PA (Bort-Roig et al., 2014). Based on Henderson et al. (2020), data was recorded into 1-minute intervals and then converted into total time spent engaging in light, moderate, or vigorous physical activity.

PA intensity assessed in the daily diary and objectively through the Pacer app, was quantified using METS. Specifically, PA intensity was quantified as follows: light < 3 METS, 3 METS < moderate < 6 METS, and vigorous > 6 METS (Giffuni et al., 2012; Pate et al., 1995) and PA was measured as total time spent engaging in any of these given intensities. Forgetting or being unable to keep their phones on them during waking hours (6am-11pm) (when for instance, engaging in water-related activities) was coded as 'non-wear' time and defined as 0 activity counts greater than 60 consecutive minutes (Schuna et al., 2013; Henderson et al., 2020). There appear to be some discrepancies between self-report and objective measurement outputs of PA (Prince et al., 2008) in that there is over-reporting in subjective measures, thereby resulting in higher than actual levels of PA among individuals. However, the use of both objective PA and self-reporting of PA in the current project may help circumvent the problem of over-reporting by providing more accurate data. Average moderate and vigorous PA were calculated as the person-specific means across all days and those values were centered at the grand mean. Daily PA deviations were calculated as day-to-day differences from the person-specific means.

Procedures

Screening items were again presented at the start of the orientation session (Day 0) to ensure that all participants who signed up were eligible to go ahead with the study. Each participant was given a unique ID number to use for baseline and follow-up surveys, daily diaries, and the behavioral task. Participants were informed that they would be taking part in a 3-week online diary study (part 2), in which they had to report their daily PA and AC and during which time their PA was continuously monitored and recorded by the Pacer health and fitness app. Three weeks was the time frame used by Conroy et al. (2014) to model within-subject changes that unfold rapidly (e.g., daily). A 21-day time period is sufficient to model rapid daily variations in PA and AC and not too long a time to lead to higher attrition. Participants were also briefed about the baseline (Day 1) and follow-up (Day 21) surveys they would complete at the start and end of the study, respectively. The baseline survey was emailed to participants through a Qualtrics link and included a consent form at the beginning of it. If participants did not consent, they were automatically directed to the end of the survey. The baseline assessment consisted of a survey battery of self-report measures as well as the BART, a behavioral task assessing impulsivity. The follow-up survey was also emailed to participants through a Qualtrics link 3 weeks following baseline (at day 21) and included the same self-report measures with the exception of the consent form. All surveys were programmed using the software Qualtrics and the behavioral measure BART was programmed using the software Inquisit by Millisecond. Daily assessments of AC and PA were also completed via a link sent from Qualtrics (see Table 1 for timeline of assessments). To ensure a high

enough response rate, both email reminders and text messages were sent out to participants once a day (in the evenings) reminding them to complete the daily diary.

Statistical Analyses

Preliminary analyses

All data were analyzed using the software Statistical Analysis System (SAS) version 9.4, using generalized linear mixed models for multilevel and repeated measures and negative binomial regressions. Preliminary analyses were conducted prior to hypothesis testing to examine extreme values and distributions of variables in order to ensure the use of appropriate tests. Preliminary analysis of the data revealed that the distribution of alcohol variables for drinking quantity deviated significantly from normal. Fitting unconditional means models with AC quantity as outcome and comparing fit indices indicated that AC quantity assumed a negative binomial distribution. Additionally, our alcohol quantity data appeared to be zero-inflated, with 72% ‘0’ observations, therefore, the best fitting model to assess PA-AC associations with drinking quantity as outcome was a generalized linear mixed model with a zero-inflated negative binomial distribution. Drinking frequency was coded as ‘1’ if participants drank on a particular day, or ‘0’ if they did not drink, and thus, preliminary analyses revealed that the distribution of drinking frequency followed a binomial distribution, therefore the best fitting model for drinking frequency as outcome was a binomial multilevel mixed model. Correlational analyses were then run to understand basic associations among variables.

Gender and time-varying covariates

Gender was coded as 1 = male and 0 = female, with female as the reference group, and was included as a covariate to account for differences in drinking and impulsivity between male and female participants. In the models that examined within-person associations between PA and AC, the following time-varying covariates were added to improve model fit: day of the week (weekday/weekend), previous day PA (1 day lag effect, i.e., PA at time Day-1), previous day AC (1 day lag effect, i.e., AC at time Day-1). Because the current project evaluated daily associations between PA and AC over 3 weeks (a shorter timeframe as opposed to over months or years) and Conroy et al. (2014) did not find a seasonal effect on the PA-AC association over 3 weeks, season/term was not factored into the analyses. Instead, a dichotomous variable for day of the week was created, dividing days of the week by weekend (Thursday to Saturday) and weekday (Sunday to Wednesday) and coded as 1 and 0, respectively. Daily measures of PA were person-centered and person-specific average measures of PA were centered at the grand mean.

Analysis strategy

Aims 1 to 3 were assessed using generalized linear mixed models for multilevel and repeated measures to fit the data structure with days (level 1) nested within individuals (level 2) (Snijders & Bosker, 1999) and to test hypotheses on within- (daily) and between- (average) subject associations between PA and AC, as well as to assess interaction effects of IMP and REL on between- and within-person PA-AC associations. A multilevel modeling approach is useful to discern the association between average PA and AC (between-person effect) from daily deviations in PA and AC for each subject

(within-person effect). To examine cross-sectional between-person associations (of Aim 3) between PA and AC at baseline and follow-up, negative binomial regressions were employed using measures collected at the baseline and follow-up, respectively.

To examine Aim 1 (characterize within-person associations between physical activity and alcohol consumption), drinking quantity and drinking frequency served as outcome variables examined in separate models. Drinking quantity was characterized as total daily alcohol servings, and drinking frequency was characterized as daily drinking or no drinking. In addition, separate models were used for each form of PA to avoid collinearity: 1- diary PA time, 2- diary PA METS, 3- objective PA time, and 4- objective PA METS. Zero-inflated negative binomial multilevel models were specified with total drinks per day each day as the outcome variable and total daily PA as predictor variables.

The between-subjects effects of PA (average PA time and METS across all days for each individual) were added as predictor variables to statistically separate daily from overall effects on AC. Furthermore, because prior research has found that PA-AC associations tend to differ based on the intensity of PA (Graupensperger et al., 2018; Leasure & Neighbors, 2014), our models included both moderate and vigorous PA. Unadjusted models comprised the following predictors: daily moderate and vigorous PA time (self-reported in the daily diary), average moderate and vigorous PA time, daily moderate and vigorous PA METS (calculated from diary PA time), average moderate and vigorous PA METS, daily objective PA time (recorded in Pacer), average objective PA time, daily and average objective PA METS (calculated from PA time recorded in Pacer).

Equations for the unconditional models with drinking quantity and drinking frequency as outcomes were written as follows. For drinking quantity:

$$E(Y_{it}) = \log(\mu_{it}) = \gamma_{00} + u_{0i} + \varepsilon_{it} \quad (1)$$

where Y_{it} is the expected number of drinks for individual *i* on day *t*, u_{0i} are the residuals for individual *i* that are assumed normally distributed with mean 0 and variance $\sigma^2_{uo,}$ ε_{it} is the residual error term for individual *i* at time *t*, γ_{00} is the fixed effects intercept coefficient. The random effects, $u_{0i} + \varepsilon_{it}$, have an autoregressive covariance structure. For drinking frequency:

$$E((yes/no)_{it}) = \text{logit}(\mu_{it}) = \gamma_{00} + u_{0i} + \varepsilon_{it} \quad (2)$$

where (yes/no) represents drinking or no drinking for individual *i* on day *t*. Hence, $E((yes/no)_{it})$ = probability of drinking for person *i* at time *t*. Because the probability is bounded by 0 and 1, we use the logit link function to model the log odds of drinking for person *i* and time *t*, which is bounded by + and - infinity. For the unadjusted models including PA predictors, Equation (1) became:

$$E(Y_{it}) = \log(\mu_{it}) = ß_{0i} + ß_{1i}(\text{Daily PA}_{it}) + \varepsilon_{it} \quad (3)$$

with

$$ß_{0i} = \gamma_{00} + \gamma_{01}(\text{average PA}_i) + u_{0i}$$

$$ß_{1i} = \gamma_{10}$$

where $ß_{1i} = \gamma_{10}$ is the average within-person association between daily changes in PA and drinking, γ_{00} represents the average log number of drinks on a given day for a person who is average in PA, γ_{01} represents the between-person association between average PA and the log number of drinks, and u_{0i} represents the difference between the average log number of drinks for person *i* and what we expect for that individual given the average log number of drinks across all participants and their average level of PA (i.e., the random intercept). Thus, $ß_{0i}$ represents average drinks adjusted for daily PA.

Because the focus of this project was on daily deviations from PA and AC over 21 days and growth or systematic change in AC and PA behaviors over time was not being examined, but rather systematic variation day-to-day, time was not included as a factor in the models. Instead, to improve model fit, day of the week coded as 1 = Weekend or 0 = Weekday (reference group), was factored into the analyses. Together, the following covariates were added to the unadjusted models: gender (specified as a time-invariant covariate included in the models at the between-person level) to control for any gender effects, as females tend to consume less alcohol and engage in less PA than males (Wilsnack et al., 2014), day of the week (specified as a time-varying covariate and dummy coded as weekday or weekend), as PA and AC behaviors may differ on weekdays and weekends (Abrantes et al., 2017; Finlay et al., 2012; Maggs et al., 2011), previous day AC (1 day lag effect; i.e., AC at Day-1), and previous day PA (1 day lag effect; i.e., PA at Day-1). Including these factors in the model may provide better estimates of characteristic PA-AC associations (Conroy et al., 2014). More specifically, Weekday was defined as Sunday to Wednesday, and Weekend was defined as Thursday to Saturday. Conroy et al. (2014) demonstrated that drinking increased on those days defining the long social weekend, and although they included Sunday in the social weekend, in our sample, drinking on Sundays was equivalent to weekday drinking. Adjusted models contained all PA variables and the above-mentioned covariates. Equations for the adjusted models were expanded from the unadjusted models' to include the covariates and their random effects.

Models including frequency as the outcome were analyzed using the GLIMMIX procedure in SAS version 9.4, which requires the specification of a covariance structure

to account for the correlation between measurements in time within each subject. Thus, we compared 3 types of covariance structures that were most meaningful to the current project's design and data, compound symmetrical (CS), first-order autoregressive AR(1) and ARH(1). The CS structure assumes that all measurements are equally correlated. The AR(1) structure assumes, 1- equal spacing between measurements in time and, 2- that measurements closer in time are more strongly correlated than those farther apart; while ARH (1) preserves the features of AR(1), it allows for unequal spacing and change in the residual variance over time (Stroup et al., 2018). Fit statistics were then compared to determine which structure fit the data better. Models including alcohol quantity as the outcome were analyzed using the NLMIXED procedure in SAS version 9.4, which relies on the specification of a covariance structure through parameters of variance and covariance specified in the models.

A second aim of this project was to explore the extent to which PA-AC associations were moderated by time-invariant covariates known to influence alcohol consumption and physical activity, including, impulsivity and religiosity. Aim 2 (evaluate the moderating effects of IMP and REL on the within-person PA-AC relation) was evaluated by expanding the final adjusted models tested in Aim 1 and then including facets of IMP (hypothesis 2a) and REL (hypothesis 2b) to the models. These predictors may help explain variations across individuals in the within-person individual slopes. IMP and REL were treated as time-invariant continuous variables (lower to higher IMP and lower to higher REL) and were included in interaction effects models with both average and daily PA.

A third aim of this project was to evaluate between-person associations between PA and AC at baseline, follow-up, and across 21 days. To assess hypothesis 3a (the between-person association between PA and AC) at baseline and follow-up, negative binomial regressions with alcohol quantity at baseline and follow-up serving as the outcome variable and physical activity serving as predictors. Specifically, total drinks over the past month, as assessed in the TLFB, served as the outcome variable. PA time, moderate and vigorous METS, as measured in the IPAQ, served as the predictor variables. PA variables were modelled separately for reasons of collinearity and gender was added as a covariate. Hypothesis 3a also examined between-person PA-AC analyses derived from generalized linear mixed models to assess the relation between the two behaviors averaged across 21 days. We examined both drinking quantity and drinking frequency across 21 days, which served as the outcome variables examined in separate models. The between-person effects of predictors on these outcome variables were attained by controlling for individual daily deviations from the predictors and covariates. To examine hypothesis 3a, the following predictors: average moderate and vigorous PA time (self-reported in the daily diary), average moderate and vigorous PA METS (calculated from diary PA time), average objective PA time (recorded in Pacer), average objective PA intensity (calculated from PA time recorded in Pacer), and the covariate, gender, were examined at the between-subject level. Next, to examine hypothesis 3b (examine potential moderating effects of IMP on the between-subject PA-AC relation), the adjusted models from hypothesis 3a were expanded to include the following predictors: the 5 facets of IMP (SS, PU, NU, PERS, PREM). Hypothesis 3c (examine potential moderating effects of REL on the between-subject PA-AC relation) was

examined by expanding the adjusted models from hypothesis 3a and interacting REL with PA.

Missing data

The number of subjects who completed baseline measures was *N* = 233 (74% female). The number of subjects who completed follow-up measures was *N* = 221 (74% female). A total of 30 participants were dropped from the daily diary (within-person analyses) because they completed less than 7 days of data (7 consecutive or non-consecutive days), a decision based on the fact that a single week captured the behaviors of PA and drinking over weekdays and the weekend. Any fewer days of time-varying data may overlook important elements of the PA-AC association. The final dataset containing daily diary variables of PA and AC, baseline and follow-up variables of PA, AC, IMP and REL consisted of 4588 daily observations with a total *N* = 250 participants. Participants completed a maximum of 21 days of data. With regards to objective PA, the total number of participants who provided complete objective PA data was *N* = 137 (78% female). Attrition was the result of, (a) participants' folders unavailable to download by the research team due to the removal of the Pacer app before data collection was finalized (*n* = 59), and, (b) no data provided by the participants (*n* = 24). The final dataset containing objective PA variables as well as daily diary, baseline and follow-up variables of PA and AC consisted of 4896 observations. We assumed that data were missing at random in both level-1 and level-2 variables. Handling missing data points in level-1 variables was not an issue requiring attention, since Hierarchical Linear Modeling handles those missing data points under the assumption of missing at random, which

implies that the observed covariates account for the missing observations. Regarding level-2 variables, missing data represented less than 4% of the total data for baseline and follow-up IPAQ, IMP and REL, and baseline TLFB, which would not influence the overall data, therefore no significant action was required to deal with this missingness. However, 45% of the total data for TLFB at follow-up were missing. Under the assumption that these data were missing at random, we performed a multiple imputation in SAS version 9.4 using the MI and the MIANALYZE procedures. We did 100 imputations using all the predictor variables used in the negative binomial regression model at follow-up and their interaction terms. Furthermore, to decrease participants' chances of accidentally failing to complete survey questions and, therefore, avoid excessive missing data that may alter the overall data, participants were required to answer all survey questions with a "prefer not to answer" option.

RESULTS

Descriptive Analyses

Correlations, means, standard deviations, and ranges among baseline variables are displayed in Table 3. Correlations, means, standard deviations, and ranges among follow-up variables are displayed in Table 4. Correlations, means, standard deviations, and ranges among daily variables are displayed in Table 5. Correlations, means, standard deviations, and ranges among total/average variables across all days and baseline IMP and REL variables are displayed in Table 6. Because these correlations do not take into consideration the multilevel structure of the data (i.e., correlations at between-subject levels overlook daily deviations in AC and PA, and correlations at within-subject levels

overlook the nesting of observations within individuals), it is recommended that they be interpreted descriptively rather than inferentially (Conroy et al., 2014).

Baseline variables

At baseline, drinking variables were uncorrelated with any other variables, gender was only significantly correlated with SS. PA variables were positively correlated with each other. Total time spent in PA and moderate PA (IPAQ) was positively correlated with SS, PU, and NU. REL was positively correlated with vigorous PA (IPAQ) (see Table 3).

Follow-up variables

At follow-up, gender was only significantly correlated with sensation-seeking. Drinking reported in TLFB was significantly correlated with PA time and PA METS reported in the IPAQ. There were no significant correlations between IMP and AC variables and IMP and PA variables, with the exception of vigorous PA METS which was negatively correlated with SS. We observed no significant correlations between REL and AC variables or REL and PA variables (see Table 4).

Daily variables

Gender was significantly correlated with daily drinking variables and vigorous PA. Specifically, gender (male coded 1) was positively correlated with daily drinks, frequency of drinking, time spent in vigorous PA, vigorous METS, objective PA minutes (recorded daily from the Pacer app) and objective PA METS. All daily PA variables were significantly correlated with each other. Daily drinks and frequency of drinking and

moderate PA were positively correlated with the social weekend (Thursday to Saturday), while objective PA time and METS were significantly negatively correlated with the social weekend. Daily drinks was significantly correlated with time in moderate PA, moderate METS, and only marginally significant with objective PA METS (see Table 5). Across all days, participants consumed an alcoholic beverage on 33% of those days and did not consume any alcohol on 67% of those days. Furthermore, approximately 72% of observations consisted of 0 drinks and 28% consisted of 1 or more drinks. Specifically, beer (less than 6% alcohol) was consumed the most with a total of 806 drinks over all participants and days. The second highest was liquor = 671 drinks, followed by wine = 580.5 drinks, cocktail = 555 drinks, alcopop = 290 drinks, beer (more than 6% alcohol) = 221.5, and other = 76 drinks.

Total/average variables across all days

Across all days, gender was positively correlated with vigorous PA time and METS, objective PA time and METS, and SS. Drinking variables were positively correlated with each other. Total drinks was positively correlated with moderate PA time and METS, and SS. Self-reported vigorous PA time and METS was positively correlated with objective PA time and METS. Moderate PA was correlated with PU. Objective PA METS was correlated with SS. REL was positively correlated with vigorous PA (Table 6).

Within-Person Analyses – Aim 1

Aim 1 of this project examined within-person PA-AC associations using generalized linear mixed models. Drinking quantity and drinking frequency served as the outcome variables, which were examined in separate models.

Drinking Quantity

The best fit for drinking quantity as the outcome variable was determined by fitting a series of unconditional models and comparing Akaike's information criteria (AIC) and Bayesian information criteria (BIC) statistics. Compared with the Poisson model (AIC = 11696.87, BIC = 11703.91), AIC and BIC for the negative binomial model were lower (AIC = 9219.62, BIC = 9230.19), therefore, alcohol quantity was modeled using a negative binomial distribution. Furthermore, 72% of the total observations for alcohol quantity were 0s, therefore the best fitting model to assess PA-AC associations with drinking quantity as outcome was a generalized linear mixed model with a zero-inflated negative binomial distribution. Table 7 displays the negative binomial multilevel adjusted and unadjusted model parameters examining within-individual associations between PA and alcohol quantity.

Since a random intercept model allows for the modeling of variability in drinking quantity between subjects, a random effect was added to the intercept, which demonstrated improved model fit (-2 Log-Likelihood = 9193, AIC = 9207, BIC = 9232, compared with, -2 Log-Likelihood = 9339, AIC = 9351, BIC = 9389). Our unconditional model was then a random intercept model without the covariates or predictor variables. We first added to the unconditional model daily and average PA variables, which

comprised the unadjusted model. We then added to the unadjusted model the level-2 control variable, gender (male coded 1), and the level-1 control variable, day of the week (weekend coded 1). Fixed effects results revealed that day of the week was strongly positively associated with drinking quantity (all *ps* < .0001), indicating that individuals drank considerably more on weekends than they did on weekdays. Similarly, gender significantly predicted drinking quantity (all *ps* < .03) suggesting that men consumed larger amounts of alcohol compared with women. Next, the time-varying covariates, previous day drinking and previous day moderate and vigorous PA, were added to the adjusted models comprising the control variables, however, all 3 covariates were unassociated with drinking quantity (all *ps* > .23), indicating that the amount of alcohol consumption or physical activity engagement on a given day did not predict next day quantity of drinking.

Effects of PA on drinking quantity

1. Diary PA time and METS

Nested tests suggested that adding random effects for self-reported moderate PA time (-2 Log-Likelihood = 9191, AIC = 9209, BIC = 9241, compared with, -2 Log-Likelihood = 9193, AIC = 9207, BIC = 9232), and vigorous PA time (-2 Log-Likelihood = 9189, AIC = 9207, BIC = 9239, compared with, -2 Log-Likelihood = 9193, AIC = 9207, BIC = 9232) did not improve model fit. Daily moderate and vigorous PA time as self-reported in the diary were added to the models comprising the control variables. Results revealed that both daily moderate and vigorous PA time were unassociated with

drinking quantity (all *ps* > .10), suggesting no significant within-person association between time spent in PA and drinking quantity.

Nested tests suggested that adding random effects for self-reported moderate PA METS (-2 Log-Likelihood = 9191, AIC = 9209, BIC = 9241, compared with, -2 Log-Likelihood = 9193, AIC = 9207, BIC = 9232), and vigorous PA METS (-2 Log-Likelihood = 9189, AIC = 9207, BIC = 9239, compared with, -2 Log-Likelihood = 9193, AIC = 9207, BIC = 9232) did not improve model fit. Daily moderate and vigorous PA METS were added to the models comprising the control variables. Results revealed that daily moderate and vigorous PA METS were unassociated with drinking quantity (all *ps* > .10), suggesting no significant within-person association between PA intensity and drinking quantity.

2. Objective PA time and METS

Nested tests suggested that adding a random effect for objective PA time (-2 Log-Likelihood = 3935, AIC = 3949, BIC = 3970, compared with, -2 Log-Likelihood = 3936, AIC = 3946, BIC = 3960) did not improve model fit. Daily objective PA time was added to the model comprising the control variables and results revealed that daily PA time was unassociated with drinking quantity (all $p = .27$), suggesting no significant within-person association between time spent in PA and drinking quantity.

Further, the variance for daily PA METS was near negligible (estimated at $\sigma^2 = .000005$) therefore, we found it unnecessary to test the model with a random effect for daily PA METS. Daily objective PA METS was added to the model comprising the control variables and results indicated that daily PA intensity was unassociated with

drinking quantity (p = .69), suggesting no significant within-person relation between PA intensity recorded objectively and drinking quantity.

Notably, in both the self-reported PA time and METS final adjusted models, we observed no gender effects on drinking quantity (p = .22), which could indicate that gender differences in self-reported PA time and METS accounted for gender differences in drinking quantity.

Interaction effects on drinking quantity

As a final step in the analyses, given our findings and the well-established gender differences in the context of drinking rates and physical activity, with particularly higher levels of alcohol intake and PA found among men (Lisha et al., 2011), we interacted gender with PA variables across all models. Main effects models were expanded and all significant predictors and covariates were retained, with the exception of PA variables, which were retained regardless of their significance. Results revealed no interaction effects of gender on the within-person PA-drinking quantity association (all ps > .26) indicating that gender had no moderating influence on the relationship between PA and alcohol quantity within individuals.

Furthermore, to examine changes in the PA-AC relation on weekends versus weekdays, given that individuals consumed higher amounts of alcohol on weekends, we looked at interaction effects between day of the week and daily PA. Results revealed that day of the week had no influence on the within-person PA-drinking quantity association (all ps > .16).

Drinking frequency

The best fitting model for drinking frequency as the outcome variable was a binomial distribution given the nature of the data for frequency, i.e., drinks (0)/no drinks (1). The best fit for a covariance structure was determined by fitting a series of models and comparing Akaike's information criteria (AIC) and Bayesian information criteria (BIC) statistics. Compared with CS (AIC = 5283, BIC = 5304) and ARH(1) (AIC = 5300; BIC = 5402), AIC and BIC for the AR(1) structure (AIC = 5274; BIC = 5299) were lowest, therefore the AR(1) covariance structure proved to be a better structure for the model. Table 8 displays the negative binomial multilevel unadjusted and final adjusted model parameters examining within-individual associations between PA and alcohol frequency.

We first added to the unconditional model daily and average PA variables. We then added to the unadjusted model the level-2 control variable, gender, and the level-1 control variable, day of the week. Fixed effects results revealed that day of the week was strongly positively associated with drinking frequency (all *ps* < .0001), indicating that participants were more likely to consume alcohol on weekends than on weekdays. Gender also significantly predicted drinking frequency (all *ps* <.003) suggesting that men consumed alcohol more frequently compared with women. Next, the time-varying covariates, previous day drinking and previous day moderate and vigorous PA, were added to the adjusted models comprising the control variables. Previous day drinking significantly predicted next day drinking (all *ps* < .0001), suggesting that the probability of drinking on a given day was higher when individuals consumed alcohol the previous day, which may seem counterintuitive, however, given that day of the week was

controlled for in the models, these results may indicate the clustering of drinking on weekends versus weekdays. Previous day moderate and vigorous PA were unassociated with drinking frequency (all *ps* > .50) and were therefore dropped from further analyses. The final adjusted models comprised all variables with significant main effects in addition to the PA variables despite their non-significance.

Effects of PA on drinking frequency

Fixed effects results indicated that drinking frequency and PA time were unassociated at the within-person level (all *ps* > .43), suggesting no significant within-person association between time spent in self-reported PA and drinking frequency. Similarly, results indicated that drinking frequency and PA METS were unassociated at within-person levels (all *ps* > .60), indicating no significant within-person association between self-reported PA intensity and drinking frequency.

Results revealed that drinking frequency and objective PA time were unassociated at within-person levels ($p = .62$), indicating no significant within-person association between time spent in objectively recorded PA and drinking frequency. Results indicated that drinking frequency and objective PA METS were not associated at within-person levels ($p = .57$), suggesting no significant within-person relation between objectively recorded PA intensity and drinking frequency.

Interaction effects on drinking frequency

As a final step in these models, given our findings and the well-established gender differences in the context of drinking rates and PA, with particularly higher rates of drinking and PA found among men (Lisha et al., 2011), we examined interaction effects between gender and PA variables on drinking frequency. Results revealed no significant interaction effects of gender on the PA-drinking frequency relation (all *ps* > .09), indicating that gender had no moderating influence on the within-person relationship between PA and frequency of drinking.

Next, to evaluate possible changes in the PA-AC relation on weekends versus weekdays, we looked at interaction effects between day of the week and PA. Results revealed a negative interaction effect between day of the week and vigorous PA time (γ = -.007, SE = .003, t = -2.52 p = .01) and day of the week and vigorous PA METS (γ = -.001, SE = .0004, t = -2.52 p = .01), suggesting that individuals who engaged in more vigorous PA on weekend days drank less frequently on those days (Figures 1 and 2). However, we observed no interaction effects between day of the week and PA recorded objectively (all *ps* > .27).

Impulsivity and Religiosity as Potential Moderators – Aim 2

Aim 2 of this project examined the role of IMP and REL on the PA-AC association at the within-person level using generalized linear mixed models. Although REL and IMP were treated as level-2 time-invariant predictors, we were interested in their effects on the PA-AC association at the within-person level. In other words, is the strength and/or direction of the within-person PA-AC relation different depending upon

an individual's REL or IMP? The outcome variables examined were alcohol quantity, characterized as total daily alcohol servings, and drinking frequency, characterized as drinking or no drinking. Hypotheses 2a and 2b, respectively, evaluated potential moderating influences of IMP and REL on the PA-AC association by examining cross-level interaction effects between daily PA and IMP and daily PA and REL. To evaluate Aim 2, hypothesis 2a, the final models from Aim 1 were expanded and the following predictors were interacted with PA: the 5 facets of subjective IMP (SS, PU, NU, PERS, PREM). To examine hypothesis 2b, the final models from Aim 1 were expanded to include REL and its interaction with PA as a predictor. Notably, although we observed no evidence of random variation across people in the within-person slopes, we may still find that the level-2 predictors (IMP and REL) influence the level-1 slopes, which Raudenbush and Bryk (2002) referred to as non-randomly varying slopes.

Interaction effects on drinking quantity

Compared with the between-subject variance in average drinking quantity in the unconditional model ($\sigma^2_{u0} = .56$), the between-subject variance in average drinking quantity decreased in the final adjusted interaction effects models ($\sigma^2_{u0} = .37$), suggesting that the predictor variables and interactions helped account for some of the variability in average drinking quantity.

Results from cross-level interactions between IMP and self-reported PA revealed that out of the 5 facets of IMP, only PU exhibited significant interactions with self-reported daily moderate PA time ($\gamma = .002$, SE = .0008, $t = 2.47$, $p = .01$) and METS ($\gamma = .0007$, SE = .0003, $t = 2.47$, $p = .01$) on drinking quantity, suggesting a moderating

influence of PU on the within-person PA-drinking quantity association. Interaction plots revealed that for those higher in PU, as daily moderate PA time and METS increased, alcohol intake also increased; and for lower levels of PU, as daily moderate PA time and METS increased, drinking quantity decreased (Figures 3 and 4). Similarly, a significant interaction effect was observed between PERS and time spent in objective PA (γ = -.004, SE = .002, t = -2.10, p = .038), indicating a significant moderating influence of lack of perseverance on the within-person PA time-drinking quantity relation. Figure 5 displays the interaction between drinking quantity and objective PA time for lower and higher levels of PERS. It appeared that drinking decreased on days when time spent in PA increased for those higher on PERS. Conversely, for those lower on PERS, it appeared that drinking increased on days when PA increased. However, we observed no significant interactions between IMP and objective PA intensity (all *ps* > .21).

With respect to REL, results revealed an absence of interaction effects between PA and REL on quantity of alcohol use (all *ps* > .08), indicating that religiosity had no moderating influence on the within-person PA-alcohol quantity relationship.

We then conducted additional analyses to evaluate the potential moderating effects of only 3 dimensions of IMP: SS, PU, and NU, primarily because of their substantial involvement with alcohol behaviors compared with the other two dimensions, lack of perseverance (PERS) and lack of premeditation (PREM) (Curcio & George, 2011; LaBrie et al., 2019; Stamates & Barraco, 2017). Consistent with the full model, cross-level interactions revealed that PU acted as a moderator of the within-person PA-drinking quantity association (all *ps* < .01). In this ‘truncated’ model as well, daily moderate PA

exhibited a marginally significant main effect on drinking quantity (γ = -.001, SE = .0006, t = -1.96, p = .0516).

Interaction effects on drinking frequency

Results from cross-level interactions between IMP and self-reported PA revealed that out of the 5 facets of IMP, only PU exhibited significant interactions with self-reported daily moderate PA time (γ = .003, SE = .001, t = 2.02, p = .043) and METS (γ = .0008, SE = .0004, t = 2.02, p = .043) on drinking frequency, suggesting a moderating influence of PU on the within-person self-reported PA-drinking frequency association. Specifically, interaction plots showed that with higher levels of PU, the likelihood of drinking increased as PA time and intensity increased, and for lower levels of PU, drinking decreased as PA time and intensity increased (Figures 6 and 7). Conversely, cross-level interactions revealed that none of the facets of IMP exhibited moderating effects on the within-person association between drinking frequency and time spent in PA or PA intensity, when PA was recorded objectively (all *ps* > .38).

With respect to REL, results revealed no interaction effects between PA and REL on drinking frequency (all *ps* > .12), indicating that religiosity had no moderating influence on the within-person PA-drinking frequency association.

We then conducted additional analyses to evaluate the potential moderating influences of SS, PU, and NU, on the within-person PA-drinking frequency association. Results from these cross-level analyses revealed a marginally significant interaction effect of PU on the within-person moderate PA-drinking frequency association (γ = .002, SE = .001, t = 1.89, p = .0584).

Between-Person Analyses – Aim 3

Aim 3 of this project examined between-person PA-AC analyses using negative binomial regressions and generalized linear mixed models. Specifically, hypothesis 3a examined the between-person association between PA and AC at baseline, follow-up, and across 21 days. Hypothesis 3b evaluated the potential moderating role of IMP on the relationship between PA and AC at the between-person level, and hypothesis 3c evaluated the potential moderating role of REL on the between-person relationship between PA and AC.

Between-person analyses across 21 days

The following models are part of the multi-level models that comprised the analyses under Aim 1. The focus in the models below is on the between-subjects coefficients, as they specifically relate to Aim 3.

Drinking quantity

Between-person effects were derived from generalized linear mixed models by examining associations of average PA across 21 days with drinking quantity. Table 7 displays the negative binomial multilevel adjusted and unadjusted model parameters examining between-subject associations between PA and alcohol quantity. Compared with the between-person variance in average drinking quantity in the unconditional model ($\sigma^2_{u0} = .56$), the between-subject variance in average drinking quantity decreased in the final adjusted models ($\sigma^2_{u0} = .44$), suggesting that the predictor variables helped account for some of the variability in average drinking quantity. As shown above under Aim 1, PA variables were added to the unconditional models and then the level-2

covariate, gender, and the level-1 covariate, day of the week were included. The coefficients pertaining to average PA were then analyzed.

Effects of PA on drinking quantity

Fixed effects results from the final adjusted model revealed that drinking quantity and average PA time were unassociated between persons (all *ps* > .08), suggesting no significant between-person association between self-reported PA time and drinking quantity. Results from the final adjusted model revealed that drinking quantity and average PA METS were not associated at between-person levels (all *ps* > .10), suggesting no significant between-person association between self-reported PA intensity and drinking quantity. Similarly, fixed effects results from both the unadjusted and final adjusted model revealed that drinking quantity and objective PA time across 21 days were not associated at the between-person level (all *ps* > .11). Results from the final adjusted model revealed that drinking quantity and objective PA intensity across 21 days were unassociated at between-person levels (all $p = .09$).

Interaction effects on drinking quantity

To examine hypothesis 3b, interaction effects between the 5 facets of IMP and PA were conducted. Results indicated no significant interactions between IMP and self-reported PA time or PA METS (all *ps* > .08). However, we found a significant interaction between NU and average objective PA METS on alcohol quantity ($\gamma = -.009$, SE = .004, $t = -2.17$, $p = .03$), suggesting a moderating influence of NU on the between-person relation between alcohol quantity and PA intensity recorded objectively. Figure 8 depicts

interaction effects of levels of NU on the relation between PA METS and quantity of drinking. The interaction plot suggests that for those higher on NU, drinking on average decreases when PA intensity increases.

To evaluate hypothesis 3c, interaction effects between REL and PA were examined. We observed no moderating influences of REL on the between-person PA-AC relation (all *ps* > .10).

As a final step, we examined interactions between gender and PA variables on drinking quantity. Results revealed no significant interaction effects of gender on the between-subject PA-drinking quantity relation (all *ps* > .27), suggesting that gender did not exert any moderating influences on the between-person association between quantity of alcohol use and average PA.

In the additional analyses including SS, PU, and NU, results revealed a significant interaction effect between NU and average vigorous PA time (γ = -.01, SE = .004, t = -2.59, p = .01) and METS (γ = -.002, SE = .006, t = -2.59, p = .01), suggesting that NU acted as a moderator of the between-person relation between alcohol quantity and vigorous PA. Moreover, we observed a main effect of SS on quantity of drinking (γ = .15, SE = .06, t = 2.57, p = .01).

Drinking Frequency

Between-person effects were derived from generalized linear mixed models by examining associations of average PA across 21 days with drinking frequency. Table 8 displays the parameters from the unadjusted and final adjusted models, including significant main and interaction effects. The proportion of between-person variance in

average drinking frequency decreased in the final adjusted model (σ^2_{u0} = .88 compared with σ^2_{u0} = 1.07 in the unconditional model), suggesting that the fixed effects predictors helped explain some of the variability in average drinking frequency. As shown above under Aim 1, PA variables were added to the models for frequency including the level-2 covariate, gender, and the level-1 covariates, day of the week and previous day drinking. The coefficients pertaining to average PA were then analyzed.

Effects of PA on drinking frequency

Results from the final adjusted model revealed that drinking frequency and average PA time across 21 days were unassociated at between-person levels (all *ps* > .08). Results from the final adjusted model indicated that the between-subject drinking frequency and average PA METS relation were unassociated (all *ps* > .10). Results from the final adjusted model revealed that drinking frequency and objective PA time were not associated at the between-person level (p = .32). Results from the final adjusted model indicated an absence of between-person association between drinking frequency and objective PA intensity (p = .67).

Interaction effects on drinking frequency

To evaluate hypotheses 3b and 3c, respectively, interaction effects between the 5 facets of IMP and PA and REL and PA were examined. Results indicated no interactions between IMP and PA (all *ps* > .14) or between REL and PA time on drinking frequency (all *ps* > .11), suggesting that neither IMP nor REL had a moderating influence on the between-person PA-drinking frequency association. We did, however, observe a main

effect of SS on drinking frequency (p = .048), suggesting that those higher on SS drank more frequently.

As a final step in the analyses, we interacted gender with all PA variables. Results revealed significant interaction effects only between PA METS recorded objectively and gender at between-persons (γ = .01, SE = .005, t = 2.05, p = .04), indicating that compared with women, men who engaged in more intense PA on average, drank more frequently (Figure 9).

Results from our additional analyses using SS, PU, and NU in the models with frequency as outcome, indicated no significant interactions between any of these facets and PA on drinking frequency (all *ps* > .29).

Taken together, our results suggest that there were no significant between- or within-person associations between AC and PA across 21 days. There was little evidence indicating that AC and PA co-varied between or within persons in any systematic way. We observed that both PA and AC varied within and between individuals when moderated by some of the dimensions of IMP, but not consistently, regardless of how PA and AC were operationally defined. Therefore, it may be that PA and AC co-vary within and between individuals, but not in any of the ways we had predicted.

Between-person analyses at baseline

Negative binomial regressions were used to analyze the association between PA and AC at baseline. Total drinks over the past month (as assessed in the TLFB) served as the outcome variable. PA time and METS (as measured in the IPAQ) served as the predictor variables. PA variables were modelled separately for reasons of collinearity. Since gender was uncorrelated with drinking quantity at baseline, we first constructed our

models by including PA variables. Gender was added to the models as a covariate but had no main effect on AC (all *ps* > .09).

Results from negative binomial regressions revealed that total time spent in PA, was unassociated with drinking quantity at baseline (p = .37). Similarly, results showed that moderate PA METS and vigorous PA METS were not significantly associated with drinking quantity at baseline (all *ps* > .95) (Table 9).

Interaction effects

Then, to examine hypothesis 3b, the 5 facets of IMP were added to the adjusted model and results indicated no significant interaction effects between PA and IMP (all *ps* > .11), suggesting that IMP did not significantly moderate the association between time spent in PA and AC at baseline. However, we observed a main effect of NU on drinking quantity (γ = .22, SE = .09, t = 2.42, p = .02).

To examine hypothesis 3c, religiosity was then added to the adjusted model and results indicated no interaction effects between religiosity and PA time or METS on AC (p > .10), suggesting that religiosity had no moderating influences on the PA-AC association at baseline.

Results from interaction effects models including only SS, PU, and NU revealed no significant interaction effects between any of the 3 facets and PA METS on drinking quantity (all *ps* > .16), indicating no moderating influences on AC, however, main effects of SS (γ = .13, SE = .06, t = 2.05, p = .04), PU (γ = -.18, SE = .09, t = -1.99, p = .047), and NU (γ = .18, SE = .08, t = 2.14, p = .03), were observed on drinking quantity. While

SS and NU showed a positive association with drinking, PU was negatively associated with drinking.

Between-person analyses at follow-up

Negative binomial regressions were used to analyze the association between PA and AC at follow-up. Similar to the analyses at baseline, total drinks over the past month (as assessed in the TLFB) served as the outcome variable and PA time and METS (as measured in the IPAQ) served as the predictor variables. PA variables were modelled separately for reasons of collinearity. Gender was added to the models as a covariate but had no main effect on AC (all *ps* > .76).

Results revealed no significant associations between total time spent in PA, moderate METS, or vigorous METS and drinking quantity at follow-up (all *ps* > .27). (Table 9).

Interaction effects

Next, to examine the potential moderating effects of IMP on the PA-AC association at between-person levels in fulfillment of hypothesis 3b, the 5 facets of IMP were added to the adjusted models. Results indicated no significant interaction effects between dimensions of IMP and PA (all *ps* > .11).

To examine hypothesis 3c, religiosity was interacted with PA time and METS and results revealed no main or interaction effects on AC (all *ps* > .14), indicating that religiosity did not exert any moderating influences on the PA-alcohol intake association at follow-up.

Additionally, results from interaction effects models including only SS, PU, and NU, revealed no significant interaction effects between any of the 3 facets and PA intensity on drinking quantity (all *ps* > .11), therefore none of these dimensions exerted a moderating influence on AC at follow-up. Table 10 displays a summary of the significant interactions.

In sum, we observed no significant main effects of PA on quantity of drinking, nor did we find any interaction effects between IMP or REL and PA on drinking quantity at baseline or follow-up. However, the between-subject PA-AC relation across 21 days was significantly moderated by gender and NU. This discrepancy in our findings may be attributed to the different measures used to collect PA and AC data, IPAQ and TLFB respectively, at baseline and follow-up compared with the daily diary used over 21 days. It is also possible that examining the relation longitudinally helped capture the effects of contextual variables, gender and NU.

DISCUSSION

The present study evaluated whether physical activity and alcohol consumption were associated at within-person and between-person levels among emerging adults, and whether impulsivity and religiosity played a moderating role in the within- and between-person PA-AC relation. We expected to find a negative within-person PA-AC association across 21 days, in that, individuals would consume less alcohol on days they engaged in more PA. We further hypothesized that people who engaged in more PA, on average, would consume more alcohol. Between-person associations between PA and AC were examined at baseline, across 21 days, and at follow-up. We also hypothesized that IMP

and REL would moderate the PA-AC relation within and between subjects, expecting IMP to make the between-person PA-AC association more positive and the within-person association less negative. In contrast, we postulated that REL would make the between-person PA-AC association less positive and the within-person association more negative. We assessed both quantity (total daily servings) and frequency (odds of drinking/not drinking on a given day) primarily because college students' patterns of alcohol use most resemble binge drinking, whereby they drink frequently on weekends but less on weekdays, and consume large amounts of alcohol during those drinking sessions. Importantly, not only is binge drinking associated with short-term damages to the brain, such as working memory impairment (Townshend & Duka, 2005; Weissenborn & Duka, 2003), but it also poses long-term health threats, such as a heightened risk of future AUD (Gowin et al., 2017). Further, Henderson et al. (2020) pointed out that the odds of alcohol use is an important outcome in treatment programs geared toward preventing problem drinking. Indeed, health behaviors established throughout college years are likely to extend into later adulthood making intervention for problem drinking more challenging (Nelson et al., 2008; Williams et al., 2002), and it is therefore important to detect and control maladaptive drinking early on. Furthermore, Buchholz and Crowther (2014) noted that young women who used exercise as a compensatory mechanism drank more in quantity but not in frequency. In light of these findings, different associations may emerge between drinking frequency and PA versus drinking quantity and PA, therefore both quantity and frequency should be taken into account when examining the between- and within-subject relation between PA and AC in student populations.

To add to the confused literature on the relationship between PA and AC, both within- and between-person associations between PA and alcohol intake across 21 days were not statistically significant, which is consistent with findings from Henderson et al. (2020), whose study design and methodology were similar to that of the current project. Cross-sectional analyses revealed that PA and AC were not associated at baseline or follow-up. Furthermore, we observed differential moderating influences of dimensions of IMP on the PA-AC relationship depending on the alcohol outcome variable (quantity or frequency), on how PA was measured, and whether these associations were evaluated at the between- or within-person level. However, no moderating effects of REL were shown to influence the association between PA and drinking. Our findings underscore the complex nature of the PA-AC association among college populations and emphasize the importance of investigating this relation at both within-and between-person levels.

Within-Subjects Associations

There was little evidence to suggest that AC and PA covaried within persons in any systematic way when controlling for average associations. We observed that both PA and AC varied within individuals on the social weekend and when moderated by some of the dimensions of IMP, however the two health behaviors did not covary consistently, regardless of how PA and AC were measured (i.e., drinking quantity or frequency, self-reported or objective PA).

It is well-established that college students tend to binge drink on weekends and engage in little to no drinking during weekdays (Abrantes et al., 2017; Finlay et al., 2012; Maggs et al., 2011; Neighbors et al., 2011), and indeed, we observed a robust association

between day of the week and both drinking quantity and frequency, which indicated larger amounts of alcohol intake and higher rates of drinking over the social weekend (Thursday to Saturday). Interestingly, previous day drinking was only positively related to drinking frequency but not quantity, suggesting that the probability of consuming alcohol on a certain day was higher if participants drank the previous day, however, consuming more alcohol on a given day was unassociated with next day drinking quantity. It is possible that, because weekend and weekdays were taken into account, higher rates of drinking were aggregated around the social weekend, so, those who drank on Thursday were also likely to drink on Friday and on Saturday, whereas amount of alcohol consumed did not predict drinking less or more the following day, perhaps because students were aware that they only had these 2 to 3 days to drink before they resumed schoolwork activities and responsibilities. Moreover, previous day PA was unassociated with alcohol intake, which is in line with Conroy et al.'s (2014) findings, who observed significant associations between previous day drinking, but not previous day PA, and alcohol use.

Regarding interaction effects between day of the week and PA on drinking outcomes, our results revealed a negative within-person association between drinking frequency and vigorous PA that pertained to weekends only, indicating that on days representing the social weekend, but not on weekdays, individuals were less likely to consume alcohol when they engaged in more vigorous PA. However, we did not observe a significant association with drinking quantity as the outcome. These findings are partially consistent with Abrantes et al. (2017), such that higher levels of weekday PA were associated with less weekend drinking, and although they specifically showed that

more weekday exercise predicted less weekend drinking over time, taking into account weekends and weekdays may yield a more meaningful relation between the behaviors of PA and AC. Conversely, Conroy et al. (2014) did not observe changes in drinking and PA on the weekend, but that was likely due to sample characteristics, in that their sample consisted predominantly of community dwellers ranging from 19 to 89 years in age, and hence, were not representative of college populations. Therefore, it seems essential to take into account days of the week when examining the longitudinal PA-AC association.

The discrepancies between our findings on within-person PA-AC associations and those of previous studies may have stemmed from our study design structure and the methods and measures we used. While Henderson et al. (2020), Abrantes et al. (2017) and Cho et al. (2018) all focused on student populations, both Henderson et al. (2020) and Cho et al. (2018) used a daily diary to collect information on AC behaviors, and neither study found significant within-person associations between PA and drinking, which is partially in line with our results. Whereas, Abrantes et al. (2017) who found a negative within-person PA-AC relation collected alcohol and PA behaviors using the TLFB, which requires recall over the past 90 days. It has been shown that participants tend to underreport their drinking when using the TLFB compared with a daily diary (Dulin et al., 2017). Further, Conroy et al. (2014) who demonstrated a positive within-person association between PA and AC did not confine their study to young college students, who likely exhibit a unique pattern of drinking and PA contingent upon the college environment. Additionally, while Henderson et al. (2020) used only an objective measure of PA and Cho et al.'s (2018) participants self-reported PA in the diary, the current study employed both objective and subjective methods of PA, which may

complement each other and provide more accurate information on the relation between PA and AC. Furthermore, alcohol outcomes examined in Henderson and colleagues (2020) consisted of drinks/no drinks odds ratio, and Cho et al. (2018) asked about quantity of drinks consumed daily, whereas we investigated both drinking outcomes (quantity and frequency). Thus, in addition to some observed differences between prior work and our results, the variability within our findings is not surprising considering the diverse methods and measures we employed.

Between-Subjects Associations

There was little evidence indicating that AC and PA co-varied between persons in any systematic way across 21 days when controlling for daily associations. We found that both PA and AC varied between individuals when moderated by gender or by some of the components of IMP, but not consistently, regardless of how PA and AC were operationally defined. Similarly, results from cross-sectional between-subjects analyses at baseline and follow-up revealed no significant relation between PA and AC. Findings from our longitudinal analyses are in line with those of Henderson et al. (2020) and Conroy et al. (2014), which is not surprising given the shared methodologies, i.e., daily diary to collect data on drinking. On the other hand, our results from baseline and follow-up were somewhat surprising in that they contradicted the majority of prior cross-sectional research demonstrating that individuals who engage in more average PA consume more alcohol. Dodge et al. (2017) reviewed 16 studies that examined PA-AC associations, all of which used a retrospective measure of alcohol use, including or similar to the TLFB. And Dulin et al. (2017) asserted that compared with a daily diary,

the TLFB is subjected to recall bias as well as underreporting of number of drinks consumed, which may explain why we found no significant between-person PA-AC relation across 21 days. However, since we also used the TLFB to collect alcohol data at baseline and follow-up, it is either that the effects of recall bias tend to vary from one study to another, or, that our alcohol data (TLFB over the past 30 days) did not map onto our PA data (collected through the IPAQ which examines activity over the past 7 days). Another plausible explanation for an absence of between-person associations between PA and AC is our low drinking sample. Indeed, across all days of data collection, participants reported consuming alcohol on 33% of those days and did not drink on 67% of those days. And, approximately 72% of observations consisted of 0 drinks and 28% consisted of 1 or more drinks.

We observed that gender was significantly associated with both drinking quantity and frequency. Evidence for a narrowing gender gap worldwide in alcohol consumption is well-depicted in a systematic review by Slade et al. (2016). Their findings demonstrated that men born in the early 20th century were twice as likely to consume alcohol and 3 times more likely to engage in problematic drinking than the same female birth cohort; whereas males born in the late 20th century were 1.1 times more likely to consume alcohol and 1.2 times more likely to engage in problematic drinking than women of the same birth cohort (Slade et al., 2016). Nevertheless, men still appear to consume more alcohol and develop problematic drinking compared with women (Erol & Karpyak, 2015; Gowin et al., 2017). Men are also twice as likely to binge drink compared with women (Centers for Disease Control and Prevention, 2019), which is consistent with

our results demonstrating that men drank more in quantity and frequency compared with women.

With respect to interaction effects of gender on the PA-AC relation, we found that gender significantly moderated the association between objective PA intensity and drinking frequency, but not quantity, suggesting that men who, on average, engaged in more vigorous PA (recorded objectively) drank more frequently. We did not, however, observe that gender moderated the relation between self-reported PA and drinking. Such discrepancies in findings between self-reported diary PA and objectively measured PA may be due to issues of over-reporting in the diary (Prince et al., 2008) or alternatively, inaccuracies in movement detection in Pacer. Although, Höchsmann et al. (2018) investigated the validity of smartphone activity trackers with respect to placement position and found that they were satisfactorily accurate independently of where on the body they were placed. In line with the current study findings, Buscemi et al. (2011) found a positive association between PA and AC that was significant in men but not in women, and similarly, Lisha and colleagues (2011) reported a stronger positive relation between moderate PA and drinking among men. Perhaps in the context of gender differences, investigating joint motives of drinking and exercise may shed light on the underlying reasons for why the association was stronger in males. The ‘work hard, play hard’ ethic suggests that when individuals engage in strenuous jobs, they then reward themselves with a pleasurable activity (Leasure et al., 2015; Lisha et al., 2011). In the context of exercise and drinking, this may translate to people using alcohol as a reward for a vigorous activity, and it is possible that our male sample endorsed this ‘work hard, play hard’ ethic more so than women. If we also think about it in the other direction,

individuals may feel the need to exercise more vigorously or spend more time working out after drinking larger amounts of alcohol. For instance, Graupensperger at al. (2018) demonstrated a positive relationship between alcohol consumption and vigorous PA, such that increased drinking predicted future increased vigorous PA. Granted, their findings pertained to the within-person level and they did not report any gender differences, however, they highlighted the importance of the association between intensity of activity and drinking, which may be driven by particular motives such as counterbalancing negative health effects and guilt (French et al., 2009). For instance, Abrantes et al. (2017) demonstrated that the positive between-subject PA-AC relation was significant for individuals who used exercise to compensate for the extra calories of alcohol. Indeed, investigating joint motives for exercise and drinking and the directionality of the relation between PA and alcohol use while taking gender into account may help further elucidate the current findings (Leasure et al., 2015).

Impulsivity

IMP as defined and measured in the UPPS-P scale was not uniformly associated with drinking and PA. Instead, the dimensions were implicated in the PA-AC association differentially. With respect to the main effects of facets of IMP on AC, we first noted that sensation-seeking (SS) and the urgencies, negative and positive (NU and PU), were predominant predictors of alcohol quantity, although, only SS predicted drinking frequency. In other words, participants who scored higher on SS, PU, and NU consumed larger volumes of alcohol and those who scored higher on SS drank more frequently. Cyders et al. (2009) reported that while PU was more strongly associated with alcohol

quantity, SS was a stronger predictor of drinking frequency. Furthermore, there seems to be a general consensus in the literature about SS, PU and NU, labeled the 'emotional' components of IMP, more strongly predicting alcohol use (Crucio & George, 2011; Cyders et al., 2009; LaBrie et al., 2019; Stamates & Barraco, 2017; Tran et al., 2018). Stamates and Barraco (2017) reviewed the association of the 5 dimensions of IMP measured in the UPPS-P scale with alcohol consumption outcomes with the goal of clarifying which dimensions were more tightly linked to alcohol use versus alcohol-related problems. They reported that among emerging adults, SS largely predicted consumption of alcohol while PU and NU more strongly predicted alcohol-related problems, which corroborate that SS, PU and NU are greatly involved in drinking and may present as risk factors, and are therefore important to investigate in the PA-AC relation. Notably, longitudinal studies revealed that PU was the strongest predictor of drinking quantity among college students (Cyders et al., 2009; Settles et al., 2010).

There is, indeed, a large body of research on the relationship between IMP and alcohol-related behaviors and IMP and exercise behaviors. However, the literature on impulsivity's role in the PA-AC association has only recently emerged and remains scarce. Only two studies have examined the moderating effect of IMP on the relationship between PA and AC and they have yielded mixed findings, perhaps because of their discrete methodologies and study designs. On the one hand, in their cross-sectional design, Leasure and Neighbors (2014) examined whether the dimensions of the UPPS-P scale moderated the PA-AC relation between persons. They demonstrated a consistent pattern of significant interactions between SS and PU and moderate PA on drinking quantity. On the other hand, Cho et al. (2018) used the Revised NEO Personality

Inventory, consisting of 8 items (compared with the UPPS-P which contains 59 items and is multidimensional) to evaluate whether IMP would influence daily deviations from PA and drinking. Their results revealed no significant moderating effects of IMP on the within-person PA-drinking association.

Because IMP was treated as a continuous variable in the current study, we used interaction plots to get a general idea about the moderating effects of some of the dimensions of IMP on the covariance between PA and AC. Our results demonstrated that positive urgency (PU) played a key moderating role in the PA-AC association. First, we found consistent patterns of interaction effects between PU and moderate PA on alcohol quantity and frequency at the within-subject level, which we did not observe in the between-subject PA-AC relation. In other words, PU influenced the strength of the within-person relation between alcohol quantity and PA and between drinking frequency and PA. Further, these findings pertained to both time spent in PA and PA METS. Interaction plots revealed that for higher levels of PU, both drinking quantity and frequency appeared to increase when daily moderate PA increased. Conversely, for lower levels of PU, it appeared that both quantity and frequency of drinking decreased on days when individuals engaged in more moderate PA. These findings are in line with those of Leasure and Neighbors (2014), who demonstrated that PU significantly moderated the positive association between moderate PA and AC at the person-level. While Leasure and Neighbors (2014) found this effect on the between-person PA-AC relation at a single time point, to the best of our knowledge, this is the first study to report a significant moderation effect of PU on the within-subject association between moderate PA and drinking across 3 weeks. However, contrary to what they demonstrated, we did not find

SS to be a moderator of the PA-AC relation, which may be attributed to our study sample characteristics, whereby our sample consisted of 26% males. Because men tend to be higher sensation-seekers than women (Cyders et al., 2013), perhaps SS was not salient enough in our sample to act as moderator of the PA-AC association. Additionally, PU is characterized by the urge to act rashly in response to positive affect (Cyders et al., 2007). Thus, to put this characterization of PU in the context of our significant interaction effects between PU and PA on drinking quantity, it may be that participants higher on PU engaged in more PA and drank more in response to positive mood, essentially because both feel good.

We also demonstrated that NU exerted a moderating effect on the between-person relation between vigorous PA and alcohol quantity, and this moderation effect applied to both self-reported vigorous PA and objective PA intensity. Interaction plots revealed that for those higher on NU, drinking decreased as PA intensity increased. The hallmark of NU is that it combines impulsivity and negative affect (Cyders et al., 2007; Cyders & Smith, 2007). It is possible, then, that for these individuals who scored higher on NU, higher intensity PA provided a substitute to drinking. Kotbagi et al. (2017) demonstrated that NU was strongly correlated with excessive maladaptive exercise that may lead to harmful health consequences, and suggested that those higher in NU may use excessive maladaptive exercise as a coping strategy to help alleviate negative affect. Another explanation for these results may lie in the idea that one rewarding activity may substitute another rewarding activity. Indeed, the hedonic substitution of alcohol intake with exercise has been consistently demonstrated in research on rodents (Darlington et al., 2014; Ehringer et al., 2009; Gallego et al., 2015). Mice concurrently exposed to a running

wheel and alcohol would consistently choose running over drinking compared with mice who had no access to running wheels (Darlington et al., 2014; Ehringer et al., 2009; Gallego et al., 2015). This idea that a substance-free activity, e.g., exercise, may have a suppressive effect on alcohol cravings is at the very basis of studies using exercise regimens as adjunctive treatment for AUD (Leasure et al., 2015). Since exercise and alcohol both activate the neurobiological pathways for reward and increase dopamine and endogenous opioids, exercise could very well compete with alcohol thereby providing a substitute for drinking (Bardo & Compton, 2015; Lynch et al., 2013).

Another dimension of IMP which significantly interacted with PA was lack of perseverance (PERS). We demonstrated that PERS significantly moderated the within-person, but not the between-person association between alcohol quantity and objective PA time, and interaction plots indicated that for higher levels of PERS, daily drinking decreased as time spent in PA increased. Lack of perseverance is described as a trait reflecting a lack of conscientiousness and people who score higher on PERS have a low sense of responsibility and are largely unable to focus on and complete tasks (Cyders & Smith, 2007). Further, Magid and Colder (2007) found that when college students higher on the trait of PERS consumed alcohol they neglected obligations and responsibilities. There is little to no information on the role of perseverance in the PA-AC association and as far as we are aware, this is the first study to show a moderating effect of PERS on the within-individual relation between PA and AC. It could be that participants higher on PERS used PA as a substitute for drinking, however, this may be a far-fetched idea given that individuals with low perseverance and conscientiousness are less likely to replace a risky behavior with a health-promoting one. Of note, the negative association moderated

by PERS was between drinking quantity and time spent engaging in PA (but not PA intensity) that was recorded objectively in Pacer. Therefore, it could be that these individuals engaged in only moderate activities, such as walking, which did not require much effort, persistence or commitment.

Taken together, the current findings indicated an inconsistent pattern of interactions between facets of IMP and PA on drinking outcomes, in that some of the components of the UPPS-P exerted significant effects on within- versus between-person PA-AC associations, while others did not. It is possible that the variability in these findings were due to the multidimensionality of our IMP measure in relation to the distinct drinking outcomes and measurements of PA.

Religiosity

Despite the vast literature on the protective role of religiosity in alcohol behaviors (Chawla et al., 2007; Cochran et al., 1992; Wells, 2010), and in particular, that religiosity is inversely proportional to alcohol use and abuse (Cochran et al., 1992), the present results indicated no main effects of REL on drinking quantity or frequency. Further, and contrary to our hypotheses, we did not find that REL had any moderating influences on within- or between-level changes between PA and AC. The current study findings on religiosity's role in the PA-AC association are in line with our previous research on religious perceptions and alcohol use, which indicated that individuals with a religious affiliation held more negative perceptions of drinking and drunkenness but they did not actually consume less alcohol compared with non-religious people (Najjar et al., 2016). In addition, the current project extended our previous findings by examining the extent of

religious devoutness as a possible moderator of the PA-AC association. Additional analyses were conducted to examine whether religious affiliation (selected in the Demographics section) interacted with religiosity, was associated with alcohol quantity and frequency. Results indicated no significant main or interaction effects of religious affiliation and religiosity on drinking quantity or frequency. Perhaps, then, among college student populations, affiliating with a particular religion and level of religious devoutness have been somewhat disconnected from drinking behaviors. In fact, the first couple of months of freshman year represent a sensitive time for new college students (Sher & Rutledge, 2007) when forming social connections, making friends, and developing a sense of belongingness may be at the top of the priority list. Therefore, drinking- and exercise-related activities may represent the gateway to achieve such social bonds, especially as drinking and exercise are typical college activities which commonly take place in social settings, e.g., parties, exercise classes, sports, etc. So, although drinking might be perceived negatively among the more highly religious, the act of drinking for the purpose of socializing and forming social bonds may override these perceptions. There is indeed a complex relation between religion and drinking behaviors (Chawla et al., 2007). Studies on descriptive norms and alcohol consumption indicate that college students' drinking is more strongly associated with the perceived drinking of friends rather than students who may share the same religious affiliation and level of religiosity (Baer et al., 1991; Thombs et al., 2005). And this relationship between norms and alcohol use may take on a new layer of complexity when PA is added to the mix. Therefore, religiosity may not be as important a factor to take into account when trying to understand the relationship between PA and drinking.

In sum, the variability that emerged with respect to the moderating influences of IMP in our findings may very well be attributed to our study design and methodology, whereby we examined the PA-AC association, 1- between versus within participants, 2- in models with quantity versus frequency as the outcome variable, 3- in models with self-reported diary PA versus objectively recorded PA, 3- using various PA intensities, 4- in interaction effects models including level-1 and/or level-2 covariates, and, 5- cross-sectionally at baseline and follow-up versus longitudinally across 21 days. Moreover, the discrepancies between the current study findings and prior work may be attributed to the underlying diversity in research designs examining the association between AC and PA, i.e., timescales, directionality, and contextual factors. Regarding moderators, the present results, along with those of Abrantes et al. (2017) and Henderson et al. (2020) emphasize the importance of factoring in contextual variables when examining PA-AC associations. For instance, Henderson and colleagues (2020) found that both drinking motives and mood significantly moderated the between-person PA-AC relation. More research is needed to further investigate how motives and moderators may influence the PA-AC association among college students and to parse out for whom the relation may be significant and particularly, whose alcohol intake may intensify as PA increases.

The present research findings are particularly informative for scholars exploring PA as a possible prevention and/or intervention method for alcohol problems. While understanding the PA-AC relation between subjects is important, it is equally important that researchers take into account longitudinal changes in the behaviors of PA and AC that may unfold daily, weekly or monthly, while also capturing relevant contextual factors that may influence these changes, i.e., day of the week, special occasions,

holidays, personality traits, drinking and exercise motives, mood states, family history of drinking, and other related traits, behaviors and events. Ultimately, this study may help address the challenges behind developing suitable multi-behavior interventions as well as health guidelines when a beneficial health behavior (e.g., PA) and a health risk behavior (e.g., drinking) systematically covary among young emerging adults in college.

LIMITATIONS AND CONCLUSIONS

This research has helped partially address the conflicting findings in the literature regarding within- and between-person associations between PA and AC. Careful consideration has been applied to the possible limitations of this project with regard to the validity and generalizability of the results. We recognize that one limitation includes the use of self-report measures of alcohol behaviors, which is partially addressed by previous research supporting the validity of measures on alcohol consumption in emerging adults (Babor et al., 1987; Kokotailo et al., 2004; Sobell et al., 2001). In particular, the alcohol TLFB is a widely used measure that has been demonstrated to have good validity and reliability (Sobell et al., 1996; Sobell et al, 2001). In addition, the IPAQ was shown to have good validity when used in healthy populations (Craig et al., 2003; Hagströmer et al., 2006) and self-report measures of IMP and REL were demonstrated to have high validity among college students (Collins et al., 1985; Cyders et al., 2007; Koenig & Büssing, 2010; Wang et al., 2014). Furthermore, daily measurements of alcohol intake and PA collected through the daily diary were expected to decrease the proportion of inaccurate answers due to retrospective recall. Also, the inclusion of an objective measure of PA may help reduce inaccuracies related to retrospective recall or self-report bias,

especially as previous studies using smartphone-based assessments of PA have shown that smartphones apps have good enough sensitivity to distinguish actual PA from noise (Bort-Roig et al., 2014; Höchsmann et al., 2018; Presset et al., 2018). Presset and colleagues (2018) found that a smartphone app was more accurate in detecting physical activity than a mechanical pedometer strapped at the waist. Moreover, we recognize that this study sample was composed of college students recruited from only two Southwestern universities across the United States, which may perhaps limit the generalizability of our findings. Therefore, future studies may wish to use more diverse student populations, especially, as distinct universities may vary as to the proportion of student drinking.

In closing, this research project has helped provide novel insights into within-person associations between PA and AC and the influences of IMP and REL, or lack thereof, thereby contributing to awareness on college drinking matters and the design and implementation of suitable interventions for maladaptive drinking in young adult populations. It is recommended that programs designed to incorporate PA in AUD treatment pinpoint ways in which the inclusion of PA does not simultaneously increase the consumption of alcohol (Dodge et al., 2017). Furthermore, because significant variability in drinking and PA may be overlooked with a shorter time frame of a few weeks or less than a month (Maggs et al., 2011), future studies examining the PA-AC association over a longer time frame may help shed a brighter light on the nature of the relation. Additionally, including additional risk factors that are strongly implicated in binge drinking and AUD such as, family history of alcoholism (Gowin et al., 2017) may provide more clues about the association between alcohol intake and PA. Lastly,

expanding beyond young college-attending adults would be constructive, given that older treatment-seeking populations may benefit from this line of research as well.

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Table 1

Timeline of self-report measures and daily assessments

	Baseline	Daily Assessments	Follow-up
	Day 1	Day 1 - 21	Day 21
Demographics	x		x
AC	x	Daily Diary of AC and PA	x
PA	x	Objective measure of PA (daily recording)	x
Impulsivity	x		x
Religiosity	x		x

Note. 'x' indicates measures completed on Days 1 and 21.

Table 2

Physical activity intensity and corresponding objective and descriptive measures

Intensity Category	Objective Measures	Descriptive Measures
Light	METS < 3	A physical activity with no noticeable change in breathing rate
Moderate	3 < METS < 6	A physical activity able to be conducted while maintaining a conversation uninterrupted
Vigorous	METS > 6	A physical activity in which a conversation cannot be maintained uninterrupted

Note. Adapted from Norton et al. (2010).

Table 3

Correlations, means, standard deviations, and ranges among baseline variables

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1.	Gender	--	.05	.006	.11	.12	.01	-.11	.29***	.05	-.07	-.08	-.04
2.	IPAQ-B (time)		--	.74***	.56***	.06	.05	-.01	.15*	.24**	.16*	.03	.14*
3.	IPAQ-B (modmet)			--	.14*	.00	.02	-.01	.14*	.24**	.15*	.03	.05
4.	IPAQ-B (vigmet)				--	.02	.16*	.13*	.09	.12	.08	-.04	.14*
5.	TLFB-B					--	.36***	.02	.13↓	-.02	.08	-.03	-.06
6.	AUDIT						--	.11	.21**	.25***	.27***	.10	.17*
7.	REL							--	-.08	.10	.04	-.18**	-.07
8.	SS								--	.28***	.17**	-.10	.19*
9.	PU									--	.67***	.34***	.42***
10.	NU										--	.39***	.42***
11.	PERS											--	.48***
12.	PREM												--
Mean		.26	1290	1281	2087	22.61	6.33	11.10	2.67	1.82	2.21	1.91	1.83

Standard Deviation	.44	1769	2556	5388	20.83	3.48	4.14	.67	.61	.61	.47	.48
Minimum	.00	.00	.00	.00	.00	.00	4.00	1.17	1.00	1.00	1.00	1.00
Maximum	1.00	15240.00	20160.00	60480.00	119.00	22.00	16.00	4.00	3.86	3.83	3.80	3.91

Note. IPAQ-B (time) = total minutes of retrospective weekly PA self-reported at baseline; IPAQ-B (modmet) = moderate MET minutes of retrospective weekly PA self-reported at baseline; IPAQ-B (vigmet) = vigorous MET minutes of retrospective weekly PA self-reported at baseline; TLFB-B= total drinks in the past month self-reported at baseline; AUDIT = problem drinking self-reported at baseline; REL = religiosity self-reported at baseline. The following are the 5 facets of impulsivity self-reported at baseline: SS = sensation-seeking; PU = positive urgency; NU = negative urgency; PERS = lack of perseverance; PREM = lack of premeditation. *$p < .05$. **$p < .01$ ***$p < .0001$.

Table 4

Correlations, means, standard deviations, and ranges among follow-up variables

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1.	Gender	--	-.05	-.08	.01	-.01	.13	-.06	.23**	.06	-.03	-.10	.02
2.	IPAQ-F (time)		--	.63***	.43***	.37***	.06	.05	-.02	.02	.05	.04	-.07
3.	IPAQ-F (modmet)			--	.51***	.23**	.06	.00	.00	.00	.03	.01	-.01

4. IPAQ-F (vigmet)				--	.35***	.07	-.02	-.15*	.01	.06	.00	.06
5. TLFB-F					--	.28**	.02	-.01	.08	.13	.12	.06
6. AUDIT-F						--	.12	.20**	.15*	.23**	-.02	-.06
7. REL-F							--	-.08	.13	.04	-.09	-.03
8. SS-F								--	.15*	.07	-.19*	.04
9. PU-F									--	.69***	.30***	.29***
10. NU-F										--	.43**	.29***
11. PERS-F											--	.61***
12. PREM-F												--
Mean	.26	1672	2231	2105	25.99	6.28	11.18	2.72	1.82	2.14	1.95	1.89
Standard Deviation	.44	4021	7141	6627	21.60	3.48	4.39	.65	.61	.63	.49	.46
Minimum	.00	.00	.00	.00	.00	.00	1.00	1.00	1.00	1.00	1.00	1.00
Maximum	1.00	42255.00	64410.00	86400.00	139.00	22.00	16.00	4.00	4.00	4.00	3.20	3.45

Note. IPAQ-F (time) = total minutes of retrospective weekly PA self-reported at follow-up; IPAQ-F (modmet) = moderate MET minutes of retrospective weekly PA self-reported at follow-up; IPAQ-F (vigmet) = vigorous MET minutes of retrospective weekly PA self-reported at follow-up; TLFB-F = total drinks in the past month self-reported at follow-up; AUDIT-F = problem drinking self-reported at follow-up; REL-F = religiosity self-reported at follow-up. The following are the 5 facets of impulsivity self-reported

at follow-up: SS-F = sensation-seeking; PU-F = positive urgency; NU-F = negative urgency; PERS-F = lack of perseverance; PREM-F = lack of premeditation. *$p < .05$. **$p < .01$ ***$p < .0001$.

Table 5

Correlations, means, standard deviations, and ranges among daily variables

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1.	Gender	--	.04*	.04**	.00	.00	.17***	.17***	.26***	.26***	-.001
2.	Drinking quantity		--	.67***	.04*	.04*	.00	.00	-.02	-.05↓	.18***
3.	Drinking frequency			--	.01	.01	-.01	-.01	.008	-.02	.14***
4.	Moderate PA (time)				--	1.0***	.31***	.31***	.16***	.15***	.03*
5.	Moderate PA (METS)					--	.31***	.31***	.16***	.15***	.03*
6.	Vigorous PA (time)						--	1.0***	.24***	.22***	-.01

7. Vigorous PA (METS)							--	.24***	.22***	-.01
8. Objective PA (time)								--	.92***	-.06**
9. Objective PA (METS)									--	-.07**
10. Weekend										--
Mean	.26	0.75	0.33	54.34	163.02	16.61	99.68	53.82	114.22	.42
Standard Deviation	.44	1.77	0.47	87.60	262.79	41.91	251.44	41.22	73.60	.49
Minimum	.00	.00	.00	.00	.00	.00	.00	.00	.81	.00
Maximum	1.00	28.00	1.00	900.00	2700.00	600.00	3600.00	319.00	588.42	1.00

Note. Drinking quantity = total drinks per day per individual; Drinking frequency = drinks (1) or no drinks (0) per day per individual; Moderate PA (time) = time in minutes spent in moderate daily PA; Moderate PA (METS) = calculated MET minutes of moderate daily PA; Vigorous PA (time) = time in minutes spent in vigorous daily PA; Vigorous PA (METS) = calculated MET minutes of vigorous daily PA; Objective PA (time) = PA time in minutes recorded from the Pacer app; Objective PA (METS) = calculated MET minutes from the Pacer app; Weekend = day of the week coded as weekend or weekday. *$p < .05$ **$p < .01$ ***$p < .0001$.

Table 6

Correlations, means, standard deviations, and ranges among average/total variables across all days and baseline impulsivity and religiosity variables

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
1.	Gender	--	.10	.12	.007	.007	.25***	.25***	-.11	.29***	.05	-.07	-.08	-.04	.41***	.45***
2.	ACquant		--	.67***	.14*	.14*	.07	.07	-.02	.07***	.04*	.05**	.00	.04**	-.07	-.04
3.	ACfreq			--	.06	.06	-.03	-.03	.00	.08***	.04**	.06**	.05	.04**	.07	.11
4.	ModPA (time)				--	1.00***	.41***	.41***	.06	.05	.15*	.10	.05	.02	.15	.14
5.	ModPA (METS)					--	.41***	.41***	.06	.05	.15*	.10	.05	.02	.15	.14
6.	VigPA (time)						--	1.00***	.16*	.02	.11	-.02	-.02	.05	.33**	.29**
7.	VigPA (METS)							--	.16*	.02	.11	-.02	-.02	.05	.33**	.29**
8.	REL								--	-.08	.10	.04	-.18**	-.07	.14	.07
9.	SS									--	.28***	.17**	-.10	.19*	.16	.26**
10.	PU										--	.67***	.34***	.42***	.04	.06
11.	NU											--	.39***	.42***	-.01	.00
12.	PERS												--	.48***	.04	.02

13.	PREM												--	-.03	-.00
14.	ObjPA (time)													--	. 86***
15.	ObjPA (METS)														--
Mean		.26	12.91	6.00	54.22	162.65	16.67	100.03	11.10	2.67	1.82	2.21	1.91	1.83	53.68	112.22
Standard Deviation		.44	12.48	4.37	87.68	192.77	41.97	164.50	4.14	.67	.61	.61	.47	.48	24.82	47.08
Minimum		.00	.00	.00	.00	.00	.00	.00	4.00	1.17	1.00	1.00	1.00	1.00	3.2	30.23
Maximum		1.00	76.50	20.00	602.86	1809.00	163.85	983.08	16.00	4.00	3.86	3.83	3.80	3.91	134.19	300.42

Note. ACquant = sum of total daily drinks; ACfreq = drinking frequency across all days; ModPA (time) = person-specific mean of moderate PA time; ModPA (METS) = person-specific mean of moderate PA MET minutes; VigPA (time) = person-specific mean of vigorous PA time; VigPA (METS) = person-specific mean of moderate PA MET minutes; ObjPA (time) = person-specific mean of objective PA minutes; ObjPA (METS) = person-specific mean of objective PA METS; REL = religiosity self-reported at baseline; SS = sensation-seeking; PU = positive urgency; NU = negative urgency; PERS = lack of perseverance; PREM = lack of premeditation. *$p < .05$. **$p < .01$ ***$p < .0001$.

Table 7

Negative binomial multilevel model coefficients examining between- and within-person associations between physical activity and drinking quantity

	Unadjusted Model				Adjusted Model			
Parameters	γ	SE	*t*	*p*	γ	SE	*t*	*p*
Diary PA time model								
Intercept	-.54***	.06	-8.85	<.0001	-1.07***	.08	-13.42	<.0001
Average moderate PA	.002	.001	1.63	.10	.002	.0009	1.75	.08
Average vigorous PA	-.0005	.002	-.21	.84	-.001	.002	-.63	.53
Daily moderate PA	-.0003	.0006	-.48	.63	-.001	.0006	-.89	.37
Daily vigorous PA	-.002	.001	-1.31	.19	-.001	.001	-.72	.47
Gender					.17	.14	1.24	.22
Weekend					.97***	.07	13.36	<.0001
PU x daily moderate PA					.004*	.001	2.48	.014
Diary PA METS model								
Intercept	-.54***	.06	-8.85	<.0001	-1.07***	.08	-13.42	<.0001
Average moderate PA	.0005	.0003	1.63	.10	.0005	.0003	1.75	.08
Average vigorous PA	-.00008	.0004	-.21	.84	-.0002	.0004	-.63	.53
Daily moderate PA	-.0001	.0002	-.48	.63	-.0002	.0002	-.89	.37
Daily vigorous PA	-.0003	.0002	-1.31	.19	-.0001	.0002	-.72	.47
Gender					.17	.14	1.24	.22
Weekend					.97***	.07	13.36	<.0001
PU x daily moderate PA					.001*	.0005	2.49	.014
Objective PA time model								
Intercept	-.59***	.09	-6.93	<.0001	-1.15***	.11	-10.23	<.0001
Average objective PA	_.004	.003	-1.11	.27	-.006	.004	-1.61	.11
Daily objective PA	-.00001	.002	-.01	.99	.0001	.002	.65	.51

Gender					.61**	.19	3.91	.002
Weekend					.89***	.11	7.98	<.0001
PERS x daily objective PA					-.004*	.002	-2.10	.038
Objective PA METS model								
Intercept	-.57***	.09	-6.55	<.0001	-1.13***	.11	-9.66	<.0001
Average objective PA	-.002	.002	-1.06	.29	-.003	.002	-1.68	.09
Daily objective PA	-.001	.001	-1.33	.18	-.0004	.001	-.40	.69
Gender					.56**	.20	2.78	.006
Weekend					.87***	.12	7.43	<.0001
NU x average objective PA					-.005*	.003	-1.98	.05

Note. Weekend = day of the week coded as weekend or weekday. *$p < .05$ **$p < .01$ ***$p < .0001$.

Table 8

Negative binomial multilevel model coefficients examining between- and within-person associations between physical activity and drinking frequency

	Unadjusted Model				Adjusted Model			
Parameters	γ	SE	*t*	*p*	γ	SE	*t*	*p*
Diary PA time model								
Intercept	-.69*	.33	-2.09	.04	-1.18**	.35	-3.33	.001
Average moderate PA	.001	.001	1.12	.26	.0001	.001	1.01	.31
Average vigorous PA	-.003	.003	-.93	.35	-.005	.003	-1.63	.10
Daily moderate PA	-.0005	.0006	-.80	.43	-.0006	.0006	-1.00	.32
Daily vigorous PA	-.0006	.001	-.53	.60	-.0003	.001	-.26	.79
Gender					.35*	.17	2.05	.04
Weekend					.72***	.08	9.25	<.0001

Previous AC					.42***	.08	5.23	<.0001
Weekend x daily vigorous PA					-.007**	.003	-2.52	.01
PU x daily moderate PA					.003*	.001	2.02	.04
Diary PA METS model								
Intercept	-.69*	.33	-2.09	.04	-1.18**	.35	-3.33	.001
Average moderate PA	.0005	.0004	1.12	.26	.0004	.0004	1.01	.31
Average vigorous PA	-.0005	.0005	-.93	.35	-.0008	.0005	-1.63	.10
Daily moderate PA	-.0002	.0002	-.80	.43	-.0002	.0002	-1.0	.31
Daily vigorous PA	-.0001	.0002	-.53	.60	-.00005	.0002	-.26	.79
Gender					.35*	.17	2.05	.04
Weekend					.72***	.08	9.25	<.0001
Previous AC					.42***	.08	5.23	<.0001
Weekend x daily vigorous PA					-.001**	.0004	-2.52	.01
PU x daily moderate PA					.0009*	.0004	2.02	.04
Objective PA time model								
Intercept	.89	1.34	.66	.51	.50	1.46	.34	.73
Average objective PA	.002	.004	.41	.68	-.004	.004	-.99	.32
Daily objective PA	.0007	.002	.50	.62	.002	.002	.99	.32
Gender					.71**	.24	2.93	.003
Weekend					.73***	.12	6.23	<.0001
Previous AC					.64***	.12	5.34	<.0001
Objective PA METS model								
Intercept	.70	1.46	.48	.63	.50	1.46	.34	.73
Average objective PA	.0009	.002	.41	.68	-.004	.004	-.99	.32
Daily objective PA	-.0005	.0009	-.57	.57	.002	.002	.99	.32
Gender					.71**	.24	2.93	.003
Weekend					.73***	.12	6.23	<.0001
Previous AC					.64***	.12	5.34	<.0001

Gender x Average objective PA	.01*	.005	2.05	.04

Note. Weekend = day of the week coded as weekend or weekday; Previous AC = the lagged outcome variable. *$p < .05$ **$p < .01$ ***$p < .0001$.

Table 9

Cross-sectional between-person physical activity-alcohol consumption associations at baseline and follow-up

	Baseline				Follow-up			
Parameters	γ	SE	*t*	*p*	γ	SE	*t*	*p*
PA time model								
Intercept	3.05***	.72	42.59	<.0001	3.24***	.10	33.20	<.0001
IPAQ (time)	.06	.07	.89	.37	.53	.49	1.10	.27
Gender	.23	.14	1.65	.10	.08	.21	.40	.69
Dispersion α	.73***	.07	9.91	<.0001	.52***	.05	9.58	<.0001
PA METS model								
Intercept	3.05*	.72	42.36	<.0001	3.24***	.10	33.20	<.0001
IPAQ (modmet)	-.003	.07	-.05	.96	-.40	.38	-1.05	.29
IPAQ (vigmet)	.0007	.07	0.01	.99	.01	.29	.04	.97
Gender	.24	.14	1.70	.09	.08	.21	.40	.69
Dispersion α	.73***	.07	9.91	<.0001	.53***	.05	9.61	<.0001

Note. IPAQ (time) = total minutes of self-reported PA in the IPAQ; IPAQ (modmet) = moderate METS self-reported in the IPAQ; IPAQ (vigmet) = vigorous METS self-reported in the IPAQ. *$p < .05$ **$p < .01$ ***$p < .0001$.

Table 10

Summary of significant interaction effects

			Quantity	**Frequency**
	Baseline	Follow-up	Across 21 days	Across 21 days
Within-person	N/A	N/A	PU significantly moderated the association between AC and moderate PA time and METS (full and truncated models) PERS significantly moderated the association between AC and objective PA time	PU significantly moderated the association between AC and moderate PA time and METS (full and truncated models) Day of the week significantly moderated the association between AC and vigorous PA time and intensity → on weekend days, individuals who engaged in more vigorous PA were less likely to drink

Between-person			NU significantly moderated the association between AC and objective PA METS (full model) vigorous PA time and METS (truncated models)	Gender significantly moderated the association between AC and objective PA intensity → compared with women, men who engaged in more vigorous PA drank more frequently

Note. Summary of results indicating significant interaction effects on drinking quantity and frequency at between- and within-person levels. Full model = model including all 5 facets of IMP and their interactions with PA; truncated model = model including SS, PU, and NU and their interactions with PA.

Table 11

Summary of significant main effects of impulsivity on alcohol use

	Quantity			**Frequency**
	Baseline	Follow-up	Across 21 days	Across 21 days
Between-person	NU positively associated with AC in PA time and		SS positively associated with AC in PA time and METS models →	SS positively associated with AC in PA time and METS models →

METS models → individuals higher on NU consumed more alcohol	individuals higher on SS consumed more alcohol (truncated models)	individuals higher on SS consumed more alcohol
SS positively associated with AC in PA time and METS models → individuals higher on SS consumed more alcohol (truncated models)	NU positively associated with AC in objective PA time and METS models → individuals higher on NU consumed more alcohol	
PU negatively associated with AC in PA time and METS models → individuals higher on PU consumed less alcohol (truncated models)		

Note. Summary of results indicating significant main effects of some dimensions of IMP on drinking quantity and frequency.

Truncated model = model including SS, PU, and NU and their interactions with PA.

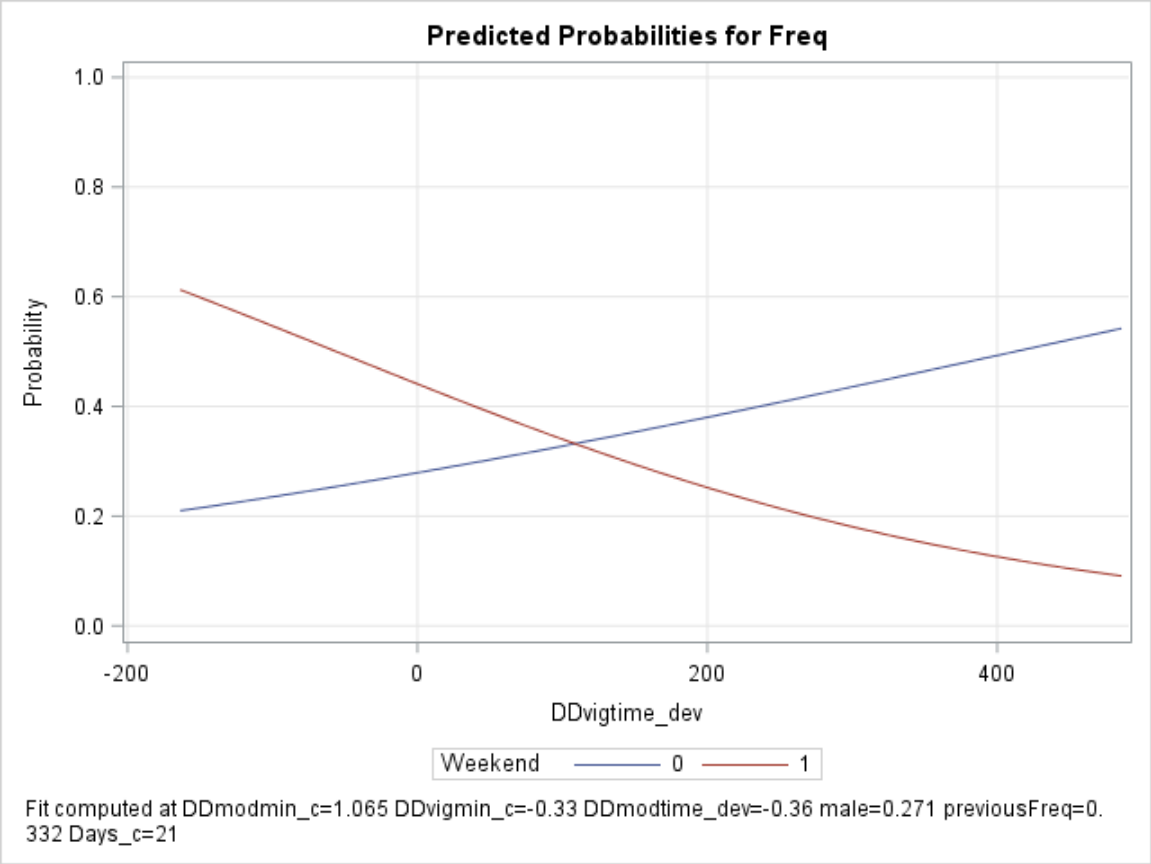


Figure 1. The probability of drinking as a function of the interaction between day of the week (weekend = 1 / weekday = 0) and self-reported vigorous PA time. These lines are computed for average vigorous PA time, DDvigmin_c = -.33. For different values of average vigorous PA time, these lines would be at different heights on the y-axis.

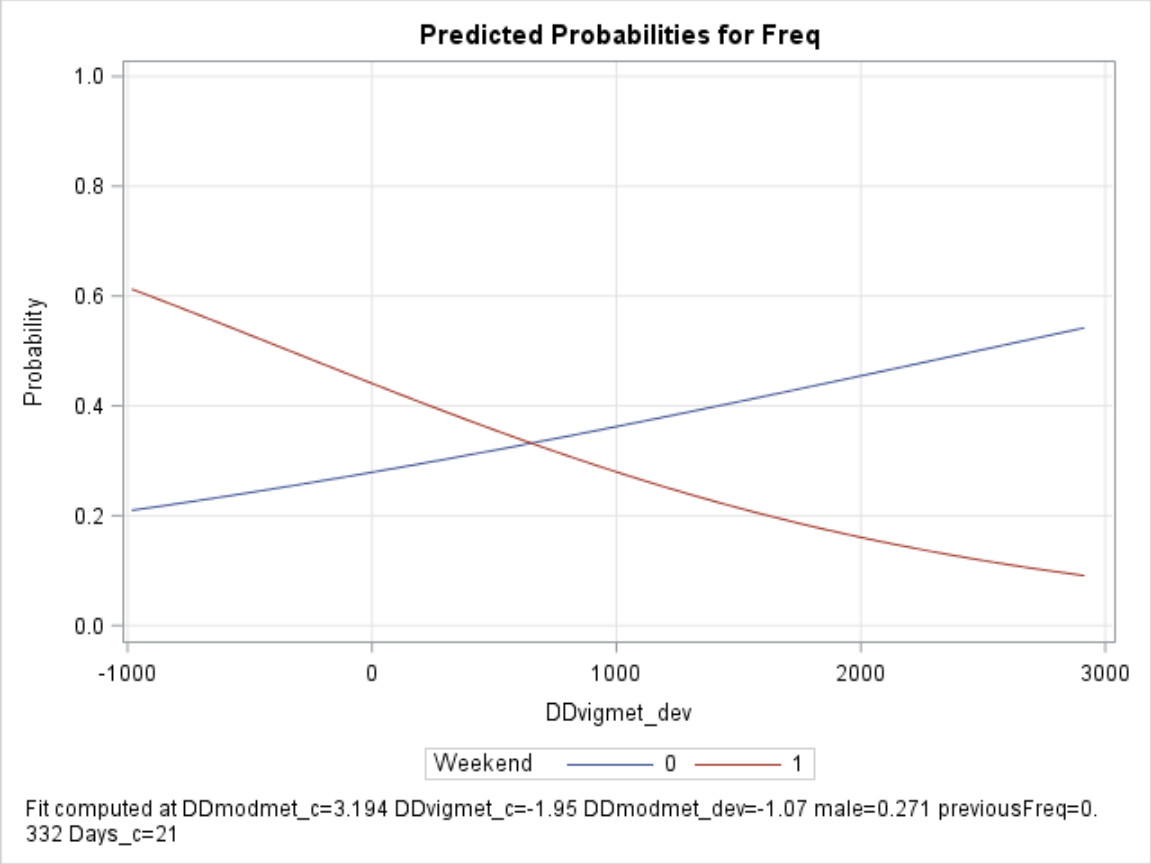


Figure 2. The probability of drinking as a function of the interaction between day of the week (weekend = 1 / weekday = 0) and self-reported vigorous PA METS. These lines are computed for average vigorous PA METS, DDvigmet_c = -1.95. For different values of average vigorous PA METS, these lines would be at different heights on the y-axis.

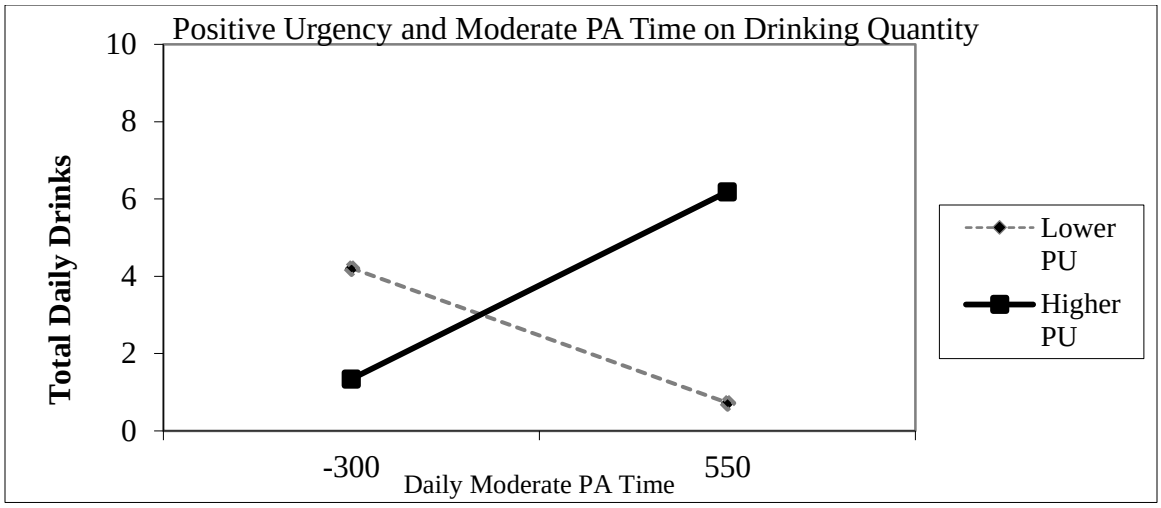


Figure 3. Quantity of drinking as a function of the interaction between daily moderate PA time and positive urgency; PU = positive urgency.

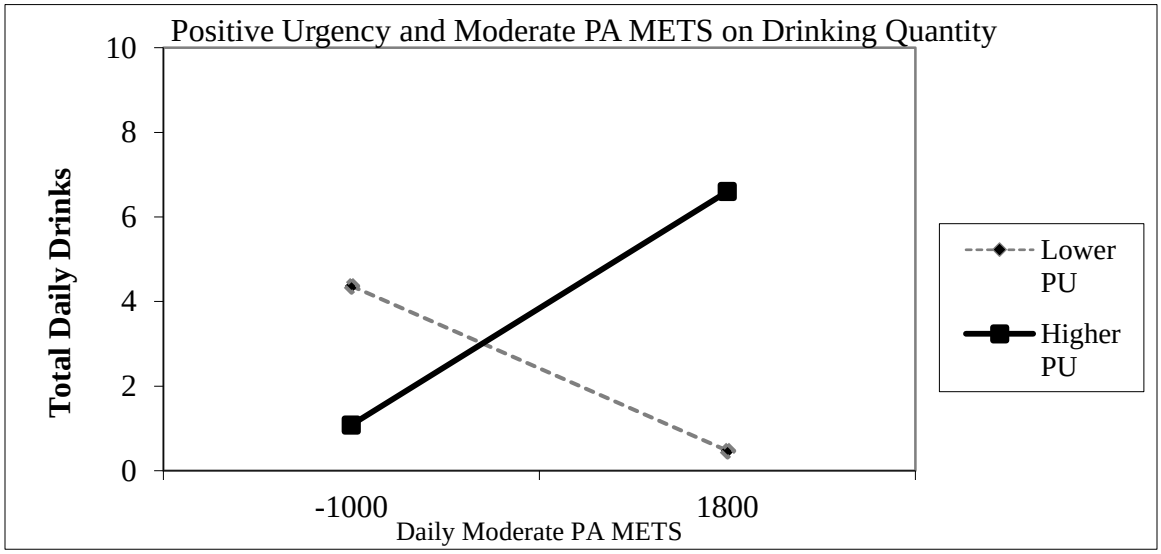


Figure 4. Quantity of drinking as a function of the interaction between daily moderate PA METS and positive urgency; PU = positive urgency.

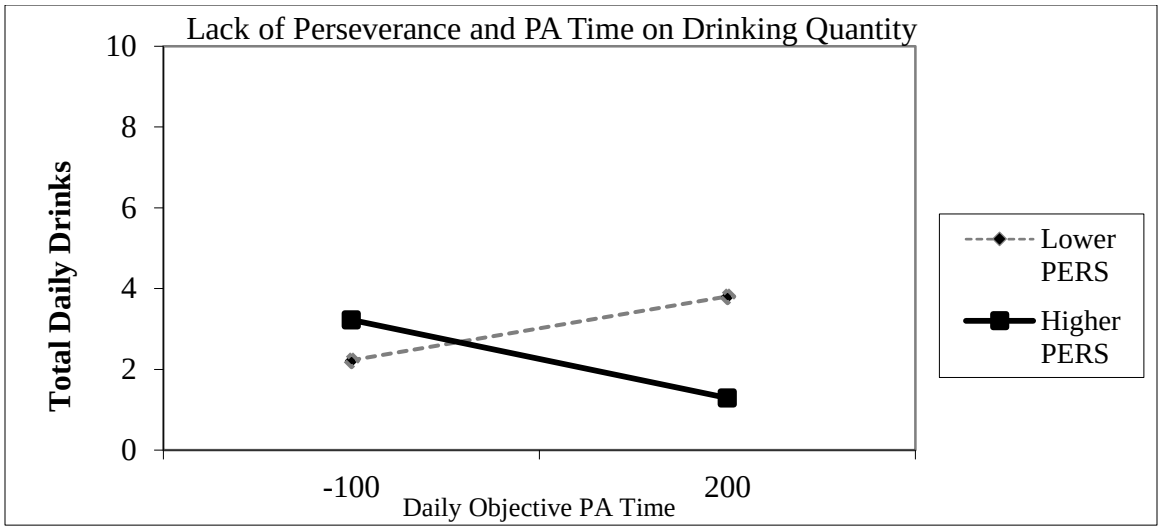


Figure 5. Quantity of drinking as a function of the interaction between daily objective PA time and lower to higher values of PERS; PERS = lack of perseverance.

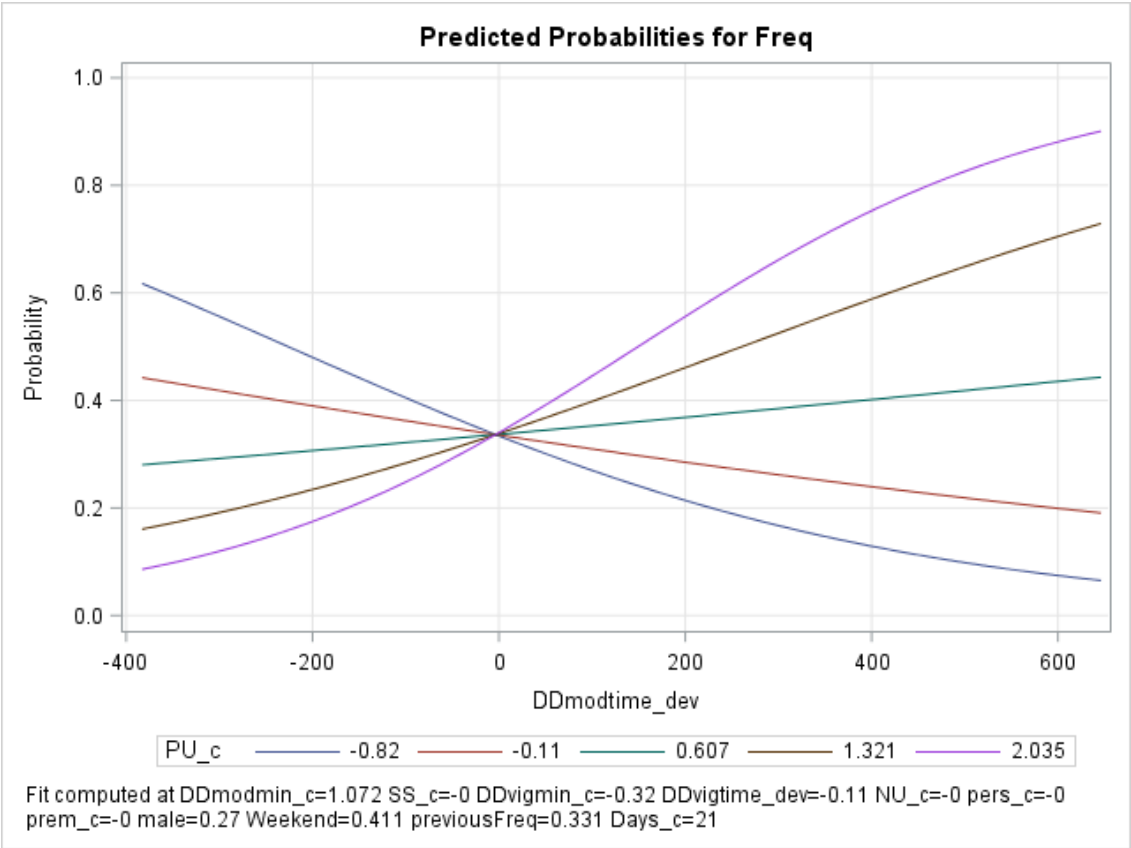


Figure 6. The probability of drinking as a function of the interaction between daily moderate PA time and lower to higher values of PU; PU = positive urgency. This collection of lines is computed for average moderate PA time, DDmodmin_c = 1.072. For different values of average moderate PA time, this collection of lines would be at different heights on the y-axis.

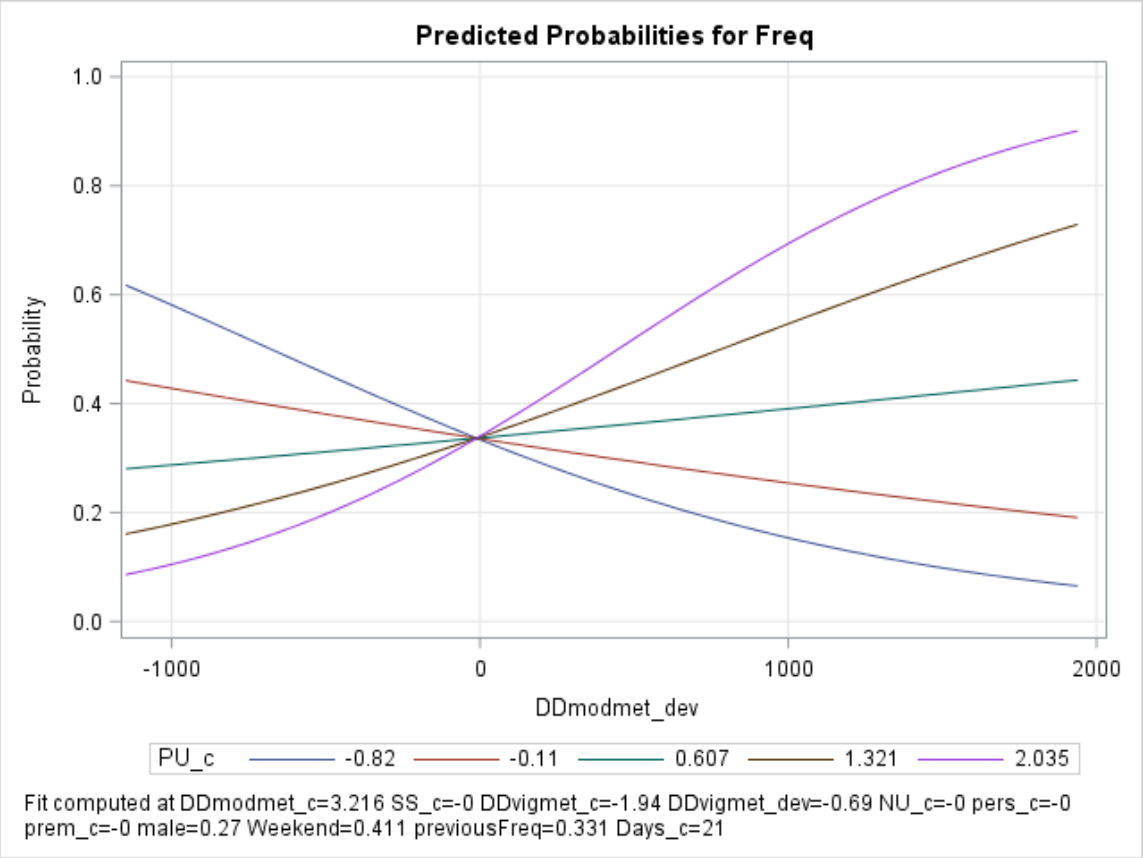


Figure 7. The probability of drinking as a function of the interaction between daily moderate PA METS and lower to higher values of PU; PU = positive urgency. This collection of lines is computed for average moderate PA METS, DDmodmet_c = 3.216. For different values of average moderate PA METS, this collection of lines would be at different heights on the y-axis.

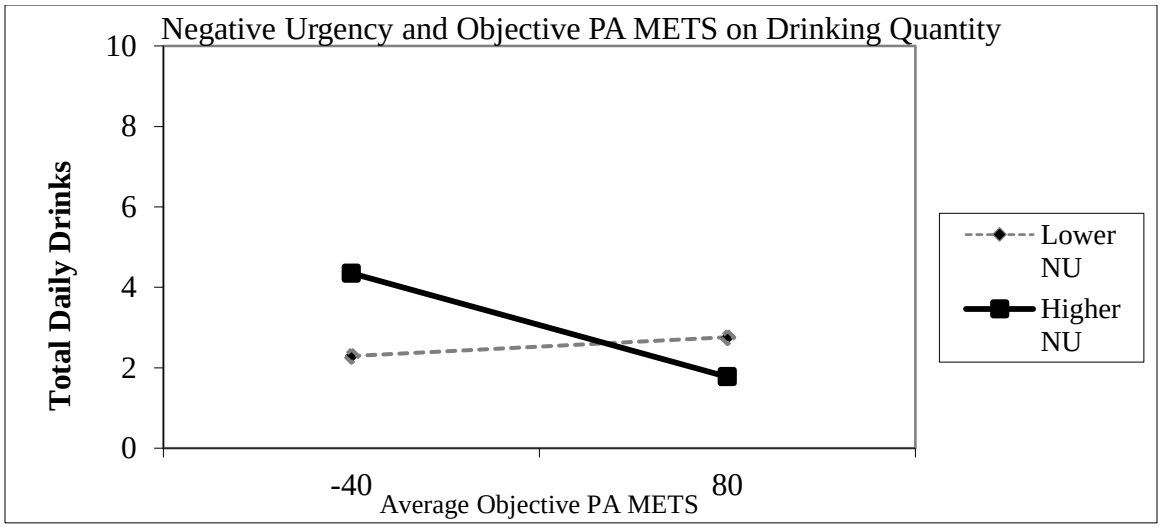


Figure 8. Quantity of drinking as a function of the interaction between average objective PA METS and lower to higher values of NU; NU = negative urgency.

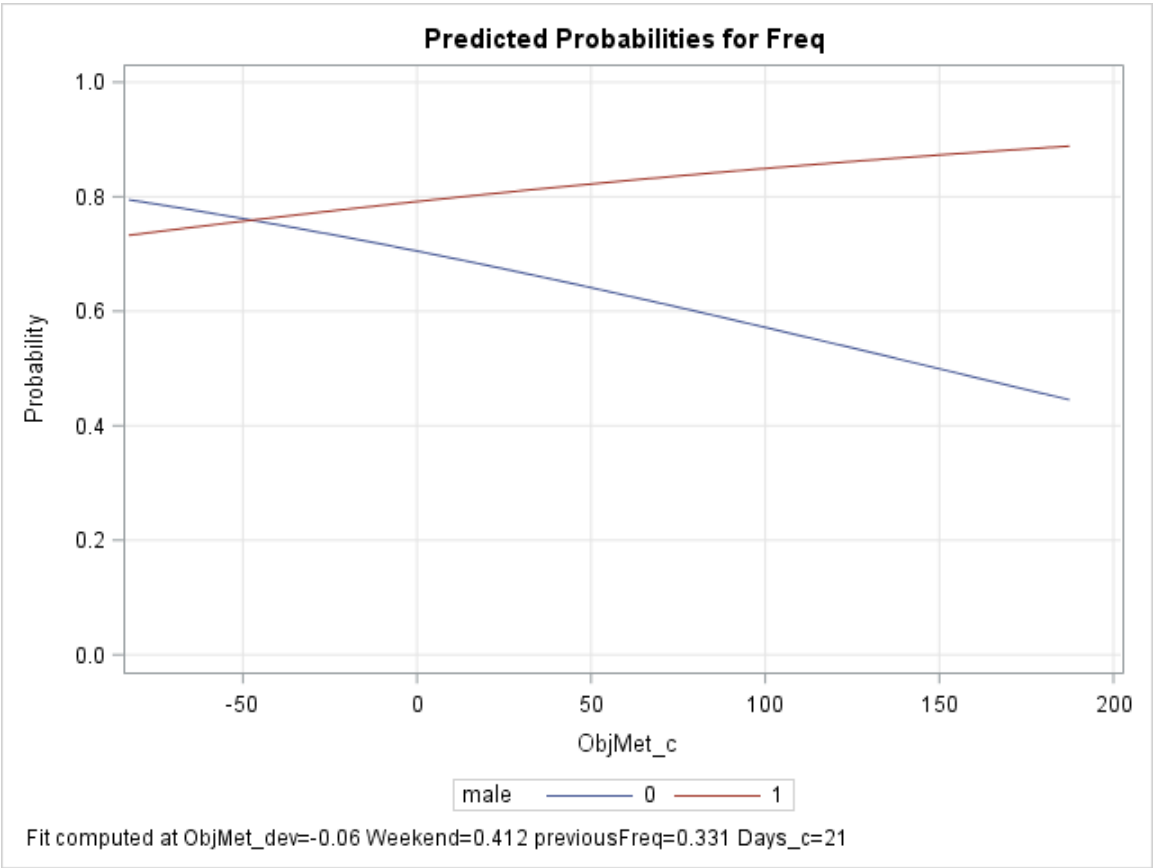


Figure 9. The probability of drinking as a function of the interaction between gender and PA intensity (recorded objectively); ObjMet_c = objectively recorded average PA METS.

APPENDIX A

Measures Packet

Baseline and Follow-up surveys

Smartphones and Health Behaviors

Demographics

Instructions: Please read each question carefully and select the most accurate response.

1. **Are you between 18-25 years of age?**
   __ Yes
   __ No (If participant marks "No," they will be sent out of the survey as they do not meet participation requirements)

2. **Age:_____**years

3. **Do you drink at least 1 alcoholic beverage per week?** __ Yes __ No (If participant marks "No," they will be sent out of the survey as they do not meet participation requirements)

4. **Do you own a smartphone?** __ Yes __ No (If participant marks "No," they will be sent out of the survey as they do not meet participation requirements)

5. **Sex:** __Male __Female

6. **Height:**_____ft._____in

7. **Weight: (for Blood Alcohol Content):**

   _____lbs.

8. **Ethnic Background:**
   __ Hispanic/Latino __ Nonhispanic

9. **Racial Background:**
   __ White/Caucasian
   __ Native American/American Indian
   __ Black/African American
   __ Asian

14. **Where are you living this semester?**
    __ Residence Halls/Dorm Room
    __ Fraternity/Sorority House
    __ Off-Campus Housing/Apartment/House
    __ With Parents

15. **Are you currently a Fraternity or Sorority Member?** __ Yes __ No

16. **Work Status:**
    __ I do not work
    __ Working part-time
    __ Working full-time

17. **Religious Affiliation?**
    __ Christian
    __ Jewish
    __ Muslim
    __ Hindu
    __ Buddhist
    __ Agnostic
    __ Atheist
    __ Non-religious/secular
    __ Other (specify)_____

18. **Religious Denomination?**
    __ Catholic
    __ Baptist
    __ Methodist
    __ Lutheran
    __ Presbyterian
    __ Episcopal
    __ Sunni
    __ Shiite

__ Native Hawaiian/Pacific Islander
__ Multi-Ethnic
__ Other

10. What is your year in school?

__1st year __2nd year __3rd year

__4th year __5th year __6th year

__7th year __ more

11. Class Standing:
__ Freshman
__ Sophomore
__ Junior
__ Senior

12. Student Status:
__ Part-time (1-11 credits)
__ Full-time (12+ credits)

13. Most recent Semester's GPA (Write N/A if this does not apply to you:_____

__ Other (specify)

19. Relationship Status?
__ Single, not dating
__ Single, casual dating
__ Single, exclusively dating
__ Engaged
__ Married/Life partner

20. If you are currently in a relationship, do you live with your partner?
__ Yes __ No __ Not applicable

21. How many children do you have, if any?
__ 0 __ 1 __ 2 or more

30 Day Timeline Follow-back

INSTRUCTIONS: To help us evaluate your drinking, we need to get an idea of what your alcohol use was like in the past **30 days**. To do this, we would like you to fill out a calendar.

- Filling out the calendar is not hard!
- Try to be as accurate as possible.
- We recognize that you won't have perfect recall. That's OKAY.

WHAT TO FILL IN

- The idea is to record **how many drinks** you consumed for **each day** on the calendar.
- On days when you did not have any alcohol, not even part of a drink, you should enter a "0."
- On days when you did have alcohol, even part of a drink, you should enter the total number of drinks you had. Also, the smallest number of drinks you can record is "1."

YOUR BEST ESTIMATE

- We realize it isn't easy to recall things with 100% accuracy.
- If you are not sure whether you drank 3 or 4 drinks or whether you drank on a Thursday or a Friday, **just give it your best guess**!
- What is important is that 3 or 4 drinks is very different from 10 or 12 drinks. The goal is to get a sense of how frequently you drank, how much you drank, and your patterns of use.

HELPFUL HINTS

- If you have an appointment book you can use it to help you recall your drinking.
- Holidays such as Thanksgiving and Christmas are marked on the calendar to help you recall your drinking. Also, think about how much you drank on personal holidays & events such as birthday, vacations, or parties.
- If you have regular patterns to your drinking, you can use these to help you recall your use. For example, some people may only drink during certain social situations.

ENTERING YOUR RESPONSES

- You will be presented with a calendar for the previous 30 days on the next page.
- You will also be presented with each week separately, starting with yesterday thru 7 days ago and will be asked to report on your drinking and number of hours spent drinking for each day of each week over the past 30 days.
- In estimating your drinking, be as accurate as possible.

- Enter in the standard sized drinks you drank on each day.
- **When you did drink, you would write in the total number of drinks you had using the Drink Conversion Chart you'll find on the next page.**

For example: If you had 6 beers, write the number 6 for that day. If you drank more than one kind of alcoholic beverage in a day such as 2 beers and 3 glasses of wine, you would write the number 5 for that day.

The time period we are talking about on the calendar is from _____ through _____.

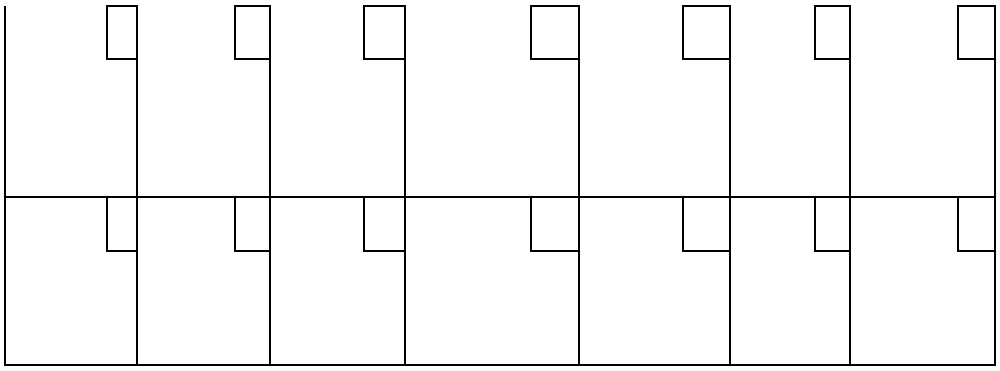
STANDARD DRINK CONVERSION CHART

For all questions, **one drink equals**:

5oz. wine; 12oz. wine cooler; 12oz. beer; 1 oz. of 100 proof liquor or 1 ½ oz of 80 proof liquor

For Example:
- If on a typical Thursday you drink 3, 12 oz. regular beers, you would type in 3 drinks.
- If on a typical Friday you drink 1 mixed drink that contains 3, 1 oz. shots of 80 proof liquor, you would type in 3 drinks.

MONTH						
Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**



Week 1

(yesterday thru 7 days prior – Day 1 thru Day 7)

Today is _____.

For each day below (__/__/___ to __/__/___), indicate the number of drinks you consumed on each day. PLEASE REMEMBER TO ENTER A 0 FOR ANY DAYS YOU DID NOT DRINK.

__/__/___	__/__/___	__/__/___	__/__/___	__/__/___	__/__/___	__/__/___

Over how many hours did you drink on each day?

__/__/___	__/__/___	__/__/___	__/__/___	__/__/___	__/__/___	__/__/___

Week 2 (Day 8 thru Day 14)

For each day below (__/__/___ to __/__/___), indicate the number of drinks you consumed on each day. PLEASE REMEMBER TO ENTER A 0 FOR ANY DAYS YOU DID NOT DRINK.

__/__/___	__/__/___	__/__/___	__/__/___	__/__/___	__/__/___	__/__/___

Over how many hours did you drink on each day?

__/__/___	__/__/___	__/__/___	__/__/___	__/__/___	__/__/___	__/__/___

Week 3 (Day 15 thru Day 21)

For each day below (__/__/___ to __/__/___), indicate the number of drinks you consumed on each day. PLEASE REMEMBER TO ENTER A 0 FOR ANY DAYS YOU DID NOT DRINK.

__/__/___	__/__/___	__/__/___	__/__/___	__/__/___	__/__/___	__/__/___

Over how many hours did you drink on each day?

__/__/___	__/__/___	__/__/___	__/__/___	__/__/___	__/__/___	__/__/___

Week 4 (Day 22 thru Day 28)

For each day below (__/__/___ to __/__/___), indicate the number of drinks you consumed on each day. PLEASE REMEMBER TO ENTER A 0 FOR ANY DAYS YOU DID NOT DRINK.

__/__/___	__/__/___	__/__/___	__/__/___	__/__/___	__/__/___	__/__/___

Over how many hours did you drink on each day?

__/__/___	__/__/___	__/__/___	__/__/___	__/__/___	__/__/___	__/__/___

Week 5 (Day 29 thru Day 30)

For each day below (__/__/___ to __/__/___), indicate the number of drinks you consumed on each day. PLEASE REMEMBER TO ENTER A 0 FOR ANY DAYS YOU DID NOT DRINK.

__/__/___	__/__/___

Over how many hours did you drink on each day?

__/__/___	__/__/___

Alcohol Use Disorders Identification Test (AUDIT)

Please select the answer that is correct for you.

1. How often do you have a drink containing alcohol?

Never	Monthly or less	Two to four times a month	Two to three times per week	Four or more times per week

2. How many drinks containing alcohol do you have on a typical day when you are drinking?

1 or 2	3 or 4	5 or 6	7 to 9	10 or more

3. How often do you have six or more drinks on one occasion?

Never	Less than monthly	Monthly	Two to three times per week	Four or more times per week

4. How often during the last year have you found that you were not able to stop drinking once you had started?

Never	Less than monthly	Monthly	Two to three times per week	Four or more times per week

5. How often during the last year have you failed to do what was normally expected from you because of drinking?

Never	Less than monthly	Monthly	Two to three times per week	Four or more times per week

6. How often during the last year have you needed a first drink in the morning to get yourself going after a heavy drinking session?

Never	Less than monthly	Monthly	Two to three times per week	Four or more times per week

7. How often during the last year have you had a feeling of guilt or remorse after drinking?

Never	Less than monthly	Monthly	Two to three times per week	Four or more times per week

8. How often during the last year have you been unable to remember what happened the night before because you had been drinking?

Never	Less than monthly	Monthly	Two to three times per week	Four or more times per week

9. Have you or someone else been injured as a result of your drinking?

No	Yes, but not in the last year	Yes, during the last year

10. Has a relative or friend, or a doctor or other health worker, been concerned about your drinking or suggested you cut down?

No	Yes, but not in the last year	Yes, during the last year

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

PART 1: JOB-RELATED PHYSICAL ACTIVITY

Circle the best answer

1. Do you currently have a job or do any unpaid work outside your home?
   1=”yes” 2=”no”
2. During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, heavy construction, or climbing upstairs as part of your work? Think about only those physical activities that you did for at least 10 minutes at a time.

1= No vigorous job-related physical activity	5= 4 days
2= 1 day	6= 5 days
3= 2 days	7= 6 days
4= 3 days	8= 7 days

3. How much time did you usually spend on one of those days doing vigorous physical activities as part of your work? _____

4. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate physical activities like carrying light loads as part of your work? Please do not include walking,

1=” No moderate job-related physical activity”	5= 4 days
2= 1 day	6= 5 days
3= 2 days	7= 6 days
4= 3 days	8= 7 days

5. How much time did you usually spend on one of those days doing moderate physical activities as part of your work?_____

6. During the last 7 days, on how many days did you walk for at least 10 minutes at a time as part of your work**?** Please do not count any walking you did to travel to or from work.

1= No job-related walking activity	5= 4 days
2= 1 day	6= 5 days
3= 2 days	7= 6 days
4= 3 days	8= 7 days

7. How much time did you usually spend on one of those days walking as part of your work?_____

PART 2: TRANSPORTATION PHYSICAL ACTIVITY

8. During the last 7 days, on how many days did you travel in a motor vehicle like a train, bus, car, or tram?

1= No traveling in a motor vehicle	5= 4 days
2= 1 day	6= 5 days
3= 2 days	7= 6 days
4= 3 days	8= 7 days

9. How much time did you usually spend on one of those days traveling in a train, bus, car, tram, or other kind of motor vehicle?_____

10. During the last 7 days, on how many days did you bicycle for at least 10 minutes at a time to go from place to place**?**

1= No bicycling from place to place	5= 4 days
2= 1 day	6= 5 days
3= 2 days	7= 6 days
4= 3 days	8= 7 days

11. How much time did you usually spend on one of those days to bicycle from place to place?_____

12. During the last 7 days, on how many days did you walk for at least 10 minutes at a time to go from place to place?

1= No walking from place to place	5= 4 days
2= 1 day	6= 5 days
3= 2 days	7= 6 days
4= 3 days	8= 7 days

13. How much time did you usually spend on one of those days walking from place to place?

_____

PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

14. During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, landscaping work, shoveling snow, or digging in the garden or yard?

1= No vigorous activity in garden or yard	5= 4 days
2= 1 day	6= 5 days
3= 2 days	7= 6 days

4= 3 days 8= 7 days

15. How much time did you usually spend on one of those days doing vigorous physical activities in the garden or yard?_____

16. During the last 7 days, on how many days did you do moderate activities like carrying light loads, sweeping, washing windows, and raking in the garden or yard?

1= No moderate activity in garden or yard	5= 4 days
2= 1 day	6= 5 days
3= 2 days	7= 6 days
4= 3 days	8= 7 days

17. How much time did you usually spend on one of those days doing moderate physical activities in the garden or yard?_____

18. During the last 7 days, on how many days did you do moderate activities like carrying light loads, washing windows, scrubbing floors and sweeping inside your home?

1= No moderate activity inside home	5= 4 days
2= 1 day	6= 5 days
3= 2 days	7= 6 days
4= 3 days	8= 7 days

19. How much time did you usually spend on one of those days doing moderate physical activities inside your home?_____

PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

20. Not counting any walking you have already mentioned, during the last 7 days, on how many days did you walk for at least 10 minutes at a time in your leisure time?

1= No walking in leisure time	5= 4 days
2= 1 day	6= 5 days
3= 2 days	7= 6 days
4= 3 days	8= 7 days

21. How much time did you usually spend on one of those days walking in your leisure time?

_____

22. During the last 7 days, on how many days did you do vigorous physical activities like aerobics, running, fast bicycling, or fast swimming in your leisure time?

1= No vigorous activity in leisure time	5= 4 days
2= 1 day	6= 5 days
3= 2 days	7= 6 days
4= 3 days	8= 7 days

23. How much time did you usually spend on one of those days doing vigorous physical activities in your leisure time?_____

24. During the last 7 days, on how many days did you do moderate physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis in your leisure time**?**

1= No moderate activity in leisure time	5= 4 days
2= 1 day	6= 5 days
3= 2 days	7= 6 days
4= 3 days	8= 7 days

25. How much time did you usually spend on one of those days doing moderate physical activities in your leisure time?_____

PART 5: TIME SPENT SITTING

26. During the last 7 days, how much time did you usually spend sitting on a weekday?

    _____

27. During the last 7 days, how much time did you usually spend sitting on a weekend day?

    _____

UPPS-P

Below are a number of statements that describe ways in which people act and think. For each statement, please indicate how much you agree or disagree with the statement. If you **Agree Strongly** circle **1**, if you **Agree Somewhat** circle **2**, if you **Disagree somewhat** circle **3**, and if you **Disagree Strongly** circle **4**. Be sure to indicate your agreement or disagreement for every statement below. Also, there are questions on the following pages.

	Agree Some	**Disagree Some**	**Disagree Strongly**
1. I have a reserved and cautious attitude toward life.	1	2	3 4
2. I have trouble controlling my impulses.	1	2	3 4
3. I generally seek new and exciting experiences and sensations.	1	2	3 4
4. I generally like to see things through to the end.	1	2	3 4
5. When I am very happy, I can't seem to stop myself from doing things that can have bad consequences.	1	2	3 4
6. My thinking is usually careful and purposeful.	1	2	3 4
7. I have trouble resisting my cravings (for food, cigarettes, etc.).	1	2	3 4
8. I'll try anything once.	1	2	3 4
9. I tend to give up easily.	1	2	3 4
10. When I am in great mood, I tend to get into situations that could cause me problems.	1	2	3 4
11. I am not one of those people who blurt out things without thinking.	1	2	3 4
12. I often get involved in things I later wish I could get out of.	1	2	3 4
13. I like sports and games in which you have to choose your next move very quickly.	1	2	3 4
14. Unfinished tasks really bother me.	1	2	3 4
15. When I am very happy, I tend to do things that may cause problems in my life.	1	2	3 4
16. I like to stop and think things over before I do them.	1	2	3 4
17. When I feel bad, I will often do things I later regret in order to make myself feel better now.	1	2	3 4
18. I would enjoy water skiing.	1	2	3 4
19. Once I get going on something I hate to stop.	1	2	3 4
20. I tend to lose control when I am in a great mood.	1	2	3 4
21. I don't like to start a project until I know exactly how to proceed.	1	2	3 4

	4				1	2	3	
1	2	3	4			4		
1	2	3	4					
1	2	3	4		1	2	3	
1	2	3	4			4		
					1	2	3	
1	2	3	4			4		
1	2	3	4		1	2	3	
1	2	3	4			4		
					1	2	3	
1	2	3	4			4		
1	2	3	4		1	2	3	
						4		
1	2	3	4					

Please go to the next page

Agree Some	Disagree Some	Disagree Strongly	Agree Strongly

22. Sometimes when I feel bad, I can't seem to stop what I am doing even though it is making me feel worse.
23. I quite enjoy taking risks.
24. I concentrate easily.
25. When I am really ecstatic, I tend to get out of control.
26. I would enjoy parachute jumping.
27. I finish what I start.
28. I tend to value and follow a rational, "sensible" approach to things.
29. When I am upset I often act without thinking.
30. Others would say I make bad choices when I am extremely happy about something.
31. I welcome new and exciting experiences and sensations, even if they are a little frightening and unconventional.
32. I am able to pace myself so as to get things done on time.
33. I usually make up my mind through careful reasoning.
34. When I feel rejected, I will often say things that I later regret.
35. Others are shocked or worried about the things I do when I am feeling very excited.
36. I would like to learn to fly an airplane.
37. I am a person who always gets the job done.
38. I am a cautious person.
39. It is hard for me to resist acting on my feelings.
40. When I get really happy about something, I tend to do things that can have bad consequences.
41. I sometimes like doing things that are a bit frightening.
42. I almost always finish projects that I start.
43. Before I get into a new situation I like to find out what to expect from it.
44. I often make matters worse because I act without thinking when I am upset.
45. When overjoyed, I feel like I can't stop myself from going overboard.

						1	2	3
1	2	3	4				4	
1	2	3	4			1	2	3
1	2	3	4				4	
1	2	3	4					
1	2	3	4			1	2	3
1	2	3	4				4	
1	2	3	4			1	2	3
1	2	3	4				4	
						1	2	3
1	2	3	4				4	
						1	2	3
1	2	3	4				4	
1	2	3	4					
1	2	3	4			1	2	3
1	2	3	4				4	
						1	2	3
1	2	3	4				4	
1	2	3	4					
1	2	3	4					

Please go to the next page

	Agree Some	Disagree Some	Disagree Strongly	Agree Strongly
46. I would enjoy the sensation of skiing very fast down a high mountain slope.	1	2	3	4
47. Sometimes there are so many little things to be done that I just ignore them all.				
48. I usually think carefully before doing anything.	1	2	3	4
49. When I am really excited, I tend not to think of the consequences of my actions.	1	2	3	4
50. In the heat of an argument, I will often say things that I later regret.				
51. I would like to go scuba diving.	1	2	3	4
52. I tend to act without thinking when I am really excited.	1	2	3	4
53. I always keep my feelings under control.				
54. When I am really happy, I often find myself in situations that I normally wouldn't be comfortable with.	1	2	3	4
55. Before making up my mind, I consider all the advantages and disadvantages.	1	2	3	4
56. I would enjoy fast driving.	1	2	3	4
57. When I am very happy, I feel like it is ok to give in to cravings or overindulge.				
58. Sometimes I do impulsive things that I later regret.	1	2	3	4
59. I am surprised at the things I do while in a great mood.	1	2	3	4

1 2 3 4

1 2 3 4

Scoring Instructions

This is a revised version of the UPPS Impulsive Behavior scale (Whiteside & Lynam, 2001). This version, UPPS-P (Lynam et al., 2006), assesses Positive Urgency (Cyders et al., 2007) in addition to the four pathways assessed in the original version of the scale-- Urgency (now Negative Urgency), (lack of) Premeditation, (lack of) Perseverance, and Sensation Seeking. The scale uses a 1 (agree strongly) to 4 (disagree strongly) response format. Because the items from different scales run in different directions, it is important to make sure that the correct items are reverse-scored. We suggest making all of the scales run in the direction such that higher scores indicate more impulsive behavior. Therefore, we include the scoring key for, (Negative) Urgency, (lack of) Premeditation, (lack of) Perseverance, Sensation Seeking, and Positive Urgency. For each scale, calculate the mean of the available items; this puts the scales on the same metric. We recommend requiring that a participant have at least 70% of the items before a score is calculated.

(Negative) Urgency (all items except one are reversed)
items 2 (R), 7(R), 12 (R), 17 (R), 22 (R), 29 (R), 34 (R), 39 (R), 44 (R), 50 (R), 53, 58 (R)

(lack of) Premeditation (no items are reversed)
items 1, 6, 11, 16, 21, 28, 33, 38, 43, 48, 55.

(lack of) Perseverance (two items are reversed)
items 4, 9 (R), 14, 19, 24, 27, 32, 37, 42, 47 (R)

Sensation Seeking (all items are reversed)
items 3 (R), 8 (R), 13 (R), 18 (R), 23 (R), 26 (R), 31 (R), 36 (R), 41 (R), 46 (R), 51 (R), 56 (R)

Positive Urgency (all items are reversed)
items 5 (R), 10 (R), 15 (R), 20 (R), 25 (R), 30 (R), 35 (R), 40 (R), 45 (R), 49 (R), 52 (R), 54 (R), 57 (R), 59 (R)

(R) indicates the item needs to be reverse scored such 1=4, 2=3, 3=2, and 4=1

Jessor's Religion Scale (Jessor & Jessor, 1977)

Below are some questions on what you think about things. Please read each one, and circle a number to show what you think.

How important is it:

(1) To believe in God?
1 - Not at all important
2 - A little important
3 - Pretty important
4 - Very Important

(2) To be able to rely on religious teaching when you have a problem?
1 - Not at all important
2 - A little important
3 - Pretty important
4 - Very Important

(3) To be able to turn to prayer when facing a personal problem?
1 - Not at all important
2 - A little important
3 - Pretty important
4 - Very Important

(4) To rely on your religious beliefs as a guide for day-to-day living?
1 - Not at all important
2 - A little important
3 - Pretty important
4 - Very Important

Scoring: sum of the items

4-8 → Lower religiosity

8-12 → Medium religiosity

12-16 → Higher religiosity

Daily diary

Daily Diary

A. Please enter the ID number given to you:

_____

B. Where do you study?

_____UH _____SHSU

C. Alcohol Consumption

Standard Drink Conversion Chart

The following questions will deal with alcohol. Each of the drinks below (12oz. lager beer; 1 alcopop, 4oz. large wine and 5oz. of small wine, 1 or 1.5 oz. hard liquor) is equal to **one standard drink (1SD)**. This means that they all contain the same amount of alcohol. Please use the definition of a standard drink that is illustrated below when answering all alcohol questions.

Please enter the approximate number of each type of standard alcoholic drinks you consumed:

YESTERDAY
(from 12 AM to 11:59 PM)

&

TODAY
(from 12 AM to 11:59 PM)

For example, if you drank two 12 oz. cans of Bud lite yesterday around 11 PM, then you would enter a 2 in the top left box. If you drank 1 shot of Vodka and 1 small glass of wine at 12 AM, than you would enter a 2 in the top right box. Please enter **0** for each listed beverage that you did not consume.

	Number of standard drinks consumed YESTERDAY	Number of standard drinks consumed TODAY
12 oz. BEER (alcohol less than 6%)		
12 oz. BEER (alcohol 6% or more)		
4 oz. WINE or CHAMPAGNE		
12 oz. ALCOPOP (1 bottle)		
1 shot HARD LIQUOR (tequila, whiskey...)		
1 MIXED DRINK (cocktail)		
Other alcoholic beverage		

D. Physical Activity

Please answer the following 3 questions on a daily basis. Moderate physical activity is defined as activity that does not considerably increase your heart rate (e.g.: fast walking). Vigorous physical activity is defined as activity that does considerably increase your heart rate (e.g.: fast running).

1. How many minutes of moderate physical activity did you engage in today? _____
2. How many minutes of vigorous physical activity did you engage in today? _____
3. What type of physical activity did you engage in today?
    1. None
    2.Walking
    3.Jogging

4. Running
5. Cycling
6. Swimming
7. Weight training
8. Cardio
9. Dance
10. Other, specify _____

APPENDIX B

Abbreviation	Variable Name/Description
AC	Alcohol Consumption
ACFREQ	Drinking frequency across all days
ACQUANT	Sum of total daily drinks
AUDIT	Problem drinking self-reported at baseline
AUDIT-F	Problem drinking self-reported at follow-up
FREQ	Frequency of drinking
IPAQ-B (MODMET)	Moderate MET minutes of retrospective weekly PA self-reported at baseline
IPAQ-B (TIME)	Total minutes of retrospective weekly PA self-reported at baseline
IPAQ-B (VIGMET)	Vigorous MET minutes of retrospective weekly PA self-reported at baseline
IPAQ-F (MODMET)	Moderate MET minutes of retrospective weekly PA self-reported at follow-up
IPAQ-F (TIME)	Total minutes of retrospective weekly PA self-reported at follow-up
IPAQ-F (VIGMET)	Vigorous MET minutes of retrospective weekly PA self-reported at follow-up
MODERATE PA (METS)	Calculated MET minutes of moderate daily PA
MODERATE PA (TIME)	Time in minutes spent in moderate daily PA
MODPA (TIME)	Person-specific mean of moderate PA time
MODPA(METS)	Person-specific mean of moderate PA MET minutes
NU	Negative urgency self-reported at baseline
NU-F	Negative urgency self-reported at follow-up
OBJECTIVE PA (METS)	Calculated MET minutes from the Pacer app
OBJECTIVE PA (TIME)	PA time in minutes recorded from the Pacer app
OBJPA (METS)	Person-specific mean of objective PA METS
OBJPA (TIME)	Person-specific mean of objective PA minutes
PA	Physical Activity

PERS	Lack of perseverance self-reported at baseline
PERS-F	Lack of perseverance self-reported at follow-up
PREM	Lack of premeditation self-reported at baseline
PREM-F	Lack of premeditation self-reported at follow-up
PU	Positive urgency self-reported at baseline
PU-F	Positive urgency self-reported at follow-up
REL	Religiosity self-reported at baseline
REL-F	Religiosity self-reported at follow-up
SS	Sensation-seeking self-reported at baseline
SS-F	Sensation-seeking self-reported at follow-up
TLFB-B	Total drinks in the past month self-reported at baseline
TLFB-F	Total drinks in the past month self-reported at follow-up
VIGOROUS PA (METS)	Calculated MET minutes of vigorous daily PA
VIGOROUS PA (TIME)	Time in minutes spent in vigorous daily PA
VIGPA (METS)	Person-specific mean of moderate PA MET minutes
VIGPA (TIME)	Person-specific mean of vigorous PA time
WEEKEND	Day of the week coded as weekend or weekday