A Longitudinal Study of Adolescent Trait Impulsivity, Cognitive Flexibility, and Risk-Seeking: Associations with Co-Occurring Alcohol Use and Social Anxiety in Young Adulthood

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ABSTRACT

Social anxiety is related to various comorbidities, with the most common being elevated alcohol use (Bolton et al., 2006). The symptom profile of this unique subset of cases with social anxiety and comorbid alcohol use is more complex and experiences higher resistance to treatment (Buckner et al., 2008). Both social anxiety and alcohol use emerge during the adolescent developmental period, and yet there remains a gap in the understanding of potential developmental risk factors associated with the onset and maintenance of these co-occurring symptoms. The current study investigated trait impulsivity, cognitive flexibility, and risk-seeking during adolescence and associations with alcohol use and social anxiety in young adulthood. Participants included 167 adolescents (M_{age} = 14.07 years, SD = 0.54; 52.7% male) followed to young adulthood (M_{age} = 22.30, SD = 0.69). Growth mixture models indicated that high levels of risk-seeking during adolescence predicted social anxiety in young adulthood. Contrary to hypotheses, high (compared to moderate) risk-seeking participants had lower alcohol use. Longitudinal patterns of high attentional impulsivity during adolescence into young adulthood predicated later social anxiety, whereas non-planning and motor impulsivity did not. Linear regression analyses indicated that lower cognitive flexibility during early adolescence was associated with social anxiety and alcohol use in young adulthood. Finally, moderation models suggested that global trait impulsivity was not a significant moderator of the relation between alcohol use during adolescence and social anxiety in young adulthood. This is the first work to evaluate these developmental risk-factors in relation to comorbid social anxiety and alcohol use, and has important implications for bolstering therapeutic interventions, especially for those with elevated impulsivity.

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GENERAL AUDIENCE ABSTRACT

Some socially anxious young adults have more difficulties with alcohol use compared to their peers. The combination of social anxiety and elevated alcohol use can lead to challenges in various aspects of life, such as school, work, and social functioning. Previous literature in the field suggests that both social anxiety and alcohol use emerge during early adolescence (ages 13-14); however, risk-factors during this important developmental period are still being explored. This dissertation evaluated the following possible risk-factors during adolescence that may be associated with the later development of social anxiety and alcohol use: trait impulsivity, cognitive flexibility, and risk-seeking. These risk-factors were explored using a dataset collected in Virginia that followed 167 adolescents over an eight-year period. Results indicated that youth with higher risk-seeking and attentional impulsivity during adolescence (ages 13-21) had significant social anxiety symptoms once they reached young adulthood (ages 22-23). Additionally, lower cognitive flexibility during ages 13-14 was associated with higher social anxiety and alcohol use in young adulthood. This is the first work to evaluate these risk-factors in relation to social anxiety and alcohol use, and has important implications for interventions, especially for those who have increased impulsivity and risk-seeking behaviors.

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List of Abbreviations

ASR……..Adult Self-Report

AUD…….Alcohol Use Disorder

AUDIT…….Alcohol Use Disorders Identification Test

BIS-15……..Barratt Impulsiveness Scale, Short Form

CFI……...Comparative Fit Index

ERQ…….Emotion Regulation Scale

GCM……Growth Curve Model

GMM……...Growth Mixture Model

LSAS……Liebowitz Social Anxiety Scale

RMSEA……Root Mean Square Error of Approximation

SRMR……..Standardized Root Mean Square Residual

UNC…….Uncertainty Task

WCST……..Wisconsin Card Sorting Test

YSR……..Youth Self-Report

Introduction

Individuals with elevated social anxiety symptoms have a persistent fear of one or more social or performance situations (American Psychiatric Association, 2022). Those with social anxiety symptoms report significant comorbidities, with the most common being alcohol use disorder (AUD; Bolton et al., 2006; Gran et al., 2005). Specifically, 13% of older adults who reported clinical levels of social anxiety symptoms in the past year and 48.2% of adults with lifetime rates of social anxiety met clinical criteria for alcohol dependence (Bolton et al., 2006; Gran et al., 2005). Regarding young adults, 43% of college-aged individuals who report clinically significant symptoms of social anxiety also report concurrent alcohol use problems (Schry & White, 2013). Young adults with social anxiety have over four times the odds of developing AUD after controlling for socio-demographic and psychiatric factors (including other anxiety disorders; Buckner & Turner, 2009). Further, even among individuals endorsing subclinical levels of social anxiety, the risk for developing alcohol use problems is greater, as compared to non-socially anxious peers (Buckner et al., 2008). This symptom profile of this unique subset of social anxiety-AUD cases is more complex and has been connected to greater overall mental and physical health impairments, resulting in higher deficits in occupational and social functioning (Buckner et al., 2008). Given that social anxiety symptoms and alcohol use both emerge during the adolescent developmental period, the investigation of developmental risk factors is crucial to early detection and treatment which can prevent substantial symptom progression over the course of adolescence into young adulthood (Ollendick et al., 2014). Accordingly, the purpose of the present study is to test a theory-driven model involving

adolescent trait impulsivity, cognitive flexibility, and risk-seeking as developmental predictors of alcohol use and social anxiety in young adults.

Prevalence and Intervention Efficacy

Social Anxiety in Adolescence and Young Adulthood. Social anxiety is among the most common mental health complaints in youth and young adults, with an average age of onset of approximately 13 years old (Gregory & Eley, 2007; Ollendick & Hirshfeld-Becker, 2002). Among adolescent samples, prevalence rates for social anxiety symptoms are between 10%-15%, ranking it as one of the most prevalent anxiety disorders during this developmental period (Kessler et al., 2005). Approximately 9.1% of the young adult population ages 18-29 suffers from symptoms related to social anxiety (National Comorbidity Survey, 2017). However, social anxiety treatment outcomes continually rank amongst the poorest of the anxiety disorders, with over half of patients remaining symptomatic after completing first-line treatment (cognitive behavioral therapy [CBT]; Herbert et al., 2009). In a minority of studies efficacy rates improve with combined psychopharmacological and psychotherapy treatments (see meta-analysis; Bandelow et al., 2009); though barriers to uptake of medications (e.g., parent comfortability, adolescent willingness) remain significant and impede treatment progress.

Alcohol Use in Adolescence and Young Adulthood. AUD is defined by the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) as "a problematic pattern of alcohol use leading to clinically significant impairment or distress, as manifested by at least two of the following [11] symptoms, occurring within a 12-month period" with symptom examples including "alcohol is often taken in a larger amount or over a longer period than was intended" and "continued alcohol use despite having

persistent or recurrent social or interpersonal problems caused or exacerbated by the effects of alcohol" (American Psychiatric Association, 2022). Reports regarding alcohol use trends show that adolescence and young adulthood demonstrate periods of increased use. Volkow and colleagues (2021) found that alcohol was the most used substance reported amongst adolescents ages 12-17 and young adults ages 18-25. In 2021, prevalence of alcohol use in adolescents was 26.3%, while trends in young adults showed 79.7%. Similarly, when sampling adolescents (8^{th} – 12^{th} graders), Peiper and colleagues (2016) found that 64% of students consumed alcohol by 12^{th} grade and 22% reported using alcohol within the last 30 days. Lastly, young adults (18-25 years old) had the highest 12-month prevalence of alcohol use compared with younger groups (Peiper et al., 2016).

The most common interventions for alcohol use in adolescents and young adults include family-based psychotherapy, motivational interviewing, and CBT (Chung et al., 2003; Fadus et al., 2019). While treatment efficacy for singular psychotherapy interventions displays a reduced number of days of drinking at four months post-treatment for most programs, combined psychosocial therapy (family-based intervention and CBT) show sustained reductions in the number of days of drinking seven months post-treatment (Chung et al., 2003). One major consideration for treatment efficacy is that most studies do not report follow-ups beyond one-year post-treatment. Those that do report beyond one year demonstrate symptom reduction for adolescents with low severity alcohol use at baseline; however, adolescents with moderate or severe alcohol use show relatively stable use one to three years post-treatment, 40% and 9% respectively (Chung et al., 2003). Recent literature has focused on addressing these retention rates with multicomponent psychosocial therapy (family-based intervention and CBT) in addition to adjunctive

interventions (pharmacotherapy), although treatment gains are inconclusive (Fadus et al., 2019). More recent treatments include "just in time" interventions delivered via apps integrating CBT skills for sensible drinking, although the efficacy is generally low, with overall consumption lowering by one standard drink per week (Haug et al., 2020). Thus, despite important work to reduce drinking behaviors during this crucial developmental period, treatment efficacy for alcohol use among adolescents and young adults remains generally low.

Social Anxiety and Co-Occurring Alcohol Use in Adolescence and Young Adulthood. As noted earlier, social anxiety is related to various comorbidities, and perhaps the most salient among these is AUD (Bolton et al., 2006; Gran et al., 2005). Most studies have focused on how adolescent social anxiety may predict alcohol use in young adulthood (rather than how adolescent alcohol use may predict later social anxiety). For example, Buckner and Turner (2009) found that social anxiety in 6th to 9th graders was predictive of AUD at ages 19-21 and was associated with functional impairment in family relationships. Further, those with a history of social anxiety during ages 12-18 were twice as likely than those without social anxiety to be characterized with severe AUD by age 25 (Black et al., 2015). Although less common yet central to the aims in this study, some studies have focused on the development of social anxiety symptoms after early engagement with alcohol. Schmits and colleagues (2015) conducted a longitudinal study in high school seniors and found that those with current social anxiety symptoms reported first consuming alcohol between grades 9-11 (ages 14-16). Another study on young adults with social anxiety symptoms evaluated retrospective reports of difficulties with alcohol overconsumption in youth and found that 23.2% of the sample displayed current hazardous

drinking as measured by a score of 15 or greater on the Alcohol Use Disorder Identification Test (AUDIT; Villarosa-Hurlocker et al., 2019). Relatedly, treatment studies have found that roughly 55% of young adults seeking detoxification from alcohol dependence report at least moderate levels of current social anxiety symptoms (Lewis & O'Neill, 2000). The symptom profile of this unique subset of cases with social anxiety and comorbid AUD is more complex and has been connected to higher resistance to treatment than either disorder alone (Buckner et al., 2008). Above and beyond treatments previously discussed, other common efficacious treatments for AUD in adults, such as the Twelve-Step Facilitation, show higher rates of relapse in young adults with social anxiety and AUD (roughly 60%; Oliveira et al., 2018). Previous treatments have focused on selective serotonin reuptake inhibitors (SSRIs) as a possible efficacious treatment to reduce symptoms of social anxiety in those with comorbid AUD who show resistance to psychotherapy. Although symptom reductions in anxiety are noted, alcohol use remains consistent (Thomas et al., 2008).

Current Models of Social Anxiety and Co-Occurring Alcohol Use

Three models have emerged in recent years to explain the relation between social anxiety and AUD. These have focused on coping-motivated use, social pressure and conformity, and impulsive choices in threat contexts, and generally have been premised on models developed among socially anxious adults. These approaches have been utilized to explain certain aspects of the social anxiety-AUD interface and are not mutually exclusive, but rather provide explanatory models for describing certain notable features of this comorbidity profile in affective, social, and cognitive domains.

Coping-Motivated Use. Negative affect is recognized as a core feature of social anxiety and is defined as the likelihood to experience negative emotions such as guilt,

sadness, fear, and anger (Baumeister & Leary, 1995; Watson et al., 1988). One potential explanation for the association between social anxiety and AUD is the motivation to use alcohol to reduce distressing negative emotions. Young adults who report high levels of social anxiety have been found to consume alcohol to cope in situations that produce unpleasant or unwanted emotions, such as feelings of sadness, guilt, or disappointment (e.g., letting oneself down; Norberg et al., 2010). Furthermore, the biopsychosocial model of social anxiety and alcohol use reflects that young adults with social anxiety use alcohol to cope with unwanted symptoms of social anxiety, such as physiological arousal or discomfort (e.g., feeling tense or uneasy; shaky, sick, or nauseous), which increases reliance on alcohol in situations that elicit these symptoms (Buckner et al., 2012).

Social Pressure and Conformity. Young adults with social anxiety may perceive alcohol use as a normative part of social encounters. Those with social anxiety often report conformity motives to use alcohol, and feelings of conformity mediate the association between social anxiety symptoms and alcohol-related problems (Terlecki et al., 2012; Villarosa-Hurlocker et al., 2019). Another related concern is that socially anxious young adults who are shy present with decreased interpersonal abilities and are more sensitive to peer pressure to conform when faced with possible thoughts of rejection (Keough et al., 2016). When considering environmental contexts such as a social gathering, individuals with higher social anxiety endorsed greater alcohol use willingness if faced with social rejection (Cloutier et al., 2021). Lastly, young adults with social anxiety are sensitive to potential conflict with peers regarding nonconformity (e.g., actively choosing not to drink when requested by peers), which mediates the association between social anxiety symptoms and alcohol-related problems (Buckner et al., 2006).

Impulsive Choices Towards Rewards in Threat Contexts. Impulsivity generally refers to a trait characterized by disinhibition, biased attention towards reward, and risky behavior used to obtain immediate gratification despite possible negative outcomes (Evenden, 1999). There is some evidence that socially anxious individuals that typically engage in avoidance behaviors may display impulsive decision-making when faced with social threat. Rounds et al. (2007) found that socially anxious young adults (M_{age} = 19.05) who were primed to complete a public speaking exercise had higher delay discounting for a monetary reward (e.g., sought immediate payout). Similarly, Subotic-Kerry et al. (2022) found that socially anxious individuals with AUD had significant increased willingness towards consuming alcohol when exposed to an alcohol-related cue over a neutral cue during a social risk task (as compared to a control task). Thus, impulsive behaviors related to alcohol use may increase in social settings in which those with social anxiety feel threatened, experience discomfort, or are unable to engage in avoidance.

Overview of Theoretical Model

Given that both social anxiety and alcohol use emerge during the adolescent developmental period, there is a need for the investigation of potential developmental risk factors associated with the onset and maintenance of these co-occurring symptoms. There is strong, consistent evidence in the literature that trait impulsivity in non-anxious adolescents is a predictor of earlier initiation to and frequency of alcohol use (Dick et al., 2010). While trait impulsivity has not been central in theories of social anxiety at large, there is literature supporting that this linkage exists (Kashdan et al., 2009; Kashdan & McNight, 2010; Nicholls et al., 2014; Van Zalk et al., 2013), which has further implications for alcohol use prediction and intervention.

Considerations for Impulsivity as a Risk Factor. Prior work in adult samples has identified that some socially anxious individuals may be sensitive to impulse driven decision-making. Specifically, Kashdan and Hofmann (2007) discovered that some socially anxious adults displayed high-novelty seeking and were more risk-prone, which contrasted with the traditional characterization of the disorder (e.g., low novelty-seeking, avoidance-prone). Importantly, follow-up research revealed that socially anxious individuals that were high-novelty seeking did not differ in terms of their severity of social anxiety symptoms compared to those who were low-novelty seeking, but did differ in their quality of life (e.g., poor social interactions, risky behaviors, and increased substance use; Kashdan & McKnight, 2010). Additional work by Kashdan and colleagues (2009) further characterized these socially anxious individuals with high-novelty seeking utilizing the National Comorbidity Survey Replication (NCS-R) and found that they displayed elevated trait impulsivity and substance use difficulties. At the core, this group was characterized by motivation to approach risk-prone contexts, leading to impulsive pursuit behaviors and engagement in unsafe health practices (Kashdan et al., 2009). This finding was novel in the sense that it highly contrasted with the traditional characteristics of social anxiety, such as motivation to avoid social threat and danger, leading to avoidance behaviors in social situations such as escape and withdrawal (Kashdan et al., 2009). Additional information characterizing this NCS-R cohort (M_{age} = 39.9, 37% male) indicated that 21% of the overall sample fell into this "atypical [impulsive] social anxiety" category and endorsed low-to-moderate substance use (51% of this sample endorsed at least one item on a substance use questionnaire). Furthermore, this group of individuals, compared to those with avoidance behaviors, were younger in age, had higher reports of physical and mental health

complaints, and greater impairments from social anxiety symptoms (e.g., poor social functioning, loneliness).

Nicholls and colleagues (2014) explored impulsivity in socially anxious adults (M_{age} = 34.21) and contrary to findings from Kashdan & McKnight (2010), found that those with approach motivated behaviors had higher social anxiety symptoms, as measured by the Liebowitz Social Anxiety Scale (LSAS). Additionally, this group had more severe alcohol and illicit substance use than those with avoidance behaviors. Treatment outcomes in socially anxious adult samples with comorbid AUD provide more evidence for impulsivity as a potential risk factor. Higher pre-treatment impulsivity in those with social anxiety and AUD is generally associated with poorer treatment outcomes in psychotherapy and pharmacotherapy studies (see review; Loree et al., 2014). One study found promising results related to CBT, such that socially anxious adults high in trait impulsivity may benefit from behavioral management skills to reduce their immediate quantity of alcohol use; however, treatment gains are not maintained over time (Subotic-Kerry et al., 2022).

Although the association between trait impulsivity and social anxiety has not been well studied in adolescents, one study found that a subgroup of socially anxious 7th and 8th graders displayed characteristics of the distinctive impulsive type discovered by Kashdan et al. (2009) and had patterns of alcohol misuse (Van Zalk et al., 2013). This group was categorized as "socially anxious-impulsive" and displayed higher alcohol use frequency compared to less impulsive socially anxious peers. In sum, research has highlighted that some socially anxious adults and adolescents display impulsivity that leads to risk-prone behaviors, such as alcohol use. For the purposes of this study, we aimed to explore impulsivity as a continuum and to identify specific facets of trait impulsivity related to

social anxiety. Additionally, most research focuses on adults and utilizes self-report measures of impulsivity to identify individuals with social anxiety that are characterized as impulsive and approach driven. There is limited research utilizing behavioral data to measure impulsivity in socially anxious samples, especially in adolescents. Thus, we provide a discussion below on the utility of behavioral tasks that measure cognitive flexibility and risk-seeking, and how these constructs may relate to behavioral manifestations of impulsivity (e.g., alcohol use) amongst those with social anxiety.

Considerations for Cognitive Flexibility and Impulsivity. Cognitive flexibility refers to the ability to adapt behavior in response to novel information or goals and is traditionally measured by utilizing task-switching or set-shifting learning tasks (Ansari et al., 2008; Klanker et al., 2013). There is growing research that those with trait anxiety experience poor cognitive flexibility (Park & Moghaddam, 2017; Wilson et al., 2018). While much of this work focuses on generalized anxiety, there are some studies demonstrating that individuals with social anxiety have difficulties with cognitive flexibility tasks (Arlt et al., 2016; Sepahvand & Moradi, 2019). Specifically, socially anxious individuals in early adulthood demonstrated a lower total number of correct responses and categories completed on the Wisconsin Card Sorting Test (WCST) compared to age, gender, and education matched controls (Topçuoğlu et al., 2009). In general, deficits in cognitive flexibility are linked to increased impulsivity and risky behaviors (Hausman et al., 2020; Ram et al., 2019). In socially anxious samples, cognitive flexibility predicted attentional and non-planning impulsivity, but not motor impulsivity (Demitci et al., 2023; Kerry et al., 2014; Yu et al., 2020). More specifically, the relationship between cognitive flexibility and substance use has been evaluated in smokers with social

anxiety. Findings indicated that smokers with social anxiety displayed lower levels of cognitive flexibility than smokers without social anxiety (Sepahvand, 2020). Given the backdrop that anxious samples display deficits in cognitive flexibility and that these deficits may be related to increased impulsivity (attentional and non-planning trait impulsivity) and risky behaviors (nicotine use), we sought to evaluate the possible implications of cognitive flexibility on alcohol use and social anxiety within our sample. Thus, we utilized the WCST as a measure of cognitive flexibility throughout adolescence to determine if patterns of poor cognitive flexibility were related to behavioral manifestations of impulsivity (e.g., alcohol use) and social anxiety symptoms.

Considerations for Risk-Seeking and Impulsivity. Risk-seeking refers to the tendency to engage in risk-prone activities including impulsive-decision making and unsafe health behaviors (Kashdan & Hofmann, 2008). The discussion above has demonstrated that some socially anxious individuals display impulsive traits and are characterized by risk-seeking behaviors (Kashdan et al., 2009). Regarding behavioral tasks that are generally used to measure risk seeking behaviors, Upton et al. (2011) found that the Iowa Gambling Task (IGT) was associated with trait impulsivity. Although work on behavioral risk-seeking tasks and social anxiety is limited, Subotic-Kerry et al. (2014) demonstrated that impulsive socially anxious participants with comorbid AUD displayed risk-seeking behaviors during the IGT. Given the nature of the IGT, which relies on a win/lose yield outcome that presents with low and high risk choices, we decided to explore a similar task that socially anxious participants with impulsive traits may be sensitive to. The Uncertainty Task (UNC) is a modified economic lottery choice task in which participants make choices between pairs of uncertain gambles with high and low monetary

outcomes, lending the task to measure risky choices. Importantly, there is evidence that risk-seeking in those with elevated impulsivity is not impacted by variation in loss magnitude, suggesting that impulsive individuals are insensitive to potential loss which may motivate continued risk-seeking (Bornovalova et al., 2009). The UNC has been previously used to measure adolescent risk-seeking behaviors within the sample utilized in this study and is sensitive to testing variations of reward (Lauharatanahirun et al., 2018). Thus, we utilized the UNC to determine if patterns of elevated risk-seeking were related to behavioral manifestations of impulsivity (e.g., alcohol use) and social anxiety symptoms.

In sum, socially anxious individuals who demonstrate elevated impulsivity may display approach-motivated behaviors in risky contexts. Although limited, there is evidence that socially anxious adults display poor cognitive flexibility and elevated risk-seeking, which are related to behavioral outcomes of impulsivity, such as alcohol use. It is currently unknown how longitudinal patterns of cognitive flexibility and risk-seeking during adolescence impact alcohol use and social anxiety in young adulthood. In addition, minimal studies to date have examined how alcohol problems in adolescence relate to the later development of social anxiety symptoms in young adulthood. Lastly, exploring facets of trait impulsivity (rather than global trait impulsivity) may provide more detailed findings regarding the impact of non-planning, attentional, and motor impulsivity on social anxiety severity in young adulthood. Thus, we sought to evaluate longitudinal trajectories of trait impulsivity, cognitive flexibility, and risk-seeking across adolescence and their associations with alcohol use and social anxiety in young adulthood.

Current Study

While it has been known for some time that alcohol use is pronounced among individuals with social anxiety, what is unknown are the developmental factors that culminate in this comorbidity. Without such knowledge it will further remain unknown whether the mechanisms under consideration here represent a targetable pathway for therapeutic intervention approaches for socially anxious populations with elevated alcohol use. The central objective was to characterize the potentially mechanistic roles of self-reported trait impulsivity and behavioral measures of cognitive flexibility and risk-seeking during adolescence on alcohol use and social anxiety in young adulthood. Collectively, the overarching working hypothesis of this study is that co-occurring alcohol use and social anxiety is due to trait impulsivity, elevations in risk-seeking, and patterns of poor cognitive flexibility in adolescence.

Aims and Hypotheses

The present study pursued the following aims in a longitudinal sample of adolescents emerging into young adulthood:

AIM 1. Model longitudinal changes in cognitive flexibility and risk-seeking across adolescence and examine outcomes of alcohol use and social anxiety in young adulthood.

> ***Hypothesis 1a:*** Participants with a trajectory of poor cognitive flexibility across adolescence will display alcohol use and social anxiety in young adulthood.
>
> ***Hypothesis 1b:*** Participants with a trajectory of high risk-seeking across adolescence will display alcohol use and social anxiety in young adulthood.

AIM 2. Model longitudinal changes in facets of trait impulsivity across adolescence into young adulthood and examine social anxiety as an outcome in young adulthood.

Hypothesis 2a: Participants with non-planning or attentional facets of trait impulsivity will display elevated social anxiety in young adulthood.

Hypothesis 2b: Participants with motor facets of trait impulsivity will not display elevated social anxiety in young adulthood.

AIM 3. Determine if trait impulsivity moderates the relation between alcohol use during adolescence and social anxiety symptoms in young adulthood.

Hypothesis 3a: Participants with higher trait impulsivity and alcohol problems in early to middle adolescence will display elevated social anxiety symptoms in young adulthood.

Hypothesis 3b: Participants with higher trait impulsivity and severity of alcohol use in late adolescence will display elevated social anxiety symptoms in young adulthood.

Method

This study utilized self-report questionnaires of behavioral and psychological functioning, a computerized executive functioning task, and a computerized lottery task in order to accomplish the central aims.

Participants

Participants in this study are from the R01 titled "*Neurobehavioral Determinants of Health Risk Behaviors: From Adolescence to Young Adulthood"* (PIs: Jungmeen Kim-Spoon and Brooks King-Casas). This R01 began in 2014 and participants visited the lab roughly one year between each time point. The sample includes 167 adolescents (52.7% males; 78.4% White) and their primary caregiver (82% biological mothers, 13% biological fathers, 2% grandmothers, 1% foster, 2% other). At the start of the study, adolescents were 13-15 years of age (Wave 1, M_{age} = 14.07, *SD* = 0.54) and 21-23 by Wave 8 (M_{age} = 22.30, *SD* = 0.69). For this study, and in line with previous work (Barrett, 1996; Salmela-Aro, 2011), adolescence is represented by Waves 1-7 (ages 13-21), and young adulthood is represented by Wave 8 (over 21 years old). For aims that explore various stages of adolescence, early to middle adolescence is represented by Waves 1-4 (M_{ages} = 14.07-17.01, *SD* = 0.54-0.55) and late adolescence is represented by Waves 5-7 (M_{ages} = 18.90-21.26, *SD* = 0.62-0.64). Table 1 provides participant demographic information, including the number of participants that completed the study at each wave.

Procedures

Participants were recruited from the community in the Southeastern United States via flyers (at libraries, community centers, parks, clinics, grocery stores), email announcements, and snowball sampling (word-of-mouth). Prior to engaging in study tasks

at Wave 1, adolescents and parents provided written assent and consent, respectively. After assent and consent were received, families participated in the protocol led by trained research assistants. Depending on adolescent age at the time of each yearly study visit, assent and/or consent were reviewed.

Measures

Table 2 provides a summary of each measure and how they were used in the study. Participants completed the same procedure as years prior, including filling out various self-report measures and engaging in behavioral tasks.

Self-Report Questionnaires:

Liebowitz Social Anxiety Scale (LSAS; Heimber et al., 1999). The LSAS is a 24-item measure that assesses social anxiety severity in young adults. Participants are asked to indicate first how anxious or fearful they would be in certain situations (e.g., "Talking with people you don't know very well"; "Going to a party") on a 4-point scale ranging from 0 = *"I do not fear it at all"* to 3 = *"Severely fear it"*. Next, they rate how often they avoid those situations on a 4-point scale ranging from 0 = *"Never avoid it (0%)"* to 3 = *"Usually (68-100% of the time)"*. Higher scores indicate higher social anxiety symptoms. The LSAS was utilized as a continuous variable in this study; however, some results are discussed in light of the potential presence of social anxiety symptoms. Previous work has demonstrated that a cut-score of 30+ is optimal for distinguishing social anxiety from other anxiety disorders. Furthermore, a cut-score of 30+ is optimal for distinguishing mild symptoms, while a cut-score of 60+ is optimal for distinguishing moderate symptoms (Mennin et al., 2002). The LSAS was administered during the last time point, Wave 8, and

demonstrated good reliability (α = .97). The full LSAS questionnaire is included in Appendix A.

Alcohol Problems (Mason et al., 2011). The Alcohol Problems questionnaire contains 8 items that ask adolescents about their alcohol use. Sample questions include "When drinking alcohol over the past year, have you ever found that you were not able to stop drinking once you had started?" and questions structured similarly to "Over the last year how often has your use of alcohol caused you to... have trouble at school the next day?". The adolescents answered on an 8-point scale ranging from *"Never"* to *"40 or more times"*. Higher scores indicate higher alcohol use. The Alcohol Problems questionnaire was administered during Waves 1-4 and replaced with the Alcohol Use Disorders Identification Test (below) for the remaining waves. The Alcohol Problems questionnaire displayed weak to good reliability throughout waves (α = .38-.76).

Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993). The AUDIT is a 10-item questionnaire that assesses alcohol consumption, drinking behavior and alcohol-related problems. Sample items include, "How often do you have a drink containing alcohol?" and "How often during the last year have you had a feeling of guilt or remorse after drinking?". The first 3 items are answered on a 0-4 scale and ask questions regarding how often the participant drinks alcohol (0 = *"Never"*, 1 = *"Monthly"*, 2 = *"Two or four times a month"*, 3 = *"Two or three times a week"*, and 4 = *"Four or more times a week"*) and how many drinks they have on a typical day when they drink (0 = "*1 or 2"*; 1 = *"3 or 4"*; 2 = *"5 or 6*"; 3 = *"7 to 9"*; and 4 = *"10 or more"*). The next 5 items ask about drinking behaviors and are also answered on a 0-4 scale, where 0 = *"Never"*, 1 = *"Less than monthly"*, 2 = *"Monthly"*, 3 = *"Weekly"*, 4 = *"Daily or almost daily"*. The final two

items ask about consequences that have resulted from their drinking and are answered on a 0, 2, or 4 scale where 0 = *"No"*, 2 = *"Yes, but not in the last year"*, and 4 = *"Yes, during the last year"*. Higher scores indicate higher alcohol use. The AUDIT was utilized as a continuous variable in this study; however, some results are discussed in light of the potential presence of alcohol use disorder. A total score of 15 or more is associated with harmful or hazardous drinking and indicates the likelihood of alcohol dependence (moderate to severe AUD). The AUDIT was administered during Waves 5-8 and demonstrated good reliability across waves (α = .65-.81). The full AUDIT questionnaire is included in Appendix B.

The Barratt Impulsiveness Scale, Short Form (BIS-15; Spinella, 2007). The BIS-15 is a 15-item questionnaire used to assess the personality trait of impulsiveness. All items are answered on a 4-point scale from 0 = *"Rarely/Never"*, 1 = *"Occasionally"*, 2 = *"Often"*, 3 = *"Almost Always*", 4 = *"Always"*. The three subscales on the BIS-15 include non-planning, motor, and attentional impulsivity and consist of 5-items each. Sample questions include, "I plan tasks carefully" and "I am a careful thinker" (non-planning), "I do things without thinking" and "I act on impulse" (motor), and "I concentrate easily" and "I don't pay attention" (attentional). Higher scores indicate higher levels of trait impulsivity. Although there are no official cut-scores for the BIS-15, research suggests that on average, if a participant selects 3 (*"Often"*) or higher for each statement, this indicates high impulsive tendencies (Meule et al., 2023). Thus, subscale scores of 15+ were considered high impulsivity. The BIS-15 was utilized as a continuous variable in this study; however, the suggested cut-score was used to label classes within our models. The BIS-15 is highly correlated with the full 30 item version scale (r = .94, Spinella, 2007). The BIS-

15 was administered during Waves 1-8 and displayed good reliability across waves (α = .70-.80).

Youth Self-Report (YSR; Achenbach & Rescorla, 2001). The YSR is a 102-item measure assessing adolescent's report of internalizing and externalizing symptomatology. Problem behaviors are rated on a 3-point scale ranging from 0 (*"Not True"*) to 2 (*"Very True"*). For this study, only the withdrawn/depressed subscale was utilized. Given the association between depression and approach-motivated deficits in the context of reward, the YSR withdrawn/depressed subscale was used to control for depression symptoms within our analyses. Items assess problems related to loneliness, level of energy, and social withdrawal. Higher scores indicate higher levels of withdrawal. The withdrawn/depressed subscale demonstrated good reliability across Waves 1-4 (α = .72-.77).

Adult Self-Report (ASR; Achenbach & Rescorla, 2003). The ASR is a 126-item measure assessing young adult's report of internalizing and externalizing symptomatology. Problem behaviors are rated on a 3-point scale ranging from 0 (*"Not True"*) to 2 (*"Very True"*). For this study, only the withdrawn/depressed subscale was utilized. Given the association between depression and approach-motivated deficits in the context of reward, the ASR withdrawn/depressed subscale was used to control for depression symptoms within our analyses. Items assess problems related to loneliness, level of energy, and social withdrawal. Higher scores indicate higher levels of withdrawal. The withdrawn/depressed subscale demonstrated good reliability across Waves 5-8 (α = .89-.93).

Emotion Regulation Questionnaire (ERQ; Gross & John, 2003). The ERQ is a 10-item instrument that assesses respondents' preference to regulate their emotions by the 6-item cognitive reappraisal scale (changing the meaning of or reinterpreting an emotion-

eliciting event) and the 4-item expressive suppression scale (the inhibition of emotion-expressive behavior). Participants were asked to rate items related to cognitive reappraisal ("When I want to feel less negative emotion [such as sadness or anger], I change what I'm thinking about"), and expressive suppression ("When I am feeling negative emotions, I am careful not to express them") from 1 (*"Strongly Disagree"*) to 7 (*"Strongly Agree"*). A total score was calculated for each scale (cognitive reappraisal and expressive suppression). Higher scores indicate higher use of the regulation strategy. Given the relationship between emotion regulation abilities and alcohol use, the ERQ was used to control for emotion dysregulation within our analyses. The ERQ was administered in Waves 1-8. The cognitive reappraisal (α = .75-.90) and expressive suppression (α =.62-.73) subscales demonstrated good reliability across waves.

Behavioral Tasks:

Wisconsin Card Sorting Test (WCST; Heaton & Staff, 2003). To assess cognitive flexibility, we utilized the 64-card computerized version of the WCST. During this task, participants must identify the sorting rule in order to effectively sort cards based on shape, color, or quantity. Sorting rules change throughout the task, thus participants must also successfully update and shift to the new sorting rules in order to sort the cards correctly. The task includes 60 trials. Errors occur when the participant is unable to switch to the new sorting rules, resulting in perseveration (e.g., continuation of using incorrect sorting rules). The number of perseverative errors represent mistakes made by the participant by using the same incorrect sorting rule, reflecting lower set-shifting abilities (e.g., lower cognitive flexibility). We used the total number of perseverative errors, so that

higher scores are indicative of lower set-shifting abilities/cognitive flexibility. The WCST was administered during Waves 1-7.

Uncertainty Task (UNC; Holt & Laury, 2022; Lauharatanahirun et al., 2019). To assess risk-seeking, we utilized the UNC task. During this modified economic lottery choice task, participants make choices between pairs of uncertain gambles. Each gamble contains a high and low monetary outcome. Specific probabilities are represented as slices of pie. Each pie contains 10 slices, thus each slice corresponds to a 10% probability of winning the displayed amount. For example, participants are instructed to choose either the first pie chart or the second, with the probabilities of each outcome shown matching the colors on each pie chart (Figure 1). Thus, in option A, the participant has a 7/10 chance of winning $1.88 and a 3/10 chance of winning $1.50 if they choose this pie graph. The dependent variable was calculated as the percentage of risky choices (higher percentages reflecting greater risk-seeking behavior). Participants were instructed that they will receive monetary compensation based on actual outcomes of five randomly selected trials (in addition to compensation for the study). The task consisted of 72 trials and took roughly 30 minutes to complete. The UNC was administered during Waves 1-7.

Data Analytic Plan

Depression (assessed by the YSR and ASR) and emotion regulation (assessed by the ERQ) were used as control variables in growth mixture model analyses given the relevance of depression and adolescent emotion regulation difficulties in risk processing and alcohol use. We utilized mean scores for the YSR/ASR (Waves 1-4 and 5-8, respectively; withdrawn/depressed subscale), and ERQ (Waves 1-8; cognitive reappraisal and expressive suppression subscales).

AIM 1. Model longitudinal changes in cognitive flexibility and risk-seeking across adolescence and examine outcomes of alcohol use and social anxiety in young adulthood.

Aim 1 Analytic Plan: All analyses for Aim 1 utilized Mplus and accounted for missing data. Growth mixture models (GMM) of cognitive flexibility and risk-seeking were examined across Waves 1-7, thus there were seven time points of data representing the trajectories. The number of perseverative errors on the WCST was used to measure cognitive flexibility, with higher scores indicating lower levels of cognitive flexibility. The percentage of risky choices on the UNC was used to measure risk seeking, with higher percentages indicating higher risk-seeking. The outcome of alcohol use was measured by the AUDIT from Wave 8. The outcome of social anxiety was measured by the LSAS from Wave 8.

First, two separate growth curve models (GCM) were run in Mplus without outcomes and covariates in order to explore differential trajectories in 1) cognitive flexibility [WCST] and 2) risk-seeking [UNC] across adolescence. A linear model was run first, followed by a latent model. In order to determine which model best fit the data, we compared the Chi-Square Test of Model Fit between the linear and latent models. This comparison is completed by subtracting the chi-square values (product is the "chi-square score") and degrees of freedom from the linear and latent models, and utilizing a chi-square calculator to determine the significance level (Social Science Statistics, 2024). If the difference in the chi-square score was statistically significant, this indicated that increasing the degrees of freedom by using a linear model did not provide benefit and resulted in a worse fit; thus, the

latent model was used for GMM analyses. If the difference in the chi-square score was not statistically significant, the linear model was used for GMM analyses.

Next, separate GMM were run in Mplus to explore differential trajectories in 1) cognitive flexibility and 2) risk-seeking across adolescence without outcomes and covariates. GMM was utilized to determine a class model best suited for trajectories by finding classes that differ with respect to their average trajectories. The percentage of the sample that fell into each class was reported. Fit statistics were reviewed to determine which class model was most appropriate. We examined the Likelihood Ratio Test (LRT) which compares the improvement of fit between each class-model. In order to indicate the preferred class-model, we investigated when the LRT became non-significant ($p < .05$; McDevitt-Petrovic et al., 2019; Ram & Grimm, 2009). Next, we reviewed the Bayesian Information Criterion (BIC) which is utilized to avoid overfitting the model. The minimum score reflects the optimal number of classes in a model (e.g., trajectories). Thus, if the BIC was lowest for the two-class model, then that model was preferred over the three-class (McDevitt-Petrovic et al., 2019). In order to further aid our decision making, we evaluated entropy. Entropy is an estimate of the probabilities of individuals' group membership. High values of entropy (>.80) indicated that individuals are classified with confidence (e.g., the model is generally sure that person belongs to a particular class; Jedidi et al., 1993).

After evaluating the fit statistics, we looked at parameter estimates for each class (e.g., trajectory) in the class-model we choose in order to characterize (or label) trajectories meaningfully (e.g., improved, remained stable, worsened). We

determined significance by evaluating *b*, *SE*, and $p < .05$. We first reviewed the intercept mean which represents group mean scores at time one (Wave 1). We then determine how group scores varied over time by reviewing the slope mean. When evaluating the slope mean, if statistically significant, a negative slope indicated a decrease in scores while a positive slope indicated an increase in scores. If the slope mean was not statistically significant ($p > .05$) then this indicated no change in scores, suggesting that this class characterized participants who remained stable. This process was repeated for each class (or trajectory) in the class-model.

Next, if a two or three-class model was identified as a good fit, GMM was run again using the "3-step" approach for model estimation using the Auxiliary option in Mplus (Palardy & Vermunt, 2010). This approach allowed for the incorporation of outcomes (alcohol use and social anxiety) while protecting the class formation gathered in the first step (unconditional model) from the potential influence of selected covariates (depression, emotion regulation; Muthén, 2003). Significance of the outcome variables were evaluated using the chi-square variable (χ^2; test of model fit) and associated p-value (<.05). Thus, we were able to determine outcomes (social anxiety and alcohol use) as they related to the specific classes of cognitive flexibility and risk-seeking.

If a two or three-class model was not the best fit for the data, GCM was utilized. At this stage, the GCM was run with outcomes and covariates. In order to determine model fit, three parameters were evaluated: Root Mean Square Error of Approximation (RMSEA), CFI (Comparative Fit Index), and SRMR (Standardized Root Mean Square Residual). The RMSEA was used to assess how far a

hypothesized model was from an ideal model, with ideal values being < 0.05. The CFI is an incremental fit indictor that compared the fit of a hypothesized model to that of a baseline model (e.g., a model with worst fit), with ideal values being > 0.95. The SRMR assess the average magnitude of discrepancies between observed and expected correlations in the model, with ideal values being < .08 (Infurna & Grimm, 2018). If model fit was deemed appropriate, the outcome variables (LSAS and AUDIT) were evaluated utilizing *b*, *SE*, and *p*, and discussed in relation to the GCM. Tables presented in the results section for GMM and GCM analyses display fit statistics for the final models, including covariates and outcomes.

If GCM was not the best fit for the data, a linear regression was utilized. The same three fit parameters that were used for the GCM were employed for the linear regression (RMSEA, CFI, and SRMR). If the model fit was deemed appropriate, each predictor (at Waves 1-7) was discussed in relation to the outcomes (LSAS and AUDIT) by evaluating *b*, *SE*, and *p*.

AIM 2. Model longitudinal changes in facets of trait impulsivity across adolescence into young adulthood and examine social anxiety as an outcome in young adulthood.

Aim 2 Analytic Plan: Three separate GMM for non-planning, attentional, and motor facets of trait impulsivity (BIS-15) were examined across Waves 1-8, thus there were eight time points of data representing the trajectories. The outcome of social anxiety was measured by the LSAS from Wave 8.

All analyses for Aim 2 utilized Mplus and accounted for missing data. The same data analytic approach outlined for Aim 1 was employed for Aim 2. First, separate GCMs were run in Mplus without outcomes and covariates in order to

explore differential trajectories in 1) non-planning, 2) attentional, and 3) motor facets of trait impulsivity across adolescence into young adulthood. For each facet (non-planning, attentional, and motor) a linear model was run first, followed by a latent model. In order to determine which model best fit the data, we compared the chi-square model score between the linear and latent models. Next, separate GMM without an outcome and covariates were run to explore differential trajectories in 1) non-planning, 2) attentional, and 3) motor facets of trait impulsivity across adolescence into young adulthood. Fit statistics and parameter estimates were evaluated. If a two or three-class model was identified as a good fit, GMM was run again using the "3-step" approach for model estimation which allowed for the incorporation of an outcome (social anxiety) while still protecting the class formation determined in the first step (i.e., unconditional model) from the potential influence of covariates (depression, emotion regulation). If a two or three-class model was not the best fit for the data, GCM (with an outcome and covariates) was utilized and fit parameters were evaluated (RMSEA, CFI, and SRMR). Tables presented in the results section for GMM and GCM analyses display fit statistics for the final models, including covariates and an outcome. If GCM was not the best fit for the data, a linear regression was utilized. The same three fit parameters that were used for GCM were employed for the linear regression (RMSEA, CFI, and SRMR) to determine model fit. If the model fit was deemed appropriate, each predictor (at Waves 1-8) was discussed in relation to the outcome (LSAS) utilizing evaluating *b*, *SE*, and *p*.

AIM 3. Determine if trait impulsivity moderates the relation between alcohol use during adolescence and social anxiety symptoms in young adulthood.

Aim 3 Analytic Plan: The moderation effect was assessed using Mplus in order to account for missing data. Separate models were evaluated based on the stated hypotheses.

Model 1 (hypotheses 3a): This model used a continuous independent variable (alcohol problems), a continuous dependent variable (social anxiety symptoms), and one continuous moderator (trait impulsivity). To address alcohol problems in early to middle adolescence, scores on the Alcohol Problems questionnaire from Waves 1-4 were averaged to create a mean score. To address trait impulsivity during early to middle adolescence, scores on the BIS-15 were averaged to create a mean score from Waves 1-4. To address social anxiety in young adulthood, the LSAS score was utilized from Wave 8. See Figure 2 for moderation model.

Model 2 (hypothesis 3b): This model used a continuous independent variable (severity of alcohol use), a continuous dependent variable (social anxiety symptoms), and one continuous moderator (trait impulsivity). To address severity of alcohol use in late adolescence, scores on the AUDIT from Waves 5-7 were averaged to create a mean score. To address trait impulsivity during late adolescence, scores on the BIS-15 were averaged to create a mean score from Waves 5-7. To address social anxiety in young adulthood, the LSAS score was utilized from Wave 8. See Figure 3 for moderation model.

We determined significance and direction of the association between variables by first examining the interaction effect (IV*Moderator) of the full model (*b*, *SE*, $p < .05$). Next, bootstrap results were evaluated to confirm the significance of the full model. If bootstrap confidence intervals (95% CI) did not include zero, the result was significant. If significant, R^2 change was utilized to provide information on how much additional variance was explained by this 3-way interaction. The interaction effect at values of the moderator was evaluated using the Johnson and Neyman technique (1936). This technique provided information on the relation between alcohol use and social anxiety symptoms at levels of trait impulsivity.

Results

Descriptive Statistics for Study Variables

Means and standard deviations for all study variables can be found in Tables 3-6.

Growth Mixture Models: Cognitive Flexibility and Risk-Seeking (Aim 1)

Cognitive Flexibility. The outcome of the linear (χ^2 = 121.24, df = 23) and latent (χ^2 = 27.34, df = 18) GCM comparison resulted in a significant chi-square score of 93.88, $p < .001$, resulting in the use of the latent model. Neither the two nor three-class models were best fitting for adolescent WCST trajectories, as the class discriminations were not acceptable (e.g., less than 10% of the sample in one of the classes; Table 7). The one-class model (GCM) was evaluated, and fit parameters indicated poor fit (RMSEA = 0.10, CFI = 0.50, SRMR = 0.12). Thus, the outcome variables were not interpreted. For information purposes, the trajectory is displayed in Figure 4. As a result, linear regression analyses were conducted. The linear regression model with alcohol use (AUDIT) as an outcome displayed good fit (RMSEA = 0.03, CFI = 0.91, SRMR = 0.09). Results indicated that WCST at Wave 1 was a significant predictor of AUDIT at Wave 8, β = 0.31, *SE* = 0.16, *p* = 0.05, whereas WCST at Waves 2-7 were not significant predictors, β*s* = -0.11-0.13, *ps* = 0.19-0.70 (Table 8). Specifically, WCST at Wave 1 account for approximately 35% of the variance in the AUDIT. The linear regression model with social anxiety (LSAS) as an outcome displayed good fit (RMSEA = 0.04, CFI = 0.90, SRMR = 0.09). Results indicated that WCST at Wave 2 was a significant predictor of LSAS at Wave 8, β = 4.37, *SE* = 1.90, *p* = 0.02, whereas WCST at Waves 1 and 3-7 were not significant predictors, β*s* = -3.87-1.61, *ps* = 0.08-0.96 (Table 7). Specifically, WCST at Wave 2 account for approximately 36% of the variance in the LSAS.

Risk-Seeking. The outcome of the linear (χ^2 = 104.24, df = 23) and latent (χ^2 = 54.47, df = 18) GCM comparison resulted in a significant chi-square score of 49.77, p < .001, resulting in the use of the latent model. A two-class model was determined to be the best fitting model for adolescent UNC trajectories. Fit indices were strong and the model displayed acceptable discrimination of classes as indicated by classification probabilities and entropy (Table 9). Importantly, the BLRT indicated a better fit for the two vs one-class model. As can be seen in Figure 5, the first trajectory in the two-class model displayed high risk-seeking (M = 0.85, SE = 0.27) that decreased across adolescence (High Improving; b = -0.45, SE = 0.19, p = .02). The second displayed moderate risk-seeking (M = 0.74, SE = 0.10) that also decreased across adolescence (Moderate Improving; b = -0.33, SE = 0.07, p < .001). Members of the High Improving latent class displayed significantly lower alcohol use severity on the AUDIT (M = 1.57, SE = 0.27) relative to the Moderate Improving (M = 5.18, SE = 0.51) class, χ^2 = 39.46, p < .001. Additionally, members of the High Improving latent class displayed significantly higher social anxiety symptoms on the LSAS (M = 79.16, SE = 6.48) relative to the Moderate Improving (M = 38.94, SE = 3.54) class, χ^2 = 24.69, p < .001. Investigation of model covariates indicated that the ERQ cognitive reappraisal subscale, b = -0.02, SE = 0.02, p = 0.50, ERQ expressive suppression subscale, b = 0.04, SE = 0.03, p = 0.18, and YSR/ASR withdrawal subscale, b = -0.06, SE = 0.08, p = 0.50, were not significant predictors of trajectories.

Growth Mixture Models: Facets of Trait Impulsivity (Aim 2)

Non-Planning. The outcome of the linear (χ^2 = 66.24, df = 31) and latent (χ^2 = 58.26, df = 25) GCM comparison resulted in a non-significant chi-square score of 7.98, p = 0.16, resulting in the use of the linear model. Neither the two or three-class models were

best fitting for adolescent non-planning trajectories, as the fit indices were not acceptable (Table 10). Importantly, the BLRT did not indicate a better fit for the two vs one-class model. The one-class model (GCM) was evaluated and fit parameters indicated good fit (RMSEA = 0.08, CFI = 0.93, SRMR = .10). As can be seen in Figure 6, the trajectory indicates moderate non-planning facets of trait impulsivity (M = 11.29, SE = 0.22) that remained stable across adolescence (non-significant slope; b = -0.04, SE = 0.05, p = 0.39). The outcome of social anxiety (LSAS) was not significant, b = 0.80, SE = 1.14, p = 0.49. Investigation of model covariates indicated that the ERQ cognitive reappraisal subscale, b = -0.34, SE = 0.88, p = 0.70, ERQ expressive suppression subscale, b = 0.02, SE = 0.04, p = 0.69, and YSR/ASR withdrawal subscale, b = 0.01, SE = 0.01, p = 0.27, were not significant predictors of the trajectory.

Attentional. The outcome of the linear (χ^2 = 74.11, df = 31) and latent (χ^2 = 115.31, df = 25) GCM comparison resulted in a significant chi-square score of 41.20, $p < .001$, resulting in the use of the latent model. A two-class model was the best fitting model for adolescent attentional trajectories. Fit indices were strong and the model displayed acceptable discrimination of classes as indicated by classification probabilities and entropy (Table 10). As can be seen in Figure 7, the first trajectory in the two-class model displayed high attentional facets of trait impulsivity (M = 11.63, SE = 1.01) that worsened (e.g., increased) across adolescence (High Impairing; b = 3.95, SE = 1.34, $p < .005$). The second displayed moderate attentional facets of trait impulsivity (M = 10.89, SE = 0.33) that remained stable across adolescence (Moderate Stable; non-significant slope; b = -0.38, SE = 0.22, p = 0.09). Members of the High Impairing latent class displayed significantly higher social anxiety symptoms on the LSAS (M = 7.56, SE = 1.42) relative to the Moderate Stable

(M = 3.07, SE = 0.48) class, χ^2 = 7.70, p = 0.01. Investigation of model covariates indicated that the ERQ cognitive reappraisal subscale, b = 0.02, SE = 0.94, p = 0.98, ERQ expressive suppression subscale, b = 0.03, SE = 0.03, p = 0.30, and YSR/ASR withdrawal subscale, b = 0.00, SE = 0.00, p = 0.38, were not significant predictors of trajectories.

Motor. The outcome of the linear (χ^2 = 40.31, df = 31) and latent (χ^2 = 22.16, df = 25) GCM comparison resulted in a significant chi-square score of 18.15, $p < .001$, resulting in the use of the latent model. Neither the two nor three-class models were best fitting for adolescent motor trajectories, as the class discriminations were not acceptable (e.g., less than 10% of the sample in one of the classes; Table 10). The one-class model (GCM) was evaluated and fit parameters indicated good fit (RMSEA = 0.00; CFI = 1.0; SRMR = 0.05). As can be seen in Figure 8, the trajectory indicates moderate motor facets of trait impulsivity (M = 10.46, SE = 0.22) that remained stable across adolescence (non-significant slope; b = -0.30, SE = 0.26, p = 0.25). The outcome of social anxiety (LSAS) was not significant, b = 0.15, SE = 0.17, p = 0.36. Investigation of model covariates indicated that the ERQ expressive suppression subscale, M = 1.04, SD = 0.03; b = 0.08, SE = 0.04, p = 0.04, was a significant predictor of the trajectory, while the ERQ cognitive reappraisal subscale, b = 0.75, SE = 1.00, p = 0.45, and YSR/ASR withdrawal subscale, b = 0.01, SE = 0.00, p = 0.16, were not.

Moderation Models: Trait Impulsivity Moderates Alcohol Use and Social Anxiety (Aim 3)

Early to Middle Adolescence. A simple moderation model included 167 observations with zero excluded cases. Results indicated that trait impulsivity in early to middle adolescence did not moderate the relation between alcohol problems in early to

middle adolescence and social anxiety symptoms in young adulthood, $b = 1.37$, $SE = 6.73$, $p = 0.84$. Further support for a non-significant moderation was indicated by the inclusion of zero in the confidence intervals [95% CI: -9.69 to 12.43]. The Johnson and Neyman technique (1936) was explored to determine if a significant interaction effect existed at a specific value of the moderator. Results indicated that confidence intervals for the interaction at all levels of the moderator included zero and thus the model remained non-significant (Figure 9). The main effect of alcohol problems in early to middle adolescence on social anxiety symptoms in young adulthood was non-significant, $b = -135.67$, $SE = 223.02$, $p = 0.54$.

To further understand associations between variables in the moderation model, correlation analyses were explored. The LSAS at Wave 8 displayed weak negative associations with Alcohol Problems at Wave 2, $r = -0.25$, $p = 0.01$, and Wave 4, $r = -0.23$, $p = 0.02$, and non-significant associations with Wave 1, $r = -0.16$, $p < 0.09$, and Wave 3, $r = 0.16$, $p = 0.10$. The LSAS at Wave 8 displayed non-significant associations with the BIS-15 (early to middle adolescence) at Waves 1-4, $rs = 0.01$-0.15, $ps = 0.12$-0.96. Alcohol Problems at Wave 1 displayed weak positive associations with the BIS-15 (early to middle adolescence) at Waves 1-3, $rs = 0.18$-0.23, $ps = 0.01$-0.03, and a non-significant association at Wave 4, $r = 0.10$, $p = 0.28$. Alcohol Problems at Wave 2 displayed weak positive associations with the BIS-15 (early to middle adolescence) at Wave 2, $r = 0.19$, $p = 0.03$, and Wave 3, $r = 0.17$, $p = 0.05$, and non-significant associations with Wave 1, $r = 0.16$, $p = 0.06$, and Wave 4, $r = 0.06$, $p = 0.46$. Alcohol Problems at Wave 3 displayed weak positive associations with the BIS-15 (early to middle adolescence) at Wave 1, $r = 0.19$, $p = 0.02$, and Wave 3, $r = 0.25$, $p < .01$, and non-significant associations with Wave 2, $r =$

0.12, $p = 0.17$, and Wave 4, $r = 0.05$, $p = 0.60$. Alcohol Problems at Wave 4 displayed non-significant associations with the BIS-15 (early to middle adolescence) at Waves 1-4, rs = -0.05-0.14, ps = 0.10-0.58.

Late Adolescence. A simple moderation model included 141 observations, as 26 cases were excluded due to missing all variables in the model. Results indicated that trait impulsivity in late adolescence did not moderate the relation between alcohol severity in late adolescence and social anxiety symptoms in young adulthood, $b = 0.12$, $SE = 0.13$, $p = 0.35$. Further support for a non-significant moderation was indicated by the inclusion of zero in the confidence intervals [95% CI: -0.09 to 0.33]. The Johnson and Neyman technique (1936) was explored to determine if a significant interaction effect existed at a specific value of the moderator. Results indicated that confidence intervals for the interaction at all levels of the moderator included zero and thus the model remained non-significant (Figure 10). The main effect of alcohol severity in late adolescence on social anxiety symptoms in young adulthood was non-significant, $b = -6.43$, $SE = 4.16$, $p = 0.12$.

To further understand associations between variables in the moderation model, correlation analyses were explored. The LSAS at Wave 8 displayed strong positive associations with the AUDIT at Wave 6, $r = 0.72$, $p < .001$, and Wave 7, $r = 0.66$, $p < .001$, and a weak negative association with Wave 5, $r = -0.24$, $p = 0.02$. The LSAS at Wave 8 displayed a weak positive association with the BIS-15 (late adolescence) at Wave 7, $r = 0.23$, $p = 0.02$, and non-significant associations with Wave 5, $r = 0.02$, $p = 0.85$, and Wave 6, $r = 0.10$, $p = 0.30$. The AUDIT at Waves 5-7 displayed non-significant associations with the BIS-15 (late adolescence) at Waves 5-7, rs = -0.01-0.15, ps = 0.10-0.99.

Discussion

The present study examined longitudinal patterns of trait impulsivity, cognitive flexibility, and risk-seeking during adolescence and their associations with the later development of social anxiety and alcohol use. We explored three aims, including (1) trajectories of cognitive flexibility and risk-seeking during adolescence and their relation to alcohol use and social anxiety in young adulthood, (2) trajectories of facets of trait impulsivity during adolescence into young adulthood and their relation to social anxiety in young adulthood, and (3) trait impulsivity as a moderator of the relation between alcohol use in adolescence and social anxiety in young adulthood. Regarding longitudinal trajectories of cognitive flexibility, GMM revealed poor class discriminations for two and three-class models, with less than 10% of the sample falling into one of the classes. One possible explanation for this finding is that the task utilized to measure cognitive flexibility, the WCST, may lend itself to practice effects which may impact scores over time. Consistent with this notion, research has found that repeating the WCST twice over a 12-month period resulted in improvement in perseverative errors (Basso et al., 2001; Bartels et al., 2010). Although the current study did not repeat the WCST prior to the 12-month period, we are hypothesizing that the nature of the task itself, such as discovering that there are sorting rules and one must adapt as these rules change, could potentially aid participants in improving or maintaining similar perseverative mistakes made each year. Thus, we acknowledge that this practice effect could have impacted the main outcome explored from the WCST in this study (e.g., preservative errors). This practice effect may lead to a more stable response pattern within the total sample over time, thus possibly leading to difficulties in differentiating participants into classes using GMM.

Ultimately, results measuring cognitive flexibility utilizing the WCST revealed that a one-class model (GCM) demonstrated poor fit and consequently a linear regression analysis was employed. Results of the linear regression demonstrated that the WCST at Wave 1 was a significant predictor of alcohol use at Wave 8, such that participants with lower set-shifting abilities in early adolescence had higher alcohol use in young adulthood. Similarly, the WCST at Wave 2 was a significant predictor of social anxiety symptoms at Wave 8, such that participants with lower set-shifting abilities in early adolescence had higher social anxiety symptoms in young adulthood. These findings are consistent with prior literature in young adults that describe associations between diminished set-shifting abilities and social anxiety symptoms, and between deficits in cognitive flexibility and increased risky behaviors (e.g., nicotine use; Hausman et al., 2020; Ram et al., 2019; Topçuoğlu et al., 2009). Regarding alcohol use specifically, considerable research has found that lower set-shifting abilities are related to increased alcohol use; however, most of these studies focus on trait anxiety, thus making it difficult to understand the effect of social anxiety on set-shifting and alcohol use (Wilson et al., 2018). Relatedly, Dvorak and Simons (2014) reported that higher set-shifting abilities do indeed predict less alcohol use throughout young adulthood and may in fact serve as a protective factor in a general sample (e.g., without screening for anxiety disorders). Future research may wish to recruit a sample with comorbid social anxiety and AUD to further understand the relation between symptom severity and set-shifting abilities. Additionally, it is important to note that the average number of perseverative errors reported on the WCST for control participants varies, with most studies reporting 4.25-7.03 errors (Basso et al., 2001). Our sample displayed a similar number of perseverative

errors, suggesting a possible range consistent with general samples; Wave 1 (*M* = 7.23, *SD* = 3.58); Wave 7 (*M* = 4.61, *SD* = 1.87). The WCST has been underutilized in socially anxious samples, with only one study reporting the average number of perseverative errors in young adults ages 26-31; however, this included a rather large standard deviation (*M* = 13.08, *SD* = 10.15; Topçuoğlu et al., 2009). Future research is needed in order to characterize the average number of perseverative errors within a socially anxious sample. Lastly, regarding initial waves of the WCST being predictors of later alcohol use and social anxiety, we again consider the impact of practice effects which may not lend the WCST to variable performance across time. Thus, the first or second wave in which the WCST was administered may represent the participant's true set-shifting abilities, as this performance was not impacted (Wave 1) or less impacted (Wave 2) by practice effects than subsequent waves.

Regarding longitudinal trajectories of risk-seeking, GMM revealed that a two-class model best fit the data, with the first trajectory demonstrating high risk-seeking that decreased across adolescence (High Improving) and the other displaying moderate risk-seeking that also decreased across adolescence (Moderate Improving). These findings are consistent with prior literature on adolescent risk-seeking that describe this period as one of heightened vulnerability to approach risk followed by a decrease in risk-seeking that is related to the development of self-regulatory competence in young adulthood (Steinberg, 2006). Regarding outcome variables, members of the High Improving class had lower alcohol use and higher social anxiety symptoms than those in the Moderate Improving class. This finding is in line with a portion of our hypothesis, which stated that participants with a trajectory of high risk-seeking across adolescence would display

alcohol use and social anxiety in young adulthood. It is important to note that although classes displayed a significant difference in alcohol use in young adulthood, the severity of symptoms reported for both classes remained well below the suggested cut-off of 15+ for the AUDIT (M = 1.57 and 5.18, respectively). Despite this, it is still noteworthy that the High Improving class reported lower alcohol use during Wave 8 compared to the Moderate Improving class. One possible explanation for this finding is derived from work by Martinez-Lorendo et al. (2019) in which they found an association between self-reported risk-seeking behaviors (e.g., gambling related to sports betting, lottery, scratch-tickers) and alcohol use for high schoolers (M_{age} = 15.21) with high general impulsivity (e.g., BIS-15 total score). Importantly, the main effect of alcohol use did not remain significant for adolescents high in the non-planning facet of trait impulsivity on the BIS-15. Thus, it is important for future work to consider the impact different facets of trait impulsivity may have on the relation between risk-seeking behaviors and alcohol use in adolescents. In order to provide insight into our results discussed above, a possible consideration within our model is to probe the relation between the UNC and alcohol use for participants varying in levels of non-planning impulsivity.

Regarding the class differences for social anxiety symptoms that emerged for the two-class risk-seeking model, the severity of symptoms reported is noteworthy (M = 79.16 and 38.94, respectively). Specifically, the High Improving class met the LSAS cut-off of 60+ which indicates moderate social anxiety symptoms, while the Moderate Improving class met the cut-off of 30+ which indicates mild social anxiety symptoms. Thus, participants who displayed high risk-seeking during early adolescence had significantly higher social anxiety symptoms in young adulthood compared to those with

moderate risk-seeking, and these symptoms were more severe. This finding supports Kashdan and Hofmann's (2007) work on the socially anxious/impulsive type and further highlights the need for monitoring risk-seeking behaviors and their impact on quality of life outcomes (e.g., poor social engagement, difficulty engaging in coping skills, substance and alcohol use). More specifically, socially anxious populations present certain challenges in the context of treatment, as the nature of the disorder inherently involves fear of negative evaluation from the therapist and hesitance to decrease maladaptive coping strategies (Salloum et al., 2016). Treatment adherence is even more difficult among individuals with moderate symptoms, such as those identified within this study, as they have been reported to experience heightened fear and anxiety of attending therapy that often leads to dropout (Olfson et al., 2000). It is important for future work to explore risk-seeking in the context of treatment adherence, as a lack of desire or motivation to discontinue risky coping mechanisms (e.g., alcohol use) may be impacting treatment gains and quality of life for impulsive, socially anxious clients. Lastly, the findings discussed here represent the first report of longitudinal adolescent risk-seeking (as measured by a behavioral risk-seeking task) as a predictor of social anxiety symptoms in young adulthood. Research utilizing behavioral risk-seeking tasks (especially without a social component) in socially anxious populations is very limited, thus this finding provides important considerations for this gap in the literature.

Regarding longitudinal trajectories of trait impulsivity, the first facet explored was non-planning impulsivity. Results revealed that a one-class model was the best fit for the data and the trajectory showed relatively moderate non-planning scores that remained stable across adolescence into young adulthood. Furthermore, this trajectory did not

predict social anxiety symptoms. This finding is not consistent with our hypothesis that participants with non-planning facets of trait impulsivity would display elevated social anxiety in young adulthood. Since different classes with varying levels of social anxiety symptoms and non-planning impulsivity did not emerge within the data, we are unable to make assumptions regarding the association between social anxiety and (preferably high) non-planning facets of trait impulsivity. We remain to hypothesize that this result would take place given the evidence within the literature that socially anxious populations display elevated non-planning impulsivity compared to controls (Demitci et al., 2023; Kerry et al., 2014). Another consideration is that our finding of moderate non-planning impulsivity may be related to the fact that a socially anxious population was not recruited for this study. Instead, we relied on self-reported social anxiety symptoms rather than the use of a clinical sample (as previous research employs; Morris et al., 2005). Thus, future work may wish to replicate such models within a clinical sample with varying levels of social anxiety. The second facet explored was attentional impulsivity. Results revelated that a two-class model was the best fit for the data, with the first trajectory demonstrating high attentional impulsivity that increased across adolescence into young adulthood (High Impairing), and the other displaying moderate attentional impulsivity that remained stable across adolescence into young adulthood (Moderate Stable). Members of the High Impairing class had higher social anxiety symptoms than those in the Moderate Stable class. This finding is consistent with our hypothesis that participants with attentional facets of trait impulsivity would display elevated social anxiety in young adulthood. This suggests that individuals with attentional impulsivity that continues to worsen (e.g., increase) throughout adolescence and into young adulthood may experience higher self-

reported social anxiety symptoms compared to those who have stable levels of attentional impulsivity. However, it is important to note that although classes experienced a significant difference in social anxiety symptoms in young adulthood, the severity of symptoms reported for both classes remained well below the suggested cut-off of 30+ for the LSAS (*M* = 7.56 and 3.07, respectively). Future research may wish to explore attentional impulsivity further into young adulthood to determine if this facet continues to increase and how that increase may be related to social anxiety severity.

The third facet explored was motor impulsivity. Results revealed that a one-class model was the best fit for the data and the trajectory showed moderate motor impulsivity that remained stable across adolescence into young adulthood. Furthermore, this trajectory did not predict social anxiety symptoms. This finding is in line with our hypothesis that participants with motor facets of trait impulsivity would not display elevated social anxiety in young adulthood. Additional findings suggested that the emotion regulation strategy of expressive suppression significantly predicted the trajectory, such that those with higher expressive suppression usage followed the trajectory of having moderate traits of motor impulsivity that remained stable across adolescence. We acknowledge that literature reviewing the relation between motor impulsivity and the use of expressive suppression is very limited. One possible explanation for our finding between motor impulsivity and expressive suppression is that when individuals engage in expressive suppression, they aim to control their facial expressions and body language (Gross & Levenson, 1993). Thus, even if an individual has elevated traits of motor impulsivity, engaging in expressive suppression may encourage control over otherwise impulsive face and body movements. Although our

hypothesis that motor impulsivity would not predict social anxiety symptoms was supported, it is important to recognize a possible alternative outcome. There is strong evidence in the literature that individuals with social anxiety heavily rely on expressive suppression as an emotion regulation strategy. One article reviewing the relation between motor impulsivity and expressive suppression found that these constructs demonstrate positive relations with behavioral self-disgust (e.g., disgust towards one's own behaviors, such as "I often do things I find revolting"; Lazuras et al., 2019). When considering this finding within the context of social anxiety, this work may have implications for the way socially anxious individuals evaluate their own behaviors using the framework around fear of embarrassment (e.g., thinking others may find their behaviors odd, leading them to feel disgusted with themselves). Future work may wish to consider the impact of such self-evaluative cognitive processes within socially anxious individuals and how that may influence traits of motor impulsivity and the use of expressive suppression.

Regarding facets of trait impulsivity overall, an additional consideration for future analyses is to control for symptoms of attention-deficit/hyperactivity disorder (ADHD). This recommendation is provided on the basis that some questions on the BIS-15 may overlap with inattention and impulsivity/hyperactivity symptoms of ADHD, such as "I don't pay attention", and "I get bored when solving thought problems" (attentional facet); "I plan tasks carefully" and "I am a careful thinker" (non-planning facet); and "I say things without thinking" and "I act in the spur of the moment" (motor facet). Current research on the intersection of ADHD and social anxiety is evolving and presents an exciting avenue for comorbidity studies, thus future work may find it useful to explore trait impulsivity in a sample with both disorders in order to further differentiate non-

planning, attentional, and motor facets. Regarding trait impulsivity as a moderator, results revealed that trait impulsivity (whether during early-middle adolescence or late adolescence) did not significantly predict the relation between alcohol use (whether during early-middle adolescence or late adolescence) and social anxiety symptoms in young adulthood. Thus, global trait impulsivity in early to late adolescence may not play a role in the relation between adolescent alcohol use and the later development of social anxiety symptoms in young adulthood. Given other results presented within the current study, this role may be better explored with risk-seeking or facets of trait impulsivity. One possible explanation for the lack of relations between the hypothesized variables in the moderation model is that our sample had relatively low scores on the Alcohol Problems Questionnaire and the AUDIT, suggesting the absence of AUD. Given that alcohol is the most used substance reported amongst adolescents ages 12-17 and young adults ages 18-25 (Volkow et al., 2021), we found the minimally reported alcohol use difficulties in our sample surprising. Although our sample was recruited from the local community, one important consideration is the possibility that socially anxious individuals with heightened alcohol use were not captured in this sample. As stated previously, this group is historically difficult to recruit and thus remains underrepresented in most anxiety samples (Salloum et al., 2016). Another possible explanation is supported by findings from Buckner and Terlecki (2016) that heightened social anxiety in young adults was positively related to greater drinking frequency in the past month and more drinking-related problems if they engaged in solitary drinking (rather than social drinking). Furthermore, socially anxious drinkers reported drinking more in quantity before or after social situations to manage negative thoughts about judgement or

performance, rather than during a social event (Buckner & Terlecki, 2016). Thus, socially anxious individuals may be more vulnerable to drinking alone rather than socially, which we hypothesize may place them at a higher risk of developing increased alcohol dependency. Future work may wish to consider the context (e.g., alone or socially) in which heavy drinking occurs in order to better determine the relation between AUD and social anxiety. Further, differences in trait impulsivity between those who drink alone or socially, and how this relates to comorbid AUD-social anxiety, should be explored.

In summary, the purpose of this study was to characterize trajectories of cognitive flexibility, risk-seeking, and facets of trait impulsivity in a longitudinal sample of adolescents developing into young adults and to determine outcomes of social anxiety and alcohol use. The overall goal was to identify possible targetable mechanisms for therapeutic consideration. Given our findings that lower cognitive flexibility is related to alcohol use, future work may wish to consider the use of cognitive training (also known as cognitive rehabilitation) alongside traditional therapeutic modalities (e.g., CBT). Cognitive training works to teach skills that improve executive functions, such as memory, problem solving, and cognitive flexibility, and can be delivered in a paper-pencil format or by a computer-assisted training program (Fals-Stewart & Lam, 2010; Uddin, 2021). Although cognitive training is traditionally known for its use in populations with neurocognitive disorders (e.g., traumatic brain injury, dementia, stroke), some alcohol use research has reported success in decreasing alcohol-related cognitive impairments (see review; Bates et al., 2013). For those with heightened social anxiety and AUD, it may be useful to consider cognitive training to decrease possible alcohol-related cognitive impairments, including those not represented in this study but often implicated

in social anxiety research (e.g., working memory and attention skills; Waechter et al., 2018).

Given our findings that young adults with heightened social anxiety displayed increased risk-seeking during adolescence, it is important to consider how to incorporate therapeutic skills to regulate emotions that may lead to risk-seeking behaviors. One potential avenue in this respect could involve Dialectical Behavioral Therapy (DBT; Linehan, 1993). Socially anxious individuals who engage in alcohol use may benefit from learning skillsets they do not inherently have access to or underutilize, such as those found within the four domains in DBT: interpersonal effectiveness, mindfulness, emotion regulation, and distress tolerance (Villalongo Andino et al., 2024). Perhaps the most promising skills for those with the AUD-social anxiety comorbidity are skills within the distress tolerance domain, which includes improving control over emotional thinking and the integration of rational thinking into daily life (Lynch et al., 2006). Importantly, prior research has found that socially anxious individuals display low distress tolerance and experience heightened reactivity to stress, leading to ineffective or risky (e.g., alcohol use) coping mechanisms in order to escape negative emotions (Keough et al., 2010). Alongside learning distress tolerance, the interpersonal effectiveness domain holds promise for improving social interactions and decreasing negative self-appraisal, which is a hallmark of social anxiety (Hofmann, 2007). Thus, DBT may serve as a promising therapeutic intervention for socially anxious individuals experiencing harmful drinking or alcohol misuse in social situations, as it targets both interpersonal and distress tolerance difficulties.

Lastly, given our finding that some facets of trait impulsivity are related to social anxiety, an additional therapeutic consideration that may be relevant for CBT is to incorporate imaginal desensitization when preparing for exposures with socially anxious individuals who display increased impulsivity. This suggestion is derived from work that has found success in utilizing imaginal desensitization for impulse control disorders and AUD (Blaszcxynski & Nower, 2002). For example, when preparing for an exposure surrounding attending a social gathering, the therapist may ask the client to visualize themselves being exposed to a situation at the social event that may increase their impulsiveness to drink, such as being ignored by an acquaintance or feeling left out of conversations. In theory, practicing imaginal desensitization should help diminish the strength of the client's drive to be impulsive by exposing them to levels of heightened arousal in session (Blaszcxynski & Nower, 2002). Given that a core element of CBT for socially anxious individuals is planning and completing exposures in feared social contexts, imaginal desensitization may help reduce the urge to drink if negative emotions arise during such exposures.

Limitations

As with any study, results presented here should be evaluated in light of study limitations. Firstly, the GMM analyses conducted in this study did not include the recommended sample size for models evaluating six or more indicators. This acknowledgement is supported by prior work that states that with our data metrics (e.g., low separation between classes, at least two classes, and six or more indicators) we would need a minimum samples size of 500 (Kim, 2012). Some models with similar metrics but high separation between classes could utilize a minimum of 300 participants (Kim, 2012),

which we acknowledge is still significantly higher than our sample size of 167. However, some longitudinal studies evaluating adolescent alcohol use using GMM did include similar sample sizes to ours presented here (n = 180, Greenbaum & Dedrick, 2007; n = 128, Li et al., 2001). Next, as with all modeling research, interpreting the results is dependent on the ability to differentiate classes with relevant explanatory variables. Although this study had a variety of explanatory variables (e.g., cognitive flexibility, risk-seeking, trait impulsivity), we acknowledge that there are potentially other predictors that could better distinguish the classes. For example, given that the WCST lends itself to practice effects as discussed above, the use of a different measure of cognitive flexibility (e.g., Stroop switching task; Hutchinson et al., 2010) may have better influenced class distinction. It is also important to note that GMM aggregates data within a class, thus the average trajectory may not represent the typical trajectory for all individuals within a class (Henson et al., 2015). Thus, some of our results could be explained by the inherent difficulty in predicting interindividual differences using GMM in a general sample. Specifically, we should consider that some individuals may have a great deal of variability in their risk-taking that was not captured by the models presented here. Recruitment of a sample with clinically elevated risk-taking, such as those with heightened alcohol use (AUDIT score of 15+), may provide more accurate average trajectories for the questions proposed in this study. Another important limitation of this study is that we did not administer a clinical interview to determine if participants met diagnostic criteria for social anxiety disorder. This consideration is important given that many research studies exploring similar variables as proposed here recruited for and utilized a clinical sample of social anxiety (see review; Morris et al., 2005). Given the

nuanced differences between mild, moderate, and severe cases of the disorder, we appreciate the importance that symptom severity could have when evaluating cognitive flexibility, risk-seeking, and trait impulsivity. Although we acknowledge this limitation, it may be important for future research to determine relations amongst the proposed variables in samples that self-report social anxiety symptoms, as we did here, as administering a clinical interview may not always be possible or time-permitting. In addition to this consideration, prior work has identified that individuals with social anxiety experience motivation to approach social rewards differently than non-social rewards and have a reduced response sensitivity to social cues that are related to positive social reward (Brown et al., 2007; Richey et al., 2014; 2017). The WCST and UNC do not include social reward components nor were they designed to measure response to social reward. It will be important for future research to characterize approach driven behaviors to both social and non-social rewards to further understand the nature of impulsivity within different contexts for socially anxious individuals. Lastly, our findings may be restricted in their generalizability, as data were obtained from participants residing in rural areas of Virginia. Considerations for risk-seeking in various contexts (e.g., rural vs urban settings) may wish to be explored.

Conclusion

The current study examined longitudinal trajectories of cognitive flexibility, risk-seeking, and facets of trait impulsivity across adolescence and explored their relation to co-occurring social anxiety and alcohol use in young adulthood. Results supported cognitive flexibility, risk-seeking, and attentional impulsivity during adolescence as predictors of self-reported social anxiety symptoms in young adulthood, with specific implications for alcohol use. As such, longitudinal measurement of these variables throughout adolescence serves as a promising avenue for understanding the later development of social anxiety and alcohol use in young adulthood. We recommend that future work consider exploring these variables in a clinical sample with comorbid social anxiety and alcohol use disorder to determine the impact symptom severity may have on this co-occurring relation.

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Tables

Table 1

Demographic Information for Participants

Age (Mean [*SD*])	
Wave 1 (n=157)	14.07 (0.54)
Wave 2 (n=150)	15.05 (0.54)
Wave 3 (n=143)	16.08 (0.55)
Wave 4 (n=143)	17.02 (0.55)
Wave 5 (n=132)	18.90 (0.62)
Wave 6 (n=124)	20.17 (0.63)
Wave 7 (n=137)	21.26 (0.64)
Wave 8 (n=135)	22.30 (0.69)
Gender	
Male (n=88)	52.7%
Female (n=79)	47.3%
Race	
White (n=131)	78.4%
Black (n=23)	13.8%
Biracial/Multiracial (n=10)	6.0%
American Indian/Alaska Native (n=2)	1.2%
Asian/Pacific Islander (n=1)	0.6%
Ethnicity	
Hispanic (n=4)	2.4%
Not Hispanic (n=163)	97.6%

Table 2

Description of Measures

Measure	Description and Use in Study
Liebowitz Social Anxiety Scale (LSAS; Heimber et al., 1999)	Assesses social anxiety in adult populations in the domains of social and performance situations and also provides indices of fear and avoidance within these situations. A cutoff score of 30 or more indicates that participants are experiencing significant social anxiety symptoms. The LSAS was administered during the last data collection, Wave 8.
The Barratt Impulsiveness Scale short form (BIS-15; Spinella, 2007)	Assesses the personality trait of impulsiveness. The three subscales include non-planning, motor, and attentional impulsivity. The BIS-15 was administered during Waves 1-8.
Alcohol Problems Questionnaire (Mason et al., 2011)	Assesses early alcohol use and problematic drinking. The Alcohol Problems questionnaire was administered during Waves 1-4.
Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993)	Assesses alcohol consumption, drinking behavior, and alcohol-related problems in young adults. A cutoff score of 15 or more signifies problematic drinking and moderate to severe alcohol dependence. The AUDIT was administered during Waves 5-8.
Emotion Regulation Questionnaire (ERQ; Gross & John, 2003)	Assesses preference to regulate emotions with cognitive appraisal or expressive suppression. The ERQ was used to control for emotion dysregulation within our analyses. The ERQ was administered in Waves 1-8.
Youth Self-Report and Adult Self-Report (YSR & ASR; Achenbach & Rescorla, 2001; 2003)	Assesses adolescent (YSR) and young adult (ASR) self-report of internalizing and externalizing symptomatology. For this study, the withdrawn/depressed subscale was utilized as a control for depression in the proposed analyses. The YSR was administered during Waves 1-4 and the ASR during Waves 5-8.
Wisconsin Card Sorting Test (WCST; Heaton & Staff, 2003)	Assess cognitive flexibility. The number of perseverative errors represent mistakes made by continuously using the same incorrect matching rule, reflecting difficulty with set switching. The WCST was administered during Waves 1-7.
Uncertainty Task (UNC; Holt & Laury, 2022; Lauharatanahirun et al., 2018)	Assess risk-seeking utilizing a modified economic lottery choice task. The dependent variable was calculated as the percentage of risky choices (higher percentages reflecting greater risk-seeking behavior). The UNC was administered during Waves 1-7.

Table 3

Means and Standard Deviations for Cognitive Flexibility and Risk-Seeking

	WCST		UNC	
	Mean	SD	Mean	SD
Wave 1	7.23	3.58	0.76	0.56
Wave 2	5.40	2.16	0.56	0.50
Wave 3	4.80	1.44	0.46	0.42
Wave 4	4.73	1.76	0.37	0.36
Wave 5	4.84	1.41	0.40	0.39
Wave 6	4.69	1.26	0.33	0.32
Wave 7	4.61	1.87	0.44	0.42

Note. Wisconsin Card Sorting Test = WCST; Uncertainty Task = UNC.

Table 4

Means and Standard Deviations for Facets and Total Score of Trait Impulsivity

	Non-Planning		Attentional		Motor		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Wave 1	11.34	3.05	11.20	3.22	10.42	3.02	33.02	7.25
Wave 2	11.01	2.78	10.94	2.84	10.32	3.14	32.28	7.00
Wave 3	10.92	3.02	10.93	2.27	10.57	3.48	32.44	7.46
Wave 4	10.65	3.02	10.96	3.04	10.38	3.20	31.96	7.39
Wave 5	10.57	3.19	10.78	3.01	9.77	3.03	31.13	7.61
Wave 6	10.83	3.06	11.46	3.20	10.14	3.24	32.49	7.67
Wave 7	10.84	3.18	11.35	3.39	9.84	3.15	32.02	7.81
Wave 8	10.94	3.16	11.32	3.07	10.04	3.25	32.30	7.81

Note. Facet (Non-Planning, Attentional, Motor) and total scores from Barratt Impulsiveness Scale, Short Form (BIS-15).

Table 5

Means and Standard Deviations for Outcome Variables

	Alcohol Problems		AUDIT		LSAS	
	Mean	SD	Mean	SD	Mean	SD
Wave 1	1.04	0.18	--	--	--	--
Wave 2	1.01	0.04	--	--	--	--
Wave 3	1.04	0.17	--	--	--	--
Wave 4	1.06	0.17	--	--	--	--
Wave 5	--	--	2.75	4.19	--	--
Wave 6	--	--	3.41	3.58	--	--
Wave 7	--	--	4.11	4.39	--	--
Wave 8	--	--	4.34	4.46	48.24	31.77

Note. Alcohol Problems Questionnaire = Alcohol Problems; AUDIT = Alcohol Use Disorder Identification Test; LSAS = Liebowitz Social Anxiety Scale.

Table 6

Means and Standard Deviations for Covariates

	ERQ Cognitive Reappraisal		ERQ Expressive Suppression		YSR/ASR Withdrawn/Depressed	
	Mean	SD	Mean	SD	Mean	SD
Wave 1	4.93	0.94	3.78	1.17	3.49	2.68
Wave 2	4.87	0.90	3.85	1.14	3.55	2.90
Wave 3	4.92	1.08	3.78	1.16	3.93	2.86
Wave 4	4.96	0.95	3.85	1.19	4.01	2.94
Wave 5	4.84	1.13	3.90	1.14	3.24	2.88
Wave 6	4.72	1.15	3.99	1.07	3.66	2.97
Wave 7	4.80	1.19	3.84	1.23	3.57	3.12
Wave 8	4.79	1.16	3.86	1.25	3.91	2.87

Note. Emotion Regulation Questionnaire = ERQ; Youth Self-Report = YSR (Waves 1-4); Adult Self-Report = ASR (Waves 5-8).

Table 7

Model Fit Statistics for Cognitive Flexibility Trajectories

Classification Model	AIC	BIC	Sample-size Adjusted BIC	LRT	*p*	BLRT	*p*	Entropy	Classification Probabilities	Class Size
Wisconsin Card Sorting Test (WCST)										
1 Factor	**3817.90**	**3870.91**	**3817.08**	**--**	**--**	**--**	**--**	**--**	**--**	**167**
2 Factor	3741.38	3803.74	3740.42	77.48	.11	-1897.95	p < .01	.97	.96, .99	16, 151
3 Factor	3693.66	3765.37	3692.55	50.43	.33	-1850.69	p < .01	.98	.96, .88, .99	11, 4, 152

Table 8

Regression Analyses for Cognitive Flexibility

	AUDIT			LSAS		
WCST	β	SE	*p*	β	SE	*p*
Wave 1	0.31	0.16	**0.05**	-1.80	1.02	0.08
Wave 2	-0.33	0.29	0.26	4.37	1.90	**0.02**
Wave 3	-0.11	0.29	0.70	-3.87	2.45	0.11
Wave 4	-0.29	0.22	0.19	0.71	2.05	0.73
Wave 5	0.04	0.27	0.90	1.61	2.59	0.53
Wave 6	0.13	0.33	0.70	0.14	2.84	0.97
Wave 7	-0.08	0.20	0.69	1.21	1.40	0.39

Note. WCST = Wisconsin Card Sorting Test; AUDIT = Alcohol Use Disorder Identification Test; LSAS = Liebowitz Social Anxiety Scale.

Table 9

Model Fit Statistics for Risk-Seeking Trajectories

Classification Model	AIC	BIC	Sample-size Adjusted BIC	LRT	*p*	BLRT	*p*	Entropy	Classification Probabilities	Class Size
Uncertainty Task (UNC)										
1 Factor	2307.43	2372.91	2306.42	--	--	--	--	--	--	167
2 Factor	**2272.85**	**2372.63**	**2271.21**	**50.52**	**.21**	**-1130.51**	**p < .01**	**.75**	**.87, .95**	**35, 132**
3 Factor	2367.97	2486.45	2366.14	40.11	.11	-1530.49	.34	.97	.99, .91, .99	157, 8, 2

Table 10

Model Fit Statistics for Trait Impulsivity Trajectories

Model	AIC	BIC	Sample-size Adjusted BIC	LRT	*p*	BLRT	*p*	Entropy	Classification Probabilities	Class Size
Non-planning										
1 Factor	**4869.39**	**4913.04**	**4868.71**	**--**	**--**	**--**	**--**	**--**	**--**	**167**
2 Factor	4876.44	4926.33	4875.67	4.60	.35	-2424.67	1.0	.64	.77, .92	22, 145
3 Factor	4875.11	4934.35	4871.20	6.88	.51	-2422.22	.26	.68	.84, .90, .85	30, 20, 117
Attention										
1 Factor	5423.03	5482.28	5422.12	--	--	--	--	--	--	167
2 Factor	**5343.25**	**5411.85**	**5342.19**	**18.91**	**.52**	**-2659.70**	**p < .01**	**.74**	**.89, .93**	**25, 142**
3 Factor	5340.76	5418.71	5339.56	7.97	.30	-2649.63	.33	.69	.88, .75, .87	120, 26, 21
Motor										
1 Factor	**4851.62**	**4910.86**	**4850.71**	**--**	**--**	**--**	**--**	**--**	**--**	**167**
2 Factor	5430.08	5498.68	5429.02	239.45	.33	-2820.56	p < .01	.99	1.0, .99	2, 165
3 Factor	5436.08	5514.03	5434.88	130.39	.50	-2693.04	1.0	.99	.99, .00, .58	165, 0, 2

Figures

Figure 1

Visual Example of the Uncertainty Task

Note. Image adapted from Lauharatanahirun et al. (2018).

Figure 2

Moderation Model for Trait Impulsivity in Early-Middle Adolescence

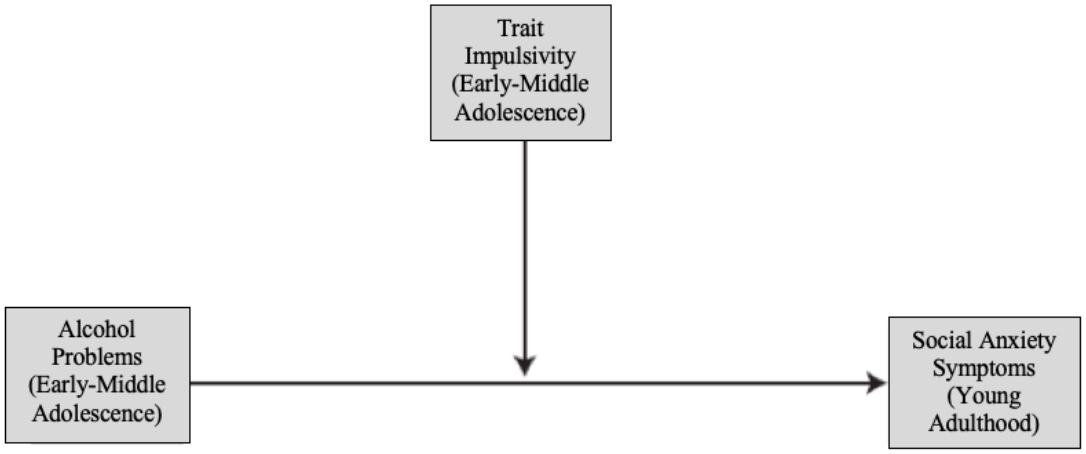


Figure 3

Moderation Model for Trait Impulsivity in Late Adolescence

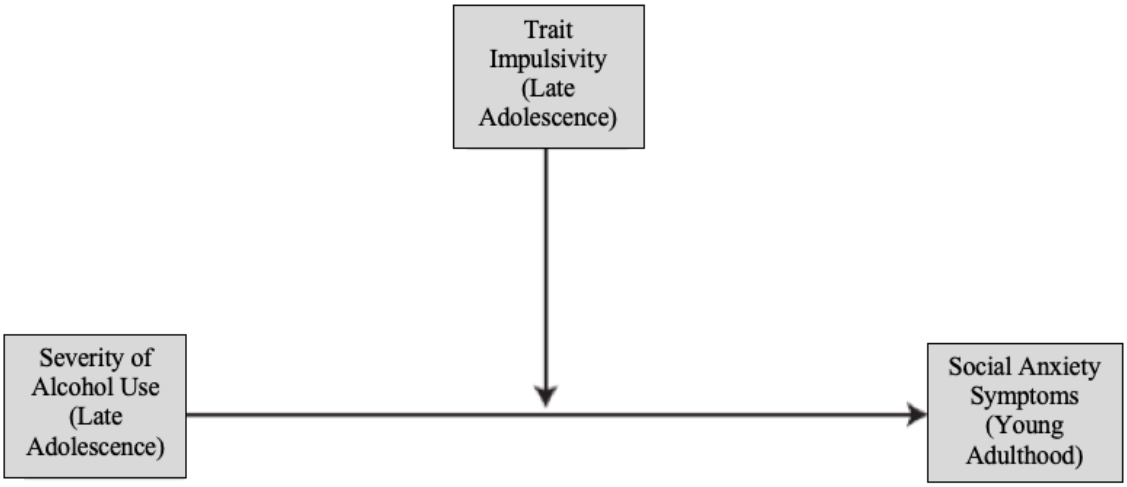
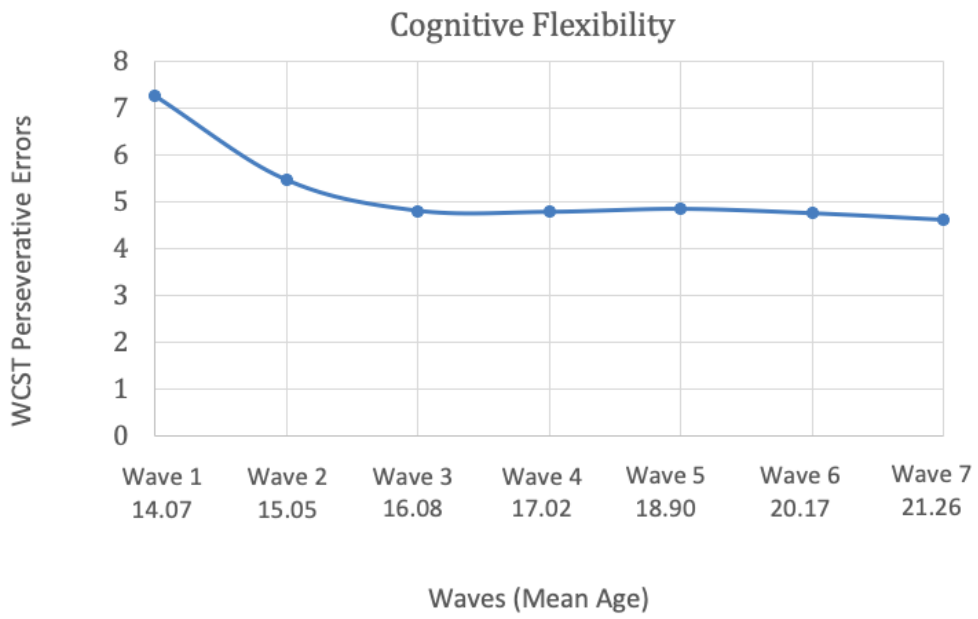


Figure 4.

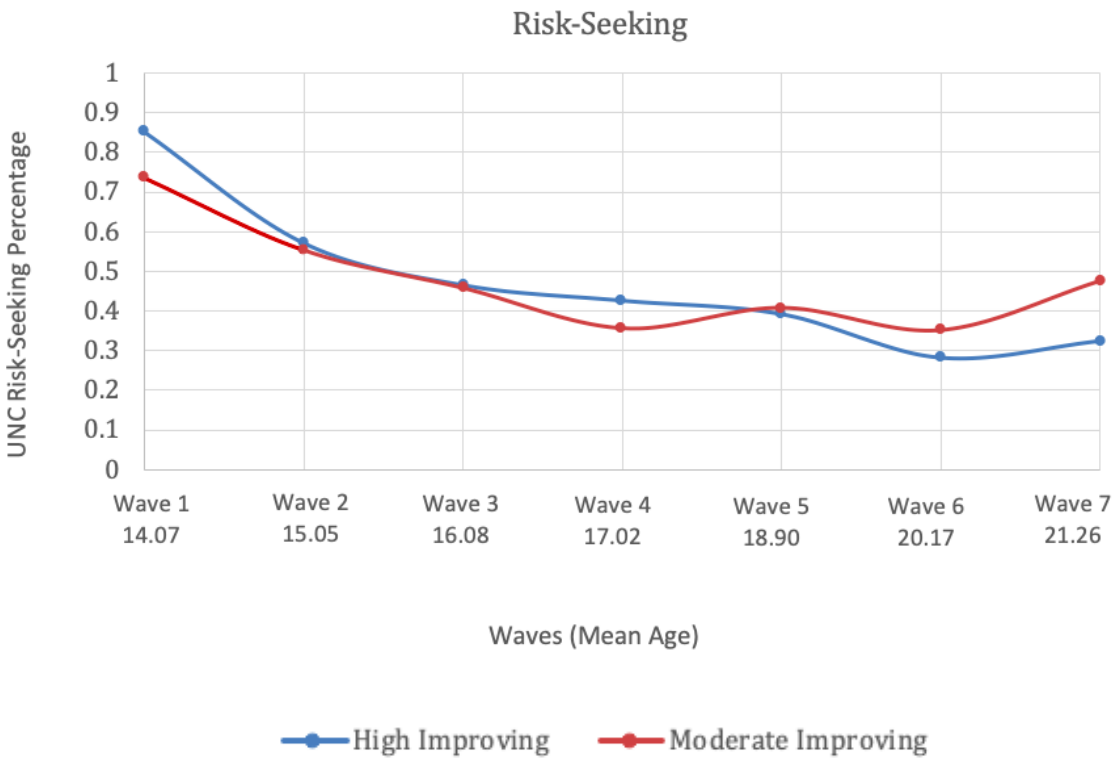
GCM for Cognitive Flexibility



Note. Mean age is in years. Higher scores are indicative of a higher number of perseverative errors (e.g., lower cognitive flexibility). The fit parameters for the one-class model indicated poor fit and outcome variables were not interpreted. For information purposes, the trajectory is displayed here. Wisconsin Card Sorting Test = WCST.

Figure 5

Two-Class GMM for Risk-Seeking

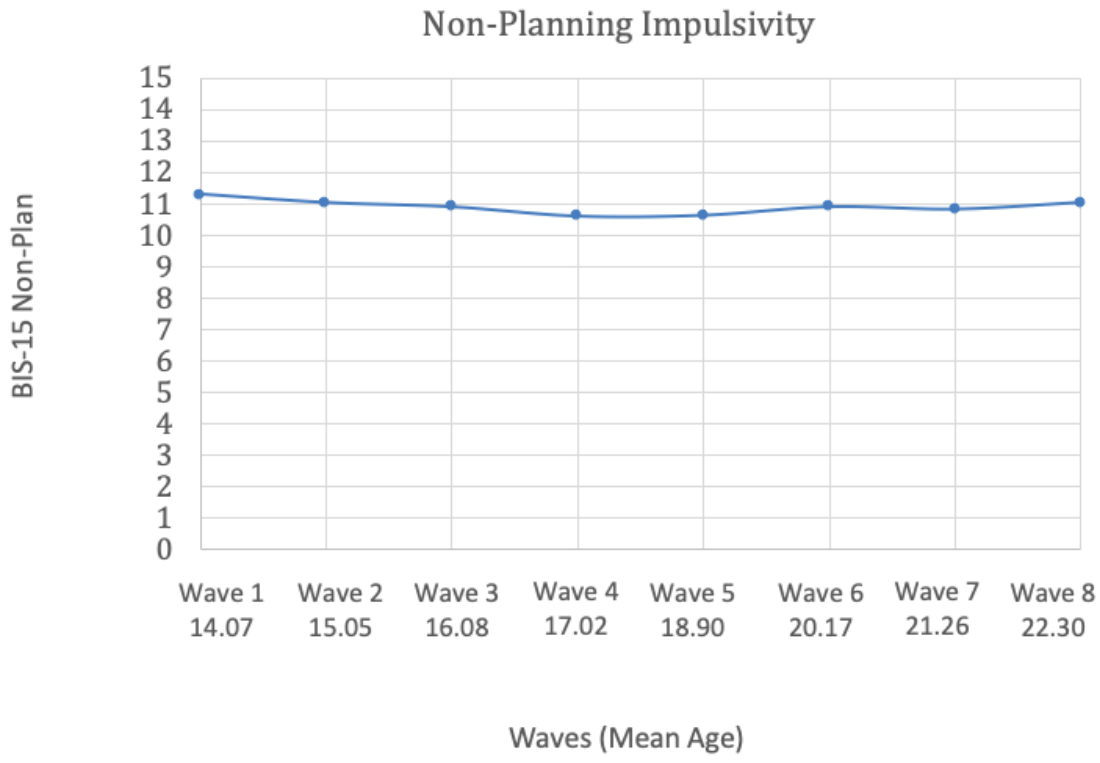


Note. Mean age is in years. Higher percentages indicate higher levels of risk-seeking.

Uncertainty Task = UNC.

Figure 6

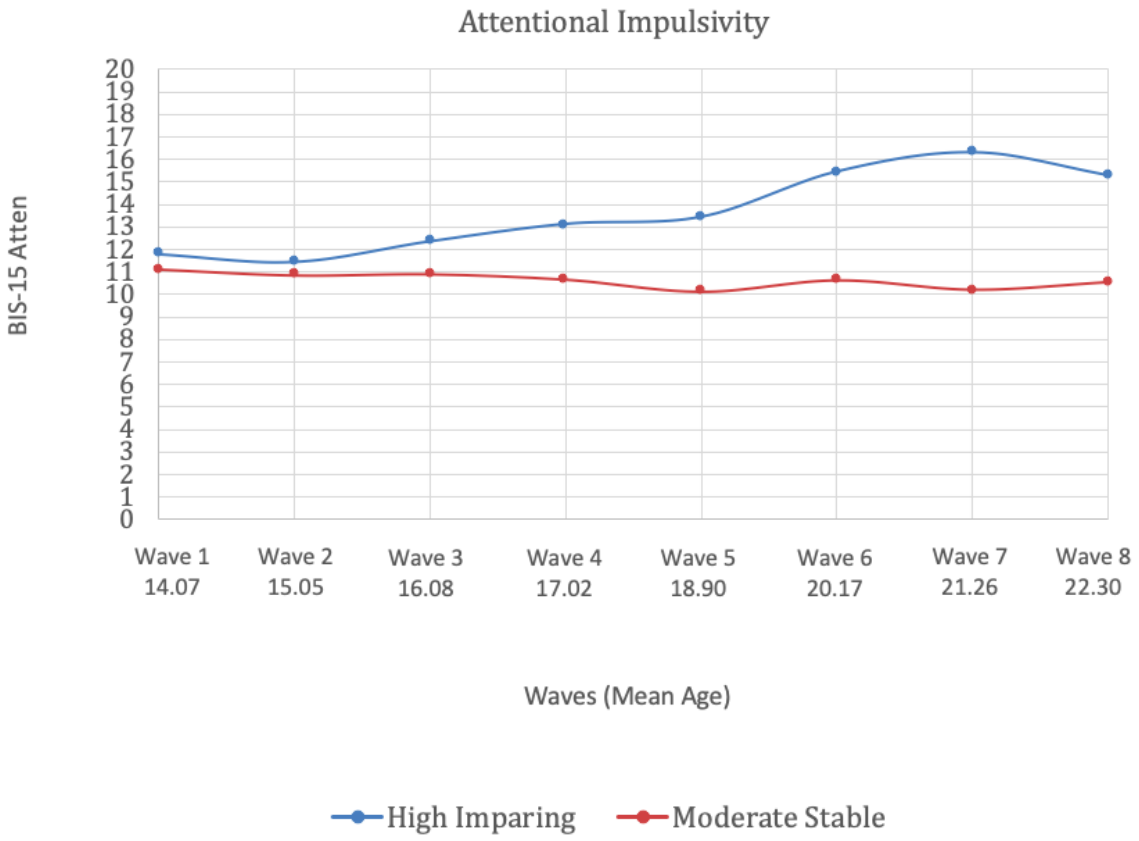
GCM for Non-Planning Impulsivity



Note. Mean age is in years. Higher scores on the BIS-15 indicate higher facets of trait impulsivity. Barratt Impulsiveness Scale, Short Form = BIS-15.

Figure 7

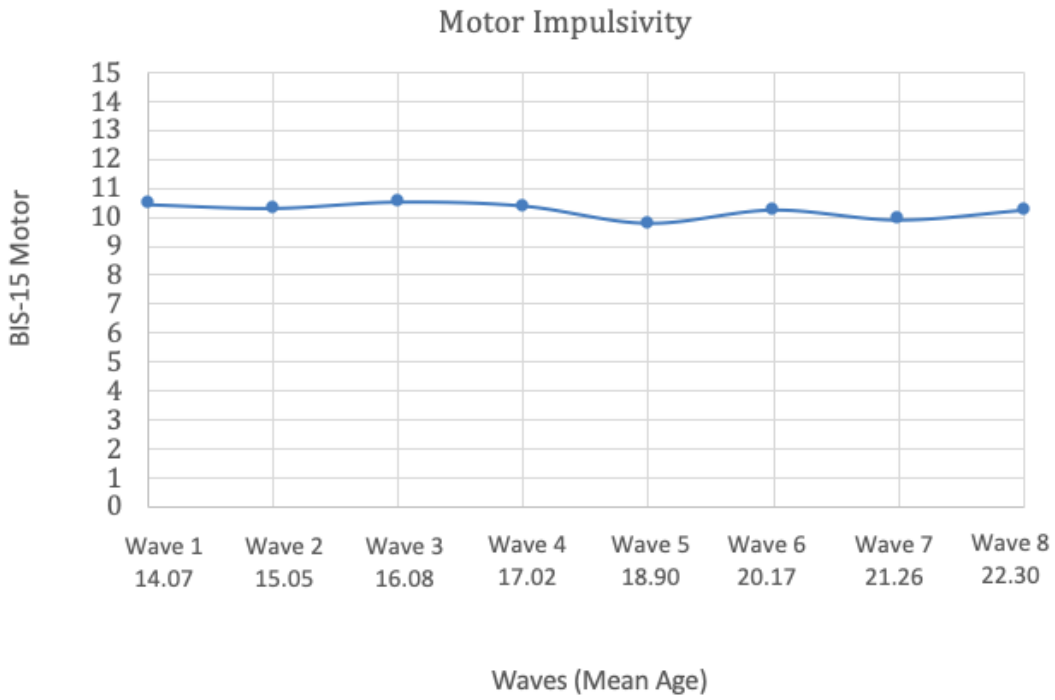
Two-Class GMM for Attentional Impulsivity



Note. Mean age is in years. Higher scores on the BIS-15 indicate higher facets of trait impulsivity. Barratt Impulsiveness Scale, Short Form = BIS-15.

Figure 8

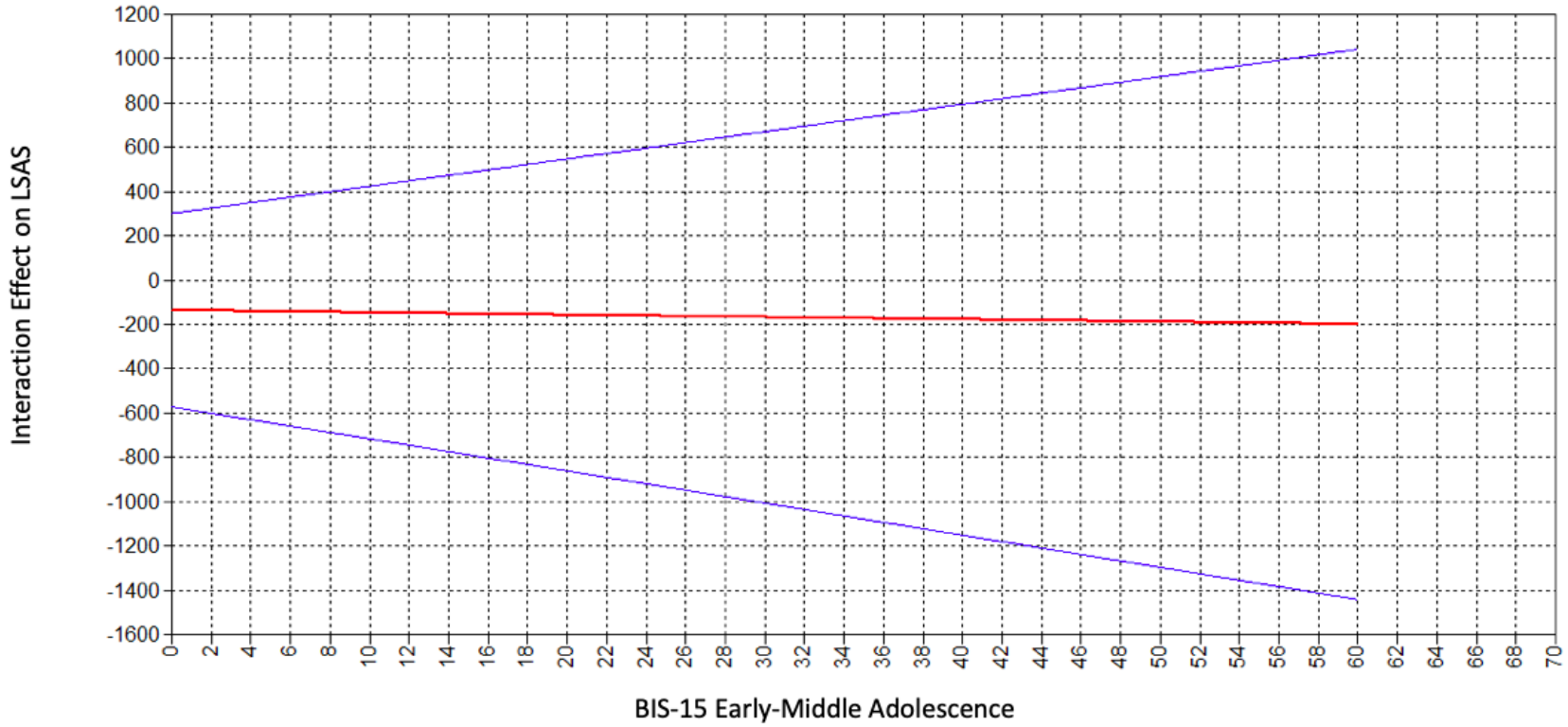
GCM for Motor Impulsivity



Note. Mean age is in years. Higher scores on the BIS-15 indicate higher facets of trait impulsivity. Barratt Impulsiveness Scale, Short Form = BIS-15.

Figure 9

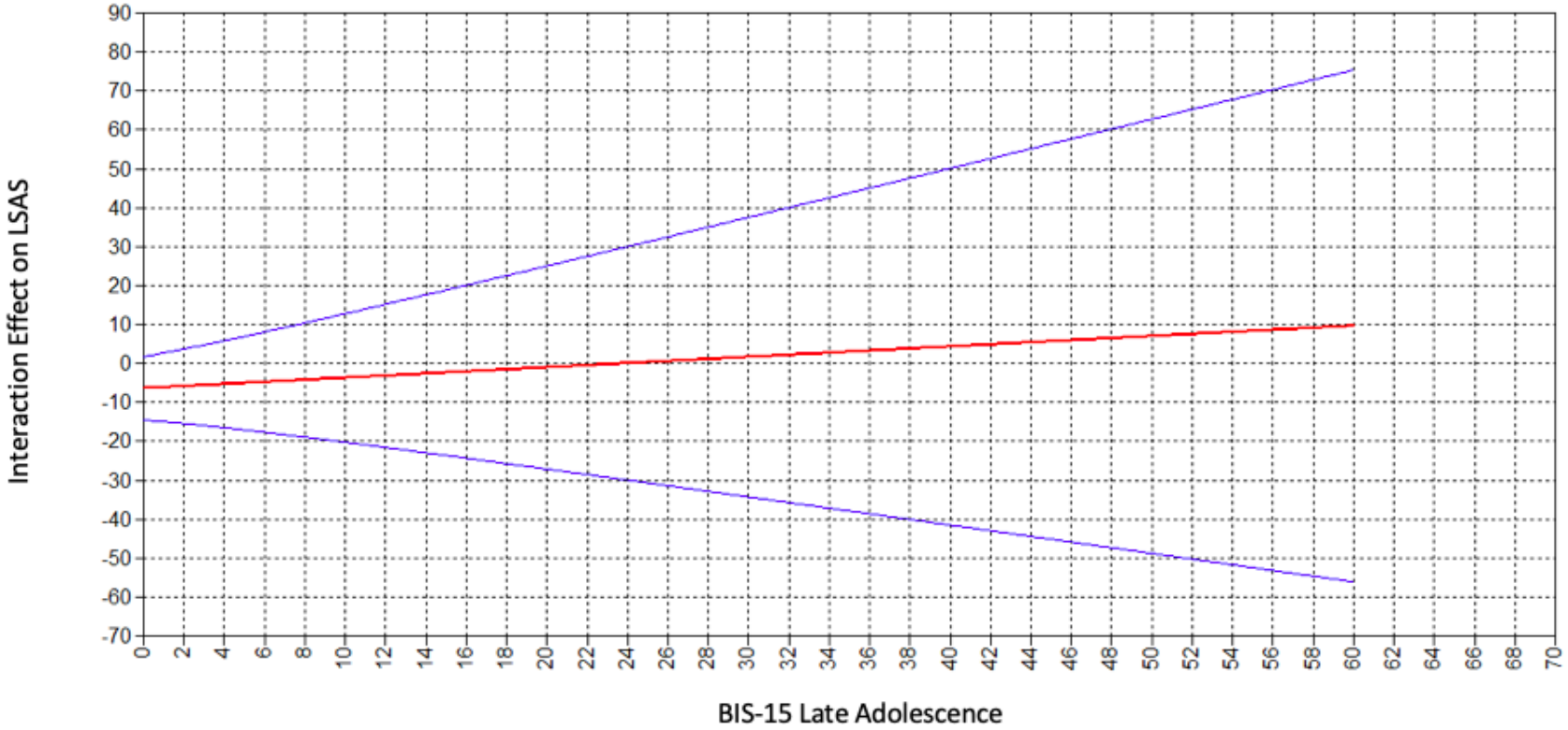
Trait Impulsivity as a Moderator in Early-Middle Adolescence



Note. Figure displays the interaction effect on social anxiety symptoms (LSAS) at levels of the moderator (trait impulsivity). The interaction effect is represented by alcohol problems (Alcohol Problems Questionnaire) and trait impulsivity (BIS-15) during early to middle adolescence. Liebowitz Social Anxiety Scale = LSAS; Barratt Impulsiveness Scale, Short Form = BIS-15.

Figure 10

Trait Impulsivity as a Moderator in Late Adolescence



Note. Figure displays the interaction effect on social anxiety symptoms (LSAS) at levels of the moderator (trait impulsivity). The interaction effect is represented by alcohol use severity (AUDIT) and trait impulsivity (BIS-15) during late adolescence. Liebowitz Social Anxiety Scale = LSAS; Alcohol Use Disorder Identification Test = AUDIT; Barratt Impulsiveness Scale, Short Form = BIS-15.

Appendix A

LSAS (Heimberg et al., 1999)

Directions: This measure assesses the way that social anxiety plays a role in your life across a variety of situations. Please read each situation carefully and answer two questions about that situation. The first question asks how anxious or fearful you feel in the situation. The second question asks how often you avoid the situation. If you come across a situation that you ordinarily do not experience, we ask that you imagine 'what if you were faced with that situation', and then rate the degree to which you would fear this hypothetical situation and how often you would tend to avoid it. Please base your ratings on the way that the situations have affected you in the last week.

0 Not at All	0 Never
1 Mildly	1 Occasionally (1-33%)
2 Moderately	2 Often (34-66%)
3 Severely	3 Usually (67-100%)

	Fear or Anxiety	**Avoidance**
1. Telephoning in public	_____	_____
2. Participating in small groups	_____	_____
3. Eating in public places	_____	_____
4. Drinking with others in public places	_____	_____
5. Talking to people in authority	_____	_____
6. Acting, performing, or giving a talk in front of an audience	_____	_____
7. Going to a party	_____	_____
8. Working while being observed	_____	_____
9. Writing while being observed	_____	_____
10. Calling someone you don't know very well	_____	_____
11. Talking with people you don't know very well	_____	_____
12. Meeting strangers	_____	_____
13. Urinating in a public bathroom	_____	_____
14. Entering a room when others are already seated	_____	_____
15. Being the center of attention	_____	_____
16. Speaking up at a meeting	_____	_____

17. Taking a written test..... _____ _____

18. Expressing appropriate disagreement or disapproval to

people you don't know very well..... _____ _____

19. Looking at people you don't know very well in the eyes..... _____ _____

20. Giving a report to a group..... _____ _____

21. Trying to pick up someone..... _____ _____

22. Returning goods to a store..... _____ _____

23. Giving an average party..... _____ _____

24. Resisting a high pressure sales person..... _____ _____

Appendix B

AUDIT Alcohol Screening Tool (Saunders et al., 1993)

Directions: Please complete the following questions about your alcohol use during the past 12 months. Place an X in the box that best describes your answer to each question. Please answer as accurately as you can.

Questions	0	1	2	3	4	Score
1. How often do you have a drink containing alcohol?	Never	Monthly or less	2-4 times a month	2-3 times a week	4+ times a 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 standard drinks on one occasion?	Never	Less than monthly	Monthly	Weekly	Daily or almost daily	
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	Weekly	Daily or almost daily	
5. How often during the last year have you failed to do what was normally expected of you because of drinking?	Never	Less than monthly	Monthly	Weekly	Daily or almost daily	
6. How often during the last year have you needed a drink first thing in the morning to get yourself going after a heavy drinking session?	Never	Less than monthly	Monthly	Weekly	Daily or almost daily	
7. How often during the last year have you had a feeling of guilt or remorse after drinking?	Never	Less than monthly	Monthly	Weekly	Daily or almost daily	
8. How often during the last year have you been unable to remember what happened the night before because of your drinking?	Never	Less than monthly	Monthly	Weekly	Daily or almost daily	
9. Have you or someone else been injured because of your drinking?	No		Yes, but not in the last year		Yes, during the last year	

10. Has a relative, friend, doctor, or other healthcare worker been concerned about your drinking or suggested you cut down?	No		Yes, but not in the last year		Yes, during the last year	
					TOTAL	

To SCORE:

1. Questions 1-8 are scores as 0, 1, 2, 3, or 4
2. Questions 9 and 10 are scores as 0, 2, or 4 only
3. Add all scores from each question to calculate total AUDIT score