ABSTRACT

Title of Dissertation:	VARIATION IN SOCIAL ANXIETY DISORDER AND EXECUTIVE FUNCTIONING: IDENTIFYING AND VALIDATING LATENT CLASSES AMONG EARLY ADOLESCENTS IN THE ADOLESCENT BRAIN AND COGNITIVE DEVELOPMENT (ABCD) STUDY
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Social anxiety disorder (SAD) in adolescence is heterogeneous in presentation and often associated with substance use behaviors. Yet, little is known about the link between these constructs. One framework of SAD identifies a subtype of behaviorally dysregulated, socially anxious individuals. Because the suite of goal-directed, cognitive processes known as executive functioning serves as a precursor to behavior regulation, we sought to explore whether heterogeneity in social anxiety presentation meaningfully varied with executive functioning in early adolescence and if this model of heterogeneity could predict substance use and other clinical outcomes. Using a person-centered approach to modeling, latent class analysis, a sample of over 10,000 children from the longitudinal Adolescent Brain and Cognitive Development (ABCD) study was used to model variation in social anxiety symptoms and performance on assessments of working memory, cognitive flexibility, and

inhibition. We also examined construct validity of the model by exploring associations with concurrent measures of behavioral inhibition, behavioral activation, and impulsivity. Finally, we tested the extent to which the identified model predicted later measures of substance use behavior, peer problems, and psychopathology. Support for a four-class solution of SAD symptoms and executive functioning performance was identified. Classes of individuals meaningfully differed on measures of behavioral inhibition and facets of impulsivity. Class membership was also predictive of later internalizing psychopathology. However, class membership did not predict later substance use, externalizing psychopathology, or peer problems. Future work should explore the generalizability of this model to older adolescents and whether alternative measurements of SAD and EF strengthen our prediction of later outcomes.

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Dedication

To my family. I am so grateful to be your daughter, your sister. Your love and support carried me to the finish line, and I could not have done this without you. And to my father - you are with me always. I love you, I miss you, and I hope you are proud of me.

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Social anxiety disorder: Background

Descriptive features

Social anxiety disorder (SAD) is characterized by a core fear of negative evaluation in social situations (American Psychological Association [APA], 2013). SAD is one of the most common anxiety disorders (Fehm et al., 2008). Lifetime prevalence rates of SAD among adults in the United States range from 5% to 10.7% (Grant et al., 2005; Kessler et al., 2012). Individuals with SAD tend to avoid feared situations, or when impossible to do so, endure the feared situation with intense distress (Spence & Rapee, 2016). Individuals with SAD are also considered by observers as shy and inhibited in nature (Turk, Heimberg, & Magee, 2008). When participating in feared situations, individuals with SAD are often preoccupied with concerns that others may find them unlikable, or they may behave inappropriately (Stein & Stein, 2008; Hope et al., 2010). Feared social situations range from formal public speaking, eating and drinking while being observed, and attending social gatherings (Stein & Deutsch, 2003).

Individuals with SAD are at higher risk for poorer outcomes across a range of domains. For example, SAD in youth and adults is associated with increased rates of co-occurring mental health concerns, including depression, substance use, and bipolar disorder (e.g., Beesdo et al., 2007; Buckner et al., 2008; Chavira et al., 2004; Chartier

et al., 2003; Knappe et al., 2011; Marmorstein, 2006). Other negative outcomes include increased academic difficulties (Davidson et al., 1993; Ranta et al., 2016), decreased workplace functioning (Moitra et al., 2011; Schneier et al., 1994), interpersonal problems (Tonge et al., 2020; Belmans et al., 2019), and overall poorer quality of life (Safren et al., 1996; Wong et al., 2012). Youth with SAD are particularly at an increased risk for peer victimization (Siegel et al., 2009; Mulder et al., 2017).

SAD is also considered a disorder of adolescent onset, such that most cases emerge from within the 10- to 19-year-old age range (Beesdo et al., 2007). Furthermore, SAD presents with a chronic element, such that pathology persists well into adulthood; one longitudinal study reports that, in the absence of intervention, more than half of all participants continued to meet diagnostic criteria for SAD 10 years after diagnosis (Beesdo-Baum et al., 2012). Given the extended time course, relatively early onset, and host of negative outcomes, considerable attention has been paid to understanding factors that contribute to the maintenance of SAD symptoms and associated impairments.

Maintenance Models

Our knowledge of maintenance models in youth SAD is largely informed by the adult literature, which implicate the combination of physical, cognitive, and behavioral factors. Prevailing maintenance models (e.g., Clark & Wells, 1995; Rapee & Heimberg, 1997) posit that the social anxiety cascade is triggered by the experience of somatic symptoms in socially threatening situations, namely autonomic nervous system activation which yields physical symptoms such as racing heart and increased

hyperventilation. It is thought that those experiencing SAD perceive this information as signs of imminent social failure, and thus it plays a role in the avoidance behaviors that characterize observable signs of the condition (Rapee & Heimberg, 1997).

Stemming from the increased somatic symptoms, maintenance models posit cognitive factors. In particular, increased somatic symptoms are accompanied by increased attention preferentially turning toward the self; the movement of attentional resources might serve coping or regulatory functions in the short-term, but at the cost of decreasing attentional resources to the immediate social situation, which portends long-term impairments to interpersonal functioning (e.g., initiating and maintaining healthy relationships; see Morrison & Heimberg, 2013). Attention is also biased to detect threat in the social environment (Clark & McManus, 2002). Perseverative thoughts and images of social catastrophe continue to *bias* interpretation of the social situation and *prevent* the processing of social cues that disconfirms fears (Clark & Wells, 1995).

Maintenance models also delineate behaviors that contribute to prolonged experiences with SAD. To further manage the anxiety, individuals experiencing SAD will often engage in safety behaviors in an effort to "counteract" negative evaluations or otherwise reduce in-the-moment distress when encountering feared situations (Helbig-Lang & Petermann, 2010). Unfortunately, these strategies may backfire for two reasons. One, safety behaviors often have the unintentional effect of making feared outcomes more likely to occur. For example, an individual who neglects to make eye contact out of fear of being scrutinized, may appear aloof and disinterested, causing social partners to eventually form negative impressions of their performance

(Alden & Bieling, 1997). Two, safety behaviors also prevent disconfirmation of fears. When the unrealistic prediction of social failure does not come true, the successful outcome is inaccurately attributed to the safety behaviors (Rapee & Heimberg, 1997; Piccirillo et al., 2016).

Maintenance models serve key roles in our understanding of SAD. Yet, as mentioned earlier, a majority of these models were developed to understand SAD as it manifests among adults. To what degree do these models inform our understanding of SAD within periods where it typically emerges, namely during adolescence? A recent review conducted by Leigh and Clark (2018) sought to examine the applicability of Clark and Wells' model (1995) to adolescents. Leigh and Clark identified multiple lines of evidence to support that adolescent SAD, similarly to adult SAD, includes physical, cognitive, and behavioral factors. For example, adolescents tend to overestimate the severity of somatic anxiety symptoms, reflecting the increased attention towards these internal experiences (Leigh & Clark, 2018). In terms of cognitive factors, socially anxious adolescents also report negative interpretations of ambiguous situations, frequent negative self-images, in addition to perseverative negative thoughts about social threat (Leigh & Clark, 2018, Esbjørn et al., 2021; Chapman et al., 2020). Additional studies with adolescents have identified that negative social cognitions, as well as increased self-focused attention predicted social anxiety symptoms (Chiu et al., 2021). Finally, adolescents have been observed to engage in safety behaviors (Chiu et al., 2021). Although these findings are promising, more work is needed to fully clarify models of SAD in youth. In particular, we require increased attention to the notion that not all adolescents may experience SAD

symptoms or impairments in the prototypical way, in part, because they may not all react to feared situations with displays of avoidance behaviors.

SAD Heterogeneity

Despite the identification of common factors of SAD in both adults and youth, there is still significant heterogeneity in its presentation. For example, although safety behaviors are key in maintaining SAD, two types of safety behaviors have been identified in both youth and adults (Evans et al., 2021; Gray et al., 2019). *Impression management* behaviors consist of positive actions taken to avoid feared outcomes by enhancing social performance including internal manipulations of emotional or physiological sensations, or external manipulations of the environment, such as mental rehearsal of conversation prior to engaging socially with others (Cuming et al., 2009). *Avoidance* behaviors consist of actions to reduce involvement within a social situation; these are more inhibitory in nature and may include limiting self-disclosure or eye contact (Plasencia, Alden, & Taylor, 2011). Of note, different outcomes have been associated with each type, such that reliance on avoidance behaviors is *only* associated with poorer quality of social interactions and peer relationships (Hirsch et al., 2004; Evans et al., 2021).

Most importantly, variation in comorbidity outcomes is also well-documented. Specifically, SAD has a uniquely high comorbidity with substance use problems, including alcohol and marijuana, relative to other mood and anxiety disorders (Morris et al., 2005; Buckner et al., 2012). Findings gleaned from the National Epidemiologic Survey on Alcohol and Related Conditions revealed that among adults with lifetime SAD, 48% also had comorbid alcohol use disorder, 33% had nicotine dependence,

and 22% had a drug use disorder (Grant et al., 2005). Similar findings have been replicated in international samples including Australia (Burns & Teesson, 2002), the Netherlands (Boschloo et al., 2011), and Norway (Bakken et al., 2005). Furthermore, dual SAD and substance use disorder diagnoses are associated with poorer treatment outcomes relative to any one disorder alone (Oliveira et al., 2018).

Indeed, multiple studies have identified retrospective, prospective, and concurrent links between social anxiety and substance use in youth populations (Blumenthal et al., 2011). SAD in youth has been identified as a unique risk factor for developing comorbid substance problems (Schneier et al., 2010). Additional work has found that early SAD symptoms predicted later problematic alcohol, cannabis, and tobacco use as an adult (Buckner et al., 2008; Marmorstein et al., 2010). For example, research surrounding the temporal ordering of SAD and substance use concerns indicate that SAD nearly always precedes development of substance use concerns (Marmorstein, 2012). Longitudinal work has also indicated that SAD symptoms in adolescence predicted alcohol use disorder in young adulthood; in contrast, early substance use did not predict social anxiety in adulthood (Wolitzky-Taylor et al., 2012). Epidemiological work has revealed that not only does substance use follow mental health concerns in adolescents, but prior SAD diagnoses presented the most risk for problematic substance use, relative to other mood and anxiety disorders (Conway et al., 2016). Longitudinal work following a cohort of boys from first grade to high school similarly concluded that social anxiety symptoms predicted earlier first use of alcohol and tobacco (Marmorstein et al., 2010). Furthermore, prior SAD diagnosis was observed to both increase the *risk* for adolescents to transition

from early, normative alcohol use to later, disordered alcohol use as well as increase the *rate* of that transition (Behrendt et al., 2011).

Attempts to explain the connection between SAD and later substance use concerns tend to rely on the self-medication model, which posits that the physiological effects of various substances are used to reduce or regulate feelings of negative affect (Khantzian, 1997). A review of the literature surrounding alcohol use and SAD found partial evidence to support this model; that is, individuals with SAD tend to use alcohol to reduce their SAD symptoms (Carrigan & Randall, 2003). Buckner and colleagues' biopsychosocial model of SAD and substance use comorbidity argues that the constituent components of SAD each uniquely reinforce substance use (2021). Within this model, substances are used to manage physiological arousal, fears of negative evaluation, post event processing, and positive affect. Substances are also used to improve perceived social deficits and avoid social evaluation. The reliance on substances to manage SAD then contributes to the development of clinically significant substance use (Buckner et al., 2021). Importantly, this model has yet to be applied to youth populations. However, preliminary findings regarding the temporal ordering of SAD and substance use provide support for the self-medication hypothesis (e.g., Marmorstein et al., 2010; Wolitzky-Taylor et al., 2012, Conway et al., 2016). Furthermore, coping motives have been associated with SAD and substance use in youth. For example, in a community sample of adolescents, increased social anxiety symptoms related to stronger desire to drink; notably, variance in this relationship was explained by disengagement coping motives (Blumenthal et al., 2016). Additionally, adolescents

with a history of SAD reported stronger expectations that alcohol would provide relief from symptoms following a social stressor task, in comparison to controls (Blumenthal et al., 2021). Although this model provides a framework for why SAD may uniquely relate to substance use, it is important to note that *not all individuals with SAD* go on to develop problematic substance use. Closely examining the heterogeneity of SAD presentation may identify key qualities or characteristics that serve as precursors to later substance use problems.

Models of SAD heterogeneity

Diagnostic models. Current diagnostic models of SAD attempt to formally operationalize heterogeneity according to scope or situational consistency of symptoms and impairments (Heimberg et al., 2014). That is, the DSM-5 includes a performance-only specifier, designed to capture individuals whose fear is limited to performance situations such as public speaking (APA, 2013). Research surrounding the validity of this subtype has highlighted its limitations (D'Avanzato & Dalrymple, 2016). For example, one study found that amongst a large community sample of Australian adolescents and young adults, only 0.3% of lifetime cases met criteria for performance-only SAD (Crome et al., 2015). Additionally, the clinical utility of specifiers has been called into question. One study concluded that diagnostic subtype did not improve predictive power for negative outcomes (e.g., comorbid depression, suicidal ideation), when controlling for severity of SAD symptoms (El-Gabalawy et al., 2010).

Similar concerns have been observed when examining the performance-only specifier in youth populations. In a large, nationally representative sample of U.S.

adolescents, only 0.7% of adolescents diagnosed with social anxiety met criteria for the performance-only subtype (Burstein et al., 2011). The low base rate of the performance-only subtype was replicated in a sample of over 200 youth seeking treatment for SAD; in this study, no participant met criteria for performance-only SAD (C.E. Kerns et al., 2013). Additional work draws attention to the variety of social fears present in adolescents, beyond public speaking. For example, one study reported that although formal public speaking is the most commonly reported fear among socially anxious adults, socially anxious adolescents most often reported fears involving informal social interactions, namely with unfamiliar same-age peers (Hofmann et al., 1999). Recent work leveraging exploratory factor analysis techniques to examine subtypes of SAD in youth revealed that although three distinct factors of feared situations were identified, including performance, observation, and interaction, only two children from a sample of over 100 were classified within the performance only subtype (Kodal et al., 2017). Taken together, there is a need to better understand the heterogeneity of SAD and whether we might use this heterogeneity to better understand how SAD portends poor clinical outcomes such as substance use.

Alternative model. One more promising way to capture SAD heterogeneity relies on the approach-avoidance continuum. The approach-avoidance continuum describes response to stress across a range of domains, including emotion regulation, personality traits, and behavioral presentation, such that individuals may be oriented toward (i.e., approach) or away (i.e., avoid) from threat (Roth & Cohen, 1986). Although SAD is typically characterized as a disorder of avoidance and inhibition,

one line of work has identified subtypes of SAD relating to *increased approach-related behaviors* (e.g., Kashdan & McKnight, 2010). Preliminary work initially identified variation in SAD as it relates to emotion regulation and personality traits, such that adults with SAD could be classified as having difficulties with either anger, hostility, and mistrustfulness or difficulties with assertion and exploitability (Kachin et al., 2001). Different treatment outcomes are also associated with these subtypes. For example, amongst socially anxious adults seeking treatment, problematic anger expression has been associated with early treatment termination (Erwin et al., 2003). Furthermore, individuals with elevated anger who completed treatment ultimately reported higher levels of symptoms at termination, relative to individuals without anger concerns (Erwin et al., 2003).

Leveraging cluster analytic techniques, Kashdan and colleagues identified two subtypes of SAD according to personality traits: high novelty seeking versus low novelty seeking with elevated avoidance (2008a). Notably, these two groups did not differ on SAD severity (Kashdan et al., 2008a). Later work similarly identified individuals with elevated SAD and approach-oriented behaviors (i.e., higher curiosity, increased desire for social status enhancement), as well as individuals with elevated SAD and avoidance-oriented behaviors; on average, the approach-oriented subtype reported poorer emotional regulation, as well as greater conflict relative to the avoidance-oriented subtype (Kashdan et al., 2008b). These groups were once again identified in a latent class analysis of a nationally representative sample of adults, such that individuals with SAD could be classified according to high or low levels of self-reported risk-taking, approach behavior; again, these classes did not

differ on SAD symptoms or severity (Kashdan et al., 2009). Differential treatment outcomes have also been identified in a Swedish sample of adults; within a sample of adults seeking treatment for SAD, nearly 80% of individuals who did not respond to treatment were considered anxious-impulsive (Mörtberg et al., 2014). Beyond personality, profiles of behavioral regulation and social anxiety have also been found in adult samples. Latent class analyses identified support for classes of adults with elevated SAD symptoms and either high or low levels of risk taking behavior (Nicholls et al., 2014). Additional research identified these classes of SAD amongst college students as well (Lipton et al., 2016).

Although the replication of these subtypes in younger populations is ongoing, findings are promising. One longitudinal study found support for these classes in a community sample of adolescents (Tilfors et al., 2013). Specifically, cluster analytic techniques were used to identify a group of youth with elevated SAD and increased inhibition as well as a group of youth with elevated SAD and increased impulsivity (Tilfors et al., 2013). Links between dysregulated behavior in socially anxious youth have also been identified. Specifically, relative to controls, socially anxious adolescents are prone to engaging in risky decision-making during laboratory tasks (i.e., Balloon Analogue Risk Task) after being socially stressed; in comparison, risk taking behavior did not change after social stress for controls (Reynolds et al., 2013).

Importantly, this model of SAD subtyping has been useful in clarifying links between SAD and substance use. For example, one study found that relative to individuals classified as only “elevated SAD” or only “elevated risk taking,” adults characterized by elevations in both SAD and risk taking demonstrated the highest

rates of substance use overall (Nicholls et al., 2014). Similarly, amongst a sample of college students, young adults characterized by elevations in both SAD symptoms and impulsivity reported significantly higher externalizing behaviors including substance use, relative to other groups (Lipton et al., 2016). In terms of youth, adolescents who were classified as socially anxious and impulsive were also found to have increased rates of substance use at baseline and in the years following (Tilfors et al., 2013).

Indeed, a growing body of literature supports evidence for a subtype of socially anxious and disinhibited individuals that are uniquely at risk for developing substance use concerns and other patterns of dysregulated behavior. These findings are especially important when considering the timing of problematic outcomes. That is, initiation of substance use typically overlaps with the onset of SAD symptoms, from ages 10 to 17 years old (Wittchen et al., 2008). Additionally, in the absence of co-occurring psychopathology, youth are most likely to transition from normative substance use to problematic substance use within three years of initiation (Wittchen et al., 2008). Because of this narrow window of time, identifying *mechanisms* related to the approach-oriented SAD subtype could be useful in improving our understanding of SAD in youth, especially as it pertains to early identification of at-risk youth and potential intervention planning.

Furthermore, the literature thus far has identified systematic variation of relying on measures of trait-like constructs (e.g., personality). These constructs tend to be long-standing in nature; indeed, the maintenance model of SAD described previously posits socio-cognitive factors that appear to already be set into motion by

adolescence. This suggests that there may be *precursors* that temporally precede the development of these traits. In turn, it may be possible to use such precursors to predict patterns of SAD earlier in development. As such, identifying SAD-relevant constructs can inform preventative efforts to stave off negative outcomes. To identify candidate constructs for potential precursors, turning to theoretical frameworks such as the self-regulatory resource model, the frustration-aggression model, and attentional control theory, may provide inspiration.

Potential mechanisms for SAD and increased approach related behaviors

The self-regulatory model proposes that the ability to favorably present oneself demands a generalized, albeit limited cognitive resource; as more effort is dedicated to managing impressions, cognitive resources begin to diminish (Baumeister & Vohs, 2003). Empirical work has identified that amongst control populations, depleting cognitive resources during a range of social interaction tasks results in reduced self-control and poorer self-impression (Vohs et al., 2005). In the context of SAD, self-regulation resources are disproportionately directed towards managing behavior to avoid the fear of negative evaluation (Kashdan et al., 2011). Response to the exhaustion of this cognitive resource may result in either avoidance of situations that could lead to rejection, or instead, yield impulsive behavior. Studies have shown that following social rejection, adults with elevated social anxiety respond with poorer levels of self-control (Oaten et al., 2008). In sum, self-regulatory theory suggests that variation in allocation of cognitive resources may relate to variation in behavioral outcomes.

In addition to self-regulation theory, the frustration-aggression model also seeks to explain the link between approach-oriented behaviors and SAD. Specifically, the model proposes that frustration and aggressive behavior follow anxiety when a goal has been perceived as blocked, such as social exclusion by peers, or inability to avoid feared situations (Polman et al., 2007). This reactive aggression is informed by biases in information processing, such that perceived threats or offenses in the environment trigger emotionally dysregulated and impulsive responses. Over time, these behaviors are speculated to develop into a maladaptive pattern of response to feared situations (Dodge et al., 1997; Bubier & Drabick, 2009). Indeed, youth with frequent displays of reactive aggression present with information processing deficits (e.g., threatening attribution biases) similar to youth with SAD (Crick & Dodge, 1996). Thus, the frustration-aggression model emphasizes variation in information processing relates to variation in behavioral and emotional regulation.

Attention control theory (ACT) may also provide insight into approach-avoidance variation in SAD populations. ACT describes the negative impact of anxiety on the balance between the two competing attentional systems (Eysenck et al., 2007). The goal-directed attention system is informed by knowledge, expectations, and current goals while the stimulus-driven attention system is designed to maximize response to salient stimuli in the environment. The experience of anxiety is theorized to divert resources away from the goal-directed attention system and towards stimulus-driven attention. As a result, this can limit task accuracy, or engaging in behaviors consistent with higher order goals such as responding appropriately to a social situation, or limit task efficiency, such that goal oriented

behavior is achieved but at a slower rate. In sum, ACT also implicates variation in the shifting between two attentional systems relating to variation in task accuracy and speed (Eysenck et al., 2007).

Taken together, each of these proposed models implicate cognitive processes to explain patterns of emotional, personality, and behavioral variation within SAD. Therefore, it stands to reason that individuals with SAD may vary on some core cognitive processes and are then predisposed to respond to threat with approach-oriented behaviors, and in turn, may be at increased risk for developing problematic substance use. One cognitive process that may warrant consideration is executive functioning.

Executive functioning

Executive functions (EF) refer to a constellation of processes that are mobilized to serve goal achievement (Diamond, 2013). The tripartite model of EF delineates three core components: working memory, cognitive flexibility, and inhibition (Miyake et al., 2000). Working memory refers to the ability to both hold and manipulate short pieces of information in mind (Zelazo, 2015). Cognitive flexibility describes the ability to shift goal-directed activity, such as changing schedules or generating alternative solutions when problem solving (Zelazo, 2015). Finally, inhibition refers to the ability to suppress prepotent responses when indicated (Zelazo, 2015).

The development of EF is relatively protracted, such that emerging EF presents in infancy and develops well into early adulthood (Best & Miller, 2010). From a neuroanatomical perspective, EF is mediated by networks of the anterior

regions of the brain (i.e., prefrontal cortex), and maturation of these regions is associated with maturation of EF skills (Anderson, 2002). As EF develops over time, links between EF variation and functioning in multiple domains have been observed. For example, stronger EF skills are associated with higher academic achievement (Willoughby et al., 2012; Ahmed et al., 2019), fewer peer problems (Holmes et al., 2016), and better quality of life (Brown & Landgraf, 2010). In contrast, poorer EF serves as a transdiagnostic risk factor for later psychopathology, including externalizing symptoms (e.g., Romer & Pizzagalli, 2021). Furthermore, psychopathology can also negatively impact the course of EF development (e.g., Poon, 2018; Brieant et al., 2022).

Importantly, EF has been associated with the approach-avoidance systems. EF is critical for self-regulation in the face of salient environmental cues; for example, reduced working memory capacity can lead to difficulty learning from negative consequences associated with externalizing behaviors (Endres et al., 2011). Empirical findings have identified links between EF and approach-avoidance systems. Imaging studies have found that activation of the dorsolateral prefrontal cortex, a key region implicated in EF, is associated with both approach and avoidance motivation (Spielberg et al., 2010; Rolle et al., 2022). Additional work has found that difficulty resolving approach-avoidance conflicts in individuals with externalizing psychopathology is related to poor regulation of frontal and limbic regions associated with EF (Lake et al., 2021). Subjective measures of behavioral inhibition and approach were found to relate to performance on a task of EF (Prabhakaran et al., 2011). Links between externalizing psychopathology, impulsivity, and sensation-

seeking behaviors and working memory capacity have been observed in adults as well (Bogg & Finn, 2010; Finn et al., 2009). In adults, working memory capacity was also found to mediate the relationship between behavioral disinhibition traits and patterns of externalizing behaviors (Endres et al., 2011). In conclusion, EF is a multi-faceted construct with well-established links to functional outcomes and links to approach-avoidance systems. Further examination of EF variation in SAD may clarify whether EF could serve as a precursor to dysregulated subtypes of SAD.

SAD and EF

Our understanding of EF in SAD overall is unclear within adults, and even less so for children. For example, a systematic review of neuropsychological performance in adult SAD populations identified only sparse evidence for EF weaknesses in SAD relative to normative populations (O'Toole & Pedersen, 2011). Empirical work also failed to find significant difference between adult SAD patients and matched controls on EF tasks (Sutterby & Bedwell, 2012; O'Toole et al., 2015), or other clinical groups such as major depressive disorder (MDD; Bourke et al., 2012) or autism spectrum disorder (Demetriou et al., 2021). However, more recent work seems to identify preliminary links between SAD and EF components (i.e., working memory, cognitive flexibility, and inhibition). Key findings are summarized below.

SAD and working memory. Research regarding the relation between SAD and working memory has demonstrated preliminary findings of note. In comparison to other clinical groups including generalized anxiety disorder and obsessive-compulsive disorder, individuals with SAD were found to perform more poorly on a task of verbal working memory (Rosa-Alcázar et al., 2021). However, in comparison

to controls, working memory capacity seems to vary as a function of stimuli. That is, adults with SAD demonstrate similar working memory capacity to controls for threatening words, yet adults with SAD recall significantly fewer neutral words relative to controls. Additionally, individuals with SAD had significantly larger working memory capacity for threatening words compared to neutral words (Amir & Bomyea, 2011). Amir and Bomyea suggest these findings may reflect more automatic orientation to threat, resulting in similar capacity to controls, but more effortful orientation to neutral stimuli, yielding poorer performance (2011). Further work has asserted that working memory capacity may not necessarily differ between adults with SAD and controls; however SAD participants are more accurate when manipulating emotionally salient stimuli (i.e., angry faces) compared to neutral stimuli (Yoon et al., 2017). These findings suggest working memory in SAD may vary in the context of emotionally significant information (Yoon et al., 2017). Furthermore, working memory capacity was found to moderate information processing biases; specifically, elevated implicit social anxiety predicted increased threat related-biases, but only for individuals with lower working memory capacity (Salemink et al., 2013).

Few studies have been conducted examining youth samples. One study found that adolescents with mild SAD performed *better* than matched controls and those with severe SAD on a task of working memory (Jarros et al., 2017).

SAD and cognitive flexibility. Relations between SAD and cognitive flexibility have been observed. Fuji and colleagues compared executive functioning performance between clinical samples of adults with SAD and matched controls

(2013). After controlling for depression, the clinical sample was observed to perform more poorly than controls on a task of cognitive flexibility, and they made significantly more perseverative errors (i.e., continuing to make the same response despite negative feedback). Findings in treatment settings have also been observed (Johnco et al., 2014). Relative to other clinical populations, such as generalized anxiety disorder and obsessive-compulsive disorder, SAD patients are also observed to perform more poorly on tasks of cognitive flexibility (Rosa-Alcázar et al., 2021). Links with treatment outcomes have also been identified with cognitive flexibility. For example, in a sample of older adults seeking SAD treatment, stronger performance on a cognitive flexibility task was associated with stronger cognitive restructuring skills, a key skill taught in cognitive behavioral therapy to cope with anxiety (Johnco et al., 2014). Additionally, these individuals reported greater reductions in distress after using these skills in daily life (Johnco et al., 2014). Similar findings were replicated in a younger, community sample of adults (Holder et al., 2021). Among adults who reported elevated social anxiety, higher frequency of perseverative errors on a cognitive flexibility task was associated with poorer performance on a cognitive restructuring task, indicating increased difficulty producing helpful alternative thoughts in response to distress (Holder et al., 2021).

However, findings are both limited and conflicting in youth samples. For example, a longitudinal study tracking adolescents over three years reported cognitive flexibility did not relate to SAD symptoms and instead, SAD symptoms *positively predicted performance on cognitive flexibility tasks* over time (Morea & Calvete, 2021). Morea and Calvete conjecture these findings may reflect perfectionism, an

inflexible desire for accuracy that is often associated with anxiety; specifically, increased SAD may relate to increased perfectionism, which may lead to a more effortful performance coupled with effective compensatory strategies; however, future empirical work is needed to support this hypothesis (2021). Additional work failed to identify differences in cognitive flexibility amongst adolescents with severe SAD, mild SAD, and matched controls (Jarros et al., 2017). In contrast, longitudinal work with younger children has found that lower parent-reported cognitive flexibility mediated the relationship between early temperament and later development of social anxiety symptoms (Buzzell et al., 2021).

SAD and inhibition. SAD and links with inhibition have also been observed. A study examining variation in event-related potentials (ERP) in a community sample of adults indicated that those with elevated social anxiety expend greater effort and slowed response time when inhibiting responses under conditions of threat, indicating impairment in efficient information processing (Judah et al., 2013). Adults with elevated social anxiety were also shown to demonstrate similar slowing of inhibition speed during an eye tracking task (Liang, 2018). Emotional salience of stimuli may also influence inhibitory skills. For example, individuals with elevated social anxiety symptoms were quicker to inhibit responses to positive stimuli compared to controls, suggesting possible deficits related to attending and processing of positive social information (Segal et al., 2015).

As noted above, research with youth and inhibition is limited. One study comparing "executive" inhibition (i.e., effortful control of automatic responses) and "behavioral" inhibition (i.e., withdrawal during novel situations) found that lower

executive inhibition *did not* predict later social anxiety in a sample of young children; instead, the combination of increased executive inhibition and behavioral inhibition predicted social anxiety three years later (Thorell et al., 2004). These findings were later replicated, such that higher parent-reported executive inhibition mediated the relationship between early behavioral inhibition and later development of social anxiety symptoms (Buzzell et al., 2021).

Gaps in the literature

Thus far, the literature has highlighted the links between subtypes of SAD and negative outcomes, yet potential links between EF and SAD are less clear. However, the interpretability of these findings is somewhat limited due to key gaps in our understanding. First, a majority of research focuses on adults, rather than youth. Given that SAD emerges in youth, EF matures into early adulthood, and normative substance use is initiated in adolescence, neglecting to examine how the combination of these constructs present in youth limits our understanding of a key population at increased risk for deleterious outcomes. Furthermore, potential intervention efforts may be best suited to overlap with observed sensitive periods of EF, or periods of relative plasticity, that occur from preschool years to adolescence (Zelazo & Carlson, 2012). For example, children as young as four demonstrate improvements in EF following intervention; furthermore, children who received intervention demonstrated stronger academic performance relative to children who did not (Sasser et al., 2017). A recent review also concluded that children up to age 12 can benefit from a range of EF intervention; children with the largest deficits tend to demonstrate the greatest improvements (Diamond & Lee, 2011). Positive support for intervention has also

been demonstrated in high school students (Duckworth et al., 2011). In sum, broadening our knowledge of SAD by focusing on youth as well as EF variation may eventually support efforts for early identification and treatment development.

Second, methodological issues such as sampling procedures and measurement selection may contribute to challenges with interpretability. For example, SAD samples recruited in the previous review of EF literature were treated as a monolith. That is, SAD participants were assumed to be *homogenous* when compared to typically developing controls. This approach may wash out subtle differences of EF *within* SAD samples. Furthermore, measures of EF were often associated with only *accuracy*. Previous findings have found that anxiety is often associated with impairments in *efficiency* more than effectiveness on tasks of EF, with greater problems emerging as task demands increase (Shi et al., 2019). Specifically, findings indicate that anxious individuals can achieve accuracy comparable to controls, but only after exerting additional effort and time (Eysenck et al., 2007). Because of this, measures of executive functioning need to account for both accuracy and speed when attempting to characterize differences. Therefore, examining samples with broader variation in SAD, as well as leveraging measures of EF that account for speed as well as accuracy are necessary in improving our understanding of both constructs.

Third, a majority of studies have leveraged cross-sectional designs. Although this allows us to identify concurrent associations between SAD and variables of interest, further longitudinal work is needed to examine variation in SAD as it develops over time, especially in regards to outcomes more relevant to later years, such as substance use. Work has indicated that early initiation of substances is

associated with increased risk for later substance use disorders (Nelson & Wittchen, 1998). Given that adolescents diagnosed with substance use disorders are unlikely to transition out of problematic substance use in adulthood, identifying precursors for comorbid SAD and substance use could be used to alert families and providers as necessary for intervention planning (McCabe et al., 2022; Volkow & Wargo, 2022).

Finally, most research regarding EF and SAD relies on variable centered approaches (e.g., regression). Variable centered approaches assume that populations are homogenous, and thus, all independent variables operate similarly on outcome variables of interest (Laursen & Hoff, 2006). In contrast, person-centered approaches capture differences at the individual level and aim to create groups of individuals that share similar characteristics (Collins & Lanza 2010). Person-centered approaches can be powerful in detecting patterns of individual differences among variables of interest. Furthermore, person-centered approaches are well suited in examining distal outcomes, such that one can examine how classes of individuals differentially relate to outcome variables over time (Laursen & Hoff, 2006).

Current Study

Given the noted gaps in the literature, the current study sought to add to our current understanding by including two unique approaches into the study design: the Adolescent Brain and Cognitive Development (ABCD) study and Latent Class Analysis (LCA). First, using an open science framework, the ABCD study is a recent endeavor into collaborative and large-scale data collection, with the goal to examine a broad variety of domains germane to child development. This includes but is not limited to measures of psychological functioning, academic achievement,

physiological factors, and environmental issues. Indeed, the span of assessed domains allows for novel means to address adjacent research questions including leveraging brain imaging to explore internalizing symptoms and impulsivity (Fan et al., 2023), examining relations between diagnoses of depression and anxiety disorders with alcohol and tobacco use (Klein, Gyorda, & Jacobson, 2022), or modeling concurrent relations between general neurocognitive functions and problem behaviors (Moore & Conway, 2023). Despite the wealth of research generated by the ABCD dataset, few studies to date have sought to examine SAD alone, above and beyond more broadband measures of internalizing concerns or global anxiety. Similarly, EF performance measures have been rarely used in conjunction with SAD assessment; EF performance measures are also infrequently examined independent from basic neuroscience (i.e., neuroimaging) approaches. Thus, the opportunity to examine the relatively unique combination of SAD experiences and measures of EF merits exploration.

Importantly, the ABCD study also aims to track their initial sample of youth from childhood to early adulthood. Beginning in 2016, the ABCD study recruited a nationally representative baseline sample of youth aged 9 to 10 and continued to assess returning participants across time, with most recent data collected at ages 12 to 13. Furthermore, the longitudinal aspect to the study design also offers the exciting opportunity to examine prediction of later outcomes over time. In the context of increased substance use in SAD, research designs that can address distal outcomes are particularly important to improving our understanding of trajectory of risk over time.

Second, as mentioned previously, leveraging a person-centered approach like LCA can be a particularly useful way to uncover patterns of heterogeneity among key variables. Briefly put, LCA emphasizes the role of a hypothesized latent variable; that is, one that is not directly observed but is instead indirectly represented by two or more observed (i.e., measured) variables (Collins & Lanza, 2010). Due to this relation, observed variables are called *indicators* of the latent variable. See Figure 1 for a diagram of the relation between a hypothetical latent variable and its indicators. It is important to note the directionality of the purported relation between a latent variable and its indicators: the latent variable causes response patterns on indicator variables. In the context of behavioral and social sciences, LCA can be useful in understanding how a vast amount of data collected from each individual such as symptoms or behavior can be organized to reflect a latent, categorical variable that classifies individuals into theoretically meaningful and internally homogenous subtypes, or *classes.* Put another way, LCA is a means to organize individuals into classes, based on similar patterns of response across many variables. With this framework in mind, it becomes quite clear why past studies have sought to use LCA to make sense of the heterogeneity of SAD. LCA can evaluate for the presence of a latent variable, that represents subtypes of SAD among indicators of SAD symptoms and behavior dysregulation. Of note, solutions gleaned from LCA are most stable when sample sizes are larger, with some research recommending samples over 300. Importantly, LCA can also be used to examine whether a particular class solution can predict distal outcomes.

Put together, the ABCD study offers rich measurement of a variety of key variables of interest (e.g., SAD, EF, substance use) and collects such data across time. The abundant sample size may improve power to detect variation in SAD and EF in a nationally representative sample. When paired with LCA, we were able to evaluate whether individual variation in SAD and EF could be meaningfully organized into classes. We were also able to examine whether a particular class solution could predict later outcomes of substance use behaviors. Working within the forms of data collected by the ABCD study, the present study selected baseline youth report of core SAD symptoms, assessed via computerized clinical interview, and three performance measures that correspond to each domain of EF (working memory, cognitive flexibility, and inhibition) indicators. To bolster confidence in the validity of an identified model of classes, relations between classes and measures of conceptually related but still distinct domains collected concurrently at baseline were examined. Due to the longitudinal nature of the dataset, this study also examined the relation between classes of SAD and EF constructed at baseline (ages 9 – 10) and later measures of substance use (ages 12 – 13). Additional exploratory analyses related to classes and later general psychopathology and later peer experiences were examined. In sum, the study had three primary specific aims:

Aim 1: We sought to characterize self -report SAD symptoms and EF in a transdiagnostic sample of youth using latent class analysis, a person-centered modeling technique used extensively in prior work to characterize heterogeneity in multiple constructs (McCutcheon, 1987).

Hypothesis 1: Due to the exploratory nature of this analysis, no hypotheses were made about the number or structure of classes according to SAD symptoms and EF. However, in line with prior work, we expected to identify classes characterized by low SAD and intact EF, elevated SAD and intact EF, and elevated SAD and impaired EF.

Aim 2: We planned to examine construct validity of identified classes with external criterion variables that are related but nevertheless distinct from selected indicators (i.e., assessments of relevant personality traits) measured at baseline.

Hypothesis 2: We expected classes characterized by elevated SAD to report increased behavioral inhibition relative to classes characterized by low SAD. Classes characterized by concurrent elevated SAD and EF challenges were predicted to report increased rates of behavioral approach, as well as increased behavioral impulsivity, relative to other classes.

Aim 3: We sought to explore the extent to which classes of SAD and EF constructed at baseline predicted later pathology and functioning.

Hypothesis 3: We predicted that classes characterized by poorer EF and increased SAD would have increased substance use, externalizing behaviors, and greater peer difficulties in later adolescence, relative to other subtypes.

Chapter 2: Method

ABCD Study Overview

The ABCD study is a multisite, longitudinal study examining child development from preadolescence to young adulthood. The baseline sample was collected from September 2016 to October 2018. A total of 11,877 nine- and ten-year-old children and their parents were recruited from 21 research sites across the United States to complete a range of assessments spanning physical, psychological, cognitive, and environmental domains. Participants are followed annually, with aims to maintain follow up for ten years. Thus, all measures involved in analyses have been previously collected. Baseline and year three follow-up data were used for analyses.

Children and their parents completed the study visit at their local research site. Parents provided consent and children provided assent. Parents and children separately completed questionnaires; children also completed neurocognitive assessments, biological samples, and an MRI scan in one 8-hour session. Families were reimbursed at the end of the visit, with rates varying across site but ranging from $200 for parent and $100 of gifts to child (Garavan et al., 2018). Families returned to their local research site for follow up visits.

Participants

Recruitment

Recruitment strategies were designed to collect a sample reflecting of the United States demographics (Garavan et al., 2018). Catchment areas were defined for each of the 21 research sites, and elementary schools within those areas were used as the primary method of recruitment. Schools were selected through stratified, probability sampling to minimize sampling biases in recruitment at the school level. Less than 10% of the final sample was recruited through a range of methods, include mailing lists and snowball referral mechanisms (Garavan et al., 2018). Parents of children aged 9 to 10 years were contacted for participation. Interested families completed a screening to determine eligibility. Inclusion criteria included being in the required age range and being able to provide informed consent and assent (Dick et al., 2021). Exclusion criteria included lack of English language proficiency in children, the presence of severe sensory, intellectual, medical or neurological concerns that could impact data validity or ability to follow protocol, and contraindications to MRI scanning; parents also had to be fluent in either English or Spanish (Dick et al., 2021).

Sample characteristics

At baseline, 11,877 children were recruited. 1,529 children with missing data necessary for model construction (i.e., SAD symptoms, EF measures) were removed from the dataset. Because targeted efforts were made to recruit twins, 516 of children in the sample were either siblings, twins, or triplets. To remove the influence of shared genetic and environmental influence, only unrelated children were retained in

the dataset; 258 children who were part of the same family were randomly selected to remain in the sample. Of the 10,090 participants retained at baseline, 5,384 remained by Year 3. See Figure 2 for sample selection flow diagram and see Table 1 for a full description of demographics for the final sample at baseline and at Year 3.

Measures

Demographics

Parents completed demographic questionnaires regarding their family at baseline (Barch et al., 2018). Parents reported race using one of five categories: White, Black, Hispanic, Asian, Other. Parents also reported the child's age in months at the time of the assessment. Sex at birth was reported as well. Finally, annual household income was reported from nine different response options, ranging from less than $5,000 to over $200,000. Household income was transformed into three levels, (<$50,000, $50,000 - 100,000, ≥$100,000) to improve interpretability in later analyses; this approach is consistent with prior work involving the ABCD study (e.g., Dennis et al., 2022).

Baseline psychiatric symptoms and diagnoses

To assess current (i.e., within the past two weeks) and past (i.e., ever experienced) symptoms of DSM-5 disorders, youth individually completed the computerized Kiddie Schedule for Affective Disorders and Schizophrenia (KSADS-COMP; Barch et al., 2018). Children completed the following KSADS-COMP modules with support from trained ABCD research assistants (Barch et al., 2018): mood, social anxiety, generalized anxiety disorder, suicide, and sleep. The KSADS-

COMP included three components: an introductory interview, a screening module to evaluate key symptoms for each disorder, and follow-up supplemental modules administered for each diagnosis when elevations were detected on the screening module (Townsend et al., 2020). That is, if items were positively endorsed on the screening module, additional follow-up questions to fully evaluate for the presence of a DSM-5 disorder were presented. If items were not endorsed, the additional questions were not presented. Questions that were deliberately not asked were coded with an 888 (Barch et al., 2021). Item response options were binary (yes or no). The youth administered KSADS-COMP has demonstrated good convergent validity against well-established clinical rating scales in terms of both categorical and dimensional ratings of pathology (Townsend et al., 2020). Of note, parents completed remaining modules of the KSADS-COMP independent of youth; however, this data was not reported in the current study due to documented errors in the algorithm used to count symptoms and establish whether diagnostic criteria were met.

Baseline executive functioning

To assess executive functioning, tests from the NIH Toolbox Cognition Battery were used. The NIH Toolbox Cognition Battery is a suite of assessments that are administered via iPad or desktop computer under supervision of trained research assistant. The NIH Toolbox Cognition Battery has demonstrated sufficient psychometric strength with youth (e.g., Zelazo & Bauer, 2013); however, the sample size used to develop standardized scores was relatively small (n = 88). Due to the much larger sample found in the ABCD study, raw scores were used for analyses to increase variability of responses. Specifically, raw scores were dichotomized into

"intact" (i.e., top 75% performance) and "impaired" (i.e., bottom 25% performance) categories.

Working memory. The Toolbox List Sorting Working Memory Test (TLSWMT) is a picture sequencing task. Participants were presented with a series of pictures from a single category (e.g., animals, foods) of different sizes, with the name of the picture orally presented at the same time. Participants were then asked to repeat back the names of the items presented but in order from smallest to largest. Participants were presented with two trials per list length. Answering at least one trial correctly allowed for the participant to continue to the next list length, which increased in length by one picture (max length of seven pictures). Regardless of their performance on the single category trials, participants were then presented with a series of pictures from both categories. For the double category trials, participants had to organize and repeat back the items for one category then the other. Similar to the single category trials, participants were allowed two opportunities to correctly respond in order to continue to the next list length (max length of seven pictures). Validation testing of this task completed with youth indicated good test-retest reliability and convergent validity with letter-number sequencing tasks, as well as expected age related effects (Tulsky et al., 2013). Of note, this task also demonstrated relatively strong correlations with picture vocabulary tests as well as other tests of executive function (Luciana et al., 2018). Scores reflected the total number of accurate trials. At baseline, raw scores ranged from 0 to 26, with an average score of 15.96 (SD = 3.10).

Cognitive flexibility. The Dimensional Change Card Sort (DCCS) was used to assess cognitive flexibility (Zelazo et al., 2013). Participants were first presented with two target objects at the bottom of a screen that vary along two dimensions (e.g., color and shape). A third object was presented in the middle of the screen and participants were asked to match the object to one of the targets by either shape or color. Participants also participated in "switch" trials, in which the matching rule alternated in pseudorandom order between sorting on color or shape (Luciana et al., 2018). Participants received feedback regarding the accuracy of their matching for each trial. In children and adolescents, the DCCS demonstrated strong test-retest reliability and convergent validity, as well as expected age related effects (Zelazo et al., 2013). Scoring was based on a combination of accuracy and reaction time, and raw scores ranged from 0 to 10. Higher scores indicated stronger cognitive flexibility. At baseline, raw scores ranged from 2.0 to 10.0, with an average score of 6.89 (SD = 1.07).

Inhibition. To measure inhibition, participants completed the Toolbox Flanker task (TF). During this task, participants were presented with a target arrow pointing either left or right that was surrounded by four flanking arrows, facing either the same or opposite direction as the target. Participants had to push a button to indicate the direction of the target, while inhibiting attention to the flankers. Validation testing in children and adolescents indicated the TF demonstrated excellent test-retest reliability, expected age-related improvements, and acceptable convergent validity (Zelazo et al., 2013). Scoring was based on a combination of accuracy and reaction time, and raw scores ranged from 0 to 10. Higher scores

indicated stronger inhibitory abilities. At baseline, raw scores ranged from 3.5 to 9.88, with an average score of 7.72 (SD = 0.88).

Self-reported behavioral inhibition and behavioral activation

Traits of behavioral inhibition and activation were measured with the BIS/BAS scales (Carver & White, 1994). The BIS (Behavioral Inhibition System) scale captures passive avoidance in the face of threat, and the BAS (Behavioral Activation System) scales reflect response to positive reinforcers and associations with approach behaviors. The BIS/BAS scales have demonstrated strong psychometric properties with children, adolescents, and adults, including internal consistency and concurrent validity with measures of psychopathology (e.g., Muris et al., 2005; Yu et al., 2011). For example, BAS subscale scores have been associated with substance use and addiction (e.g., Pardo et al., 2007; Keough & O'Connor, 2014) and BIS subscale scores have been associated with internalizing problems (e.g., Vervoort et al., 2010). Youth completed the BIS/BAS scales at baseline. The BIS/BAS scales included 20 items with four response options ranging from 0 (Not true) to 3 (Very true). Factor analytic studies identified four stable subscales: inhibition (worry, fearfulness), drive (intensity of goal directed behaviors), reward responsiveness (excitement over positive reinforcement), and fun-seeking (desire for new rewards; Pagliaccio et al., 2016). Higher scores indicated increased presentation of behavioral inhibition or approach. See table 2 for descriptive statistics for each subscale.

Behavioral impulsivity

The Urgency-Premeditation-Perseverance-Sensation Seeking-Positive Urgency (UPPS-P) scale is a self-report measure of impulsivity (Zapolski et al., 2010). The version used in the ABCD study was an abbreviated form, shortened from 40 items to 20 items in order to reduce participant burden. A preliminary validation study conducted by Watts and colleagues indicated that the modified form of the UPPS-P demonstrated excellent structural validity and external validity; internal consistency of each subscale was also acceptable (2020). Youth endorsed items on a 4 point scale, ranging from 1 (Agree Strongly) to 4 (Disagree Strongly). Higher scores on the UPPS-P indicated higher impulsivity. The UPPS-P has five subscales to represent multiple dimensions of impulsivity including lack of premeditation (difficulty planning ahead), lack of perseverance (inability to sustain motivation to complete tasks), sensation seeking (drive to seek novel experiences), negative urgency (acting without thinking when upset) and positive urgency (acting without thinking when excited); subscale scores ranged from 4 to 16 (Barch et al., 2018). See table 2 for descriptive statistics.

Substance use

To measure substance use, youth participated in an extensive series of interviews with a trained research assistant during the year three follow up visit (Lisdahl et al., 2018). To reduce exposing youth to novel substances, youth were first asked if they have heard of certain substances. Gating procedures were used such that follow up questions were only presented after certain questions were answered positively. Knowledge of a given substance triggered questions regarding quantity

and frequency of substance use since their last visit. A range of substances were evaluated including alcohol, nicotine, and marijuana. Due to the low rates of endorsement of substance use across the range of classes (e.g., alcohol, nicotine, stimulants, etc.), a binary composite variable was computed to describe participants who have never engaged in substance use or engaged in any level of substance use; this approach is consistent with other studies examining ABCD data (e.g., Pelham et al., 2021). See Table 3 for specific substance use patterns.

Dimensional mental health

Dimensional measures of psychopathology were assessed with the Brief Problem Monitor (BPM; Achenbach et al., 2011). Participants completed this measure at the three year follow up. The BPM has also demonstrated strong test-retest reliability, internal consistency, and criterion validity in a nationally representative sample of children in the United States (Achenbach & Rescorla, 2001). The BPM is a 19-item measure that captures broadband psychopathology in multiple domains, including internalizing and externalizing concerns. Participants rated each item on a three point scale ranging from 0 (Not True) to 2 (Very True). The BPM was developed as a short-form of the Child Behavior Checklist and parallel Youth Self Report using item response theory and factor analysis (Chorpita et al., 2010). The BPM yields one total problems score, as well as three subscale scores: internalizing problems, externalizing problems, and attention problems. Raw scores were used in analyses per developer recommendation (Achenbach et al., 2011). See Table 4 for detailed response patterns.

Peer functioning

To assess peer experiences, participants completed the Revised Peer Experiences Questionnaire (RPEQ; Prinstein et al., 2001). The RPEQ is an 18-item measure that examines both self-reported peer aggression and victimization. Participants rated the frequency of events occurring in the past two months using a 5-point scale ranging from 1 (Never) to 5 (A Few Times a Week). Subscale scores to assess overt and relational aggression as well as overt and relational victimization were calculated. Higher subscale scores indicated greater experiences with aggression or victimization. The RPEQ has demonstrated acceptable levels of reliability and convergent validity in youth (La Greca & Harrison, 2005; De Los Reyes & Prinstein, 2004). See Table 4 for detailed response patterns.

Chapter 3: Data analytic plan

Aim 1: Model estimation

To address the first aim, a LCA was conducted in Mplus Version 7.4 (Muthén & Muthén, 2015). LCA uses categorical, ordinal, or continuous variables to identify groups of participants according to similar patterns of indicator variables (McCutcheon, 1987). Models are tested in an iterative fashion (i.e., testing incrementally increasing estimated class size), such that the absolute and relative fit of each model is calculated to determine if the model serves as a parsimonious solution to the data (relative to other model solutions), with lower estimates of information criterion statistics (e.g., Akaike Information Criterion [AIC], Bayesian Information Criterion [BIC]) indicating greater parsimony (Raftery, 1986). LCA solutions yield estimates of probability of participant assignment to classes (McCutcheon, 1987). Six indicator variables were selected: three SAD symptoms derived from the KSADS (i.e., fear of social situations, avoidance of feared social situations, fear of embarrassment), and dichotomized scores of EF (i.e., TLSWMT, DCCS, TF).

Preliminary examination of the sample revealed low base rates of SAD diagnoses as calculated by the KSADS-Comp (i.e., less than 1%, Table 5). Because applying a LCA model to a sample of socially anxious participants would be underpowered to detect variation, the LCA was applied to the entire sample. By including all participants, including those who do not endorse any SAD symptoms, there is potential to compare "clinical" classes (i.e., classes characterized by SAD

symptoms) with "control" classes (i.e., classes characterized by the absence of SAD symptoms). These comparisons can clarify whether meaningful differences between "clinical" groups and "control" groups are observed. Furthermore, rates of endorsement of current SAD symptoms were also relatively low, ranging from 0.7% to 1.5% (Table 5), To further enhance our ability to detect effects, SAD indicators included both present and past endorsement of SAD symptoms. Taken together, if support for a particular class solution is identified, this approach would capture variation in the experience of SAD symptoms and EF within a non-clinical sample.

Given the influence of sex, race, and household income on the development of EF as well as SAD symptoms (e.g., Holochwost et al., 2016; Ready & Reid, 2019; Rhoades et al., 2011), these covariates were included in the model as auxiliary variables to determine whether these variables significantly predict class membership. Multinomial logistic regression coefficients were calculated accordingly, with the latent classes considered as dependent variables and covariates as predictor variables. These coefficients (e.g., odds ratios) were used to examine differences in class membership according to the selected covariates (Nylund-Gibson & Choi, 2018). Including covariates as auxiliary variables can prevent changes in class estimation and reduce error and bias in parameter estimates, compared to including covariates into the latent class measurement model (Nylund-Gibson et al., 2014, 2019).

Per recommendations for best practices, model fit was evaluated according to theoretical relevance, as well as the following fit indices: sample size adjusted Bayesian Information Criteria, Lo-Mendell Rubin likelihood ratio test (LMR-LRT), and Bayes factor (BF). Simulation studies indicate that the sample size adjusted BIC

is superior to BIC when sample sizes are smaller (Chen et al., 2017). Lower BIC values indicate better model fit. The LMR-LRT determines whether there is a statistically significant improvement in fit between neighboring class models (i.e., comparing k class model to a model with k-1 classes); a nonsignificant p-value for a k class model indicates support for the k-1 class model (Nylund et al., 2007). Additional fit indices are reported to demonstrate model quality, including entropy. Entropy values range from 0 to 1, and greater values suggest greater classification accuracy.

LCA assumes independence of observations (McCutcheon, 1987); however, the sampling strategy violated this assumption because eligible participants were located within a reasonable travel distance from a study site, thus resulting in geographic clustering of observations. To account for the non-independence of data, LCA models were estimated using TYPE = COMPLEX, which adjusts standard errors and fit statistics using the Hubert-Sandwich estimator (Muthén & Muthén, 2015).

Aims 2 and 3: Construct validity and distal outcomes

The manual form of the Bolck-Croon-Hagenaars (BCH) method was used to examine the relation between latent class membership and external criterion variables (i.e., baseline and follow up measures; Asparouhov & Muthén, 2021). The BCH method is a stepwise approach in which the LCA model is first estimated without the inclusion of covariates or outcome variables (Nylund-Gibson et al., 2019). Next, individuals were assigned to the latent class for which they had the highest posterior probability. Multinomial logistic regressions were then calculated, such that assigned

classes were used as predictors of the external criterion variables. The individual level error rates were used as weights in the analytic model to correct for misclassification errors (Bakk & Kuha, 2020). The multinomial logistic regression yields beta coefficients when predicting continuous outcomes and class-specific intercepts for predicting categorical outcomes; Wald's Chi-square test was used to determine whether these parameter estimates variedly significant differences were observed across classes for a given external criterion variable. Covariates were also included to control for their influence on prediction of outcome variables. The BCH method has been shown to outperform other methods for predicting distal outcomes (Asparouhov & Muthén, 2021).

In sum, to test construct validity of the latent model, estimated classes were used to predict baseline measures of impulsivity (UPPS-P) and behavioral inhibition and behavioral approach (BIS/BAS). To examine distal outcomes, estimated classes were used to predict Year 3 measures of substance use, internalizing and externalizing problems (BPM), and peer functioning (RPEQ).

Chapter 4: Results

Preliminary analyses

Point biserial correlations between SAD symptoms and performance on EF measures were conducted to examine potential relation between proposed indicators (Table 6). SAD symptoms were strongly and positively correlated with one another. Similarly, measures of EF performance were positively correlated with one another. SAD symptoms and EF performance were generally correlated, albeit weakly, in the negative direction. Notably, TF performance was not significantly correlated with any SAD symptom.

A multinomial logistic regression was also calculated to examine whether individual SAD symptoms predicted later substance use. The model was not statistically significant, χ^2 (4) =4.919, p = 0.296.

Model estimation

LCAs were conducted using Mplus Version 7.4 (Muthén & Muthén, 2015). A total of six observed indicators were entered into the model which included experience of three SAD symptoms derived from the KSADS (i.e., fear of social situations, avoidance of feared social situations, fear of embarrassment), and three dichotomized scores of EF (i.e., TLSWMT, DCCS, TF). One through five class solutions were evaluated.

The data was best characterized by a four class solution (see Table 7). The

model did not show any further improvement in evaluation criteria with the addition of a fifth class (see Table 7). The four class solution had a lower adjusted BIC value than the three class solution or five class solution as well as satisfactory entropy. Finally, absolute fit statistics did not reach significance, suggesting a four class solution was consistent with response patterns found in the data. However, the BLMR-LR did not reach significance for the four class solution, instead indicating support for a three class solution. When disagreement among fit indices is observed, best practices suggest favoring the BIC, which is considered the more accurate fit statistic for detecting the true number of classes (Weller, Bowen, & Faubert, 2020); this lends support for the four class solution.

Selecting a class solution also depends on examining the fit indices alongside interpretability (Weller, Bowen, & Faubert, 2020). That is, a solution is considered interpretable when most of the conditional probabilities are close to either 0 or 1; conditional probabilities that are "medium-sized" (i.e., around .5) are difficult to interpret because individuals in this class do not clearly belong to one class or another. In this case, the four class solution outperformed the three class and five class solutions. Furthermore, the mean assignment probability for the four classes (0.871) was well above Nagin's (2006) 0.70 cutoff.

Class 1, labeled "Combined Impairment" (CI; n = 146; 1.5%), was a class characterized by a relatively high probability of social anxiety symptom endorsement (i.e., fear of social situations and embarrassment) and poorer performance on TLSWMT and DCCS. Class 2, labeled "Social Anxiety Impairment" (SAI; n = 390; 3.9%), was a class characterized by high probability of social anxiety symptom

endorsement, but low probability of EF impairment. Class 3, labeled "No Impairment" (NI; *n* = 8014; 79.4%), was a class characterized by a low probability of both social anxiety symptom endorsement and relative EF impairments. Class 4, labeled "EF Impairment" (EFI; *n* = 1540; 15.2%) was a class characterized by low probability of social anxiety endorsement, with high probability of relative EF impairments (i.e., poorer performance on TLSWMT and DCCS). See Figure 3 for estimated probability plots of each class. See Table 8 for overall frequencies of indicators across the four classes.

Covariate effects

To examine class differences in sex, race, and household income, these variables were included as covariates during model estimation. Household income and race variables were recoded into dummy variables to allow for comparisons across all possible levels of income and race.

Differences in sex. When using the NI class as the reference class, sex was a significant predictor of class membership for the CI and EFI classes (p <.000), such that males were more likely to be in the CI class (Odds Ratio = 0.35, 95% CI = [0.323, 0.674]) and the EFI class (Odds Ratio = 0.506, 95% CI = [0.323, 0.674]).

Differences in race. When using the NI class as the reference class, race was a significant predictor of class membership for the CI, SAI, and EFI classes (p <.000), such that White participants were more likely to be in the CI class (Odds Ratio = 2.17, 95% CI = [1.54, 3.06]), the SAI class (Odds Ratio = 1.39, 95% CI = [1.13, 1.71]) and the EFI class (Odds Ratio = 2.34, 95% CI = [2.03, 2,79]).

Differences in household income. When using the NI class as the reference class, household income was a significant predictor of class membership for the CI, SAI and EFI class (p <.000), such that high income participants were more likely to be in the CI class (Odds Ratio = 2.69, 95% CI = [1.47, 4.95]), SAI class (Odds Ratio = 1.36, 95% CI = [1.02, 1.82]), and the EFI class (Odds Ratio = 2.60, 95% CI = [2.013, 3.37]).

Construct validity

To address aim 2, construct validity of the four class solution was examined by analyzing mean differences in behavioral inhibition, behavioral approach, and impulsivity across classes using the manual BCH approach to control for race, sex, and SES. Table 9 describes the results of these analyses, including predicted means and significance testing.

Behavioral inhibition. Omnibus testing indicated significant differences in BIS scores across the four classes, (χ^2 (3) =53.296, p<.0000). The NI class had the lowest mean BIS score, which was significantly lower from the CI class and the SA class (p's <.0000).

Behavioral activation. Omnibus testing revealed no significant differences in Reward Responsiveness (χ^2 (3) =3.457, p=.3264). Significant differences in Drive were identified in omnibus testing (χ^2 (3) = 111.445, p<.001); the NI class had the lowest mean Drive score, which significantly differed from the EFI class (p <.0000). Fun-Seeking was also significantly different across classes (χ^2 (3) = 30.869, p<.0000), with the NI class having the lowest mean. This class was significantly lower than the SAI class (p <.0001).

Impulsivity. The UPPS-P was used to measure impulsivity. Omnibus testing revealed no significant differences in Planning (χ^2 (3) =3.443, p=.3283), Sensation Seeking (χ^2 (3) =5.204, p=.1574), or Perseverance (χ^2 (3) =10.151, p=.0173). In contrast, differences in Negative Urgency were identified (χ^2 (3) = 48.932, p <.0000); the NI class had the lowest mean and was significantly lower than the CI and SAI classes. Positive urgency also differed among the classes (χ^2 (3) = 40.313, p <.0000); the NI class had the lowest mean and was significantly lower than the SAI and the EFI classes.

Attrition analyses

Preceding examination of aim 3, descriptive analyses of participants lost to follow-up were conducted in SPSS version 27. The group of participants who returned to follow-up differed significantly from the participants that were lost in terms of sex (χ2(2) = 166.981, p <.001), racial background (χ2(5) = 348.120, p <.001), and household income (χ2(2) = 56.089, p <.001). Significant differences in SAD were also detected across groups, (χ2(2) = 167.564, p <.001). The groups also differed significantly in terms of EF performance, such that participants at follow up tended to have higher average scores on TF (t(6863.169) = -4.944, p < .001), TLSWMT (t(8181.948) = -7.631, p < .001), and DCCS (t(7931.01) = -3.406, p < .001).

Prediction of distal outcomes

To address aim 3, class differences in distal outcomes (i.e., substance use, psychopathology, peer relationships) measured at Year 3 were examined with the manual BCH approach to include covariates (Table 10).

Substance use. Omnibus testing revealed no class differences in frequency of substance use behaviors ($\chi^2(3) = 4.278$, p=.233).

Psychopathology. Omnibus testing revealed no significant differences in mean externalizing symptoms across classes ($\chi^2(3) = 9.701$, p <.0213). Internalizing symptoms were significantly different across classes ($\chi^2(3) = 20.817$, p <.0001). Although the CI class presented with the highest mean, no significant differences across classes were detected with the corrected Bonferroni p-value (p's from .0022 to .799).

Peer relationships. Omnibus testing revealed no significant differences in mean scores of overt aggression ($\chi^2(3) = 3.421$, p =.3311) or relational aggression ($\chi^2(3) = 12.971$, p = .0047). Similarly, there were no differences in overt victimization ($\chi^2(3) = 7.839$, p <.0495) or relational victimization ($\chi^2(3) = 8.343$, p <.0394).

Chapter 5: Discussion

Main findings

This study was one of the first to explore heterogeneity SAD symptoms in non-clinical sample of early adolescents, by examining the role of EF.. Within data collected from the ABCD study, we evaluated a latent class analytic model using three core symptoms of SAD and three measures of inhibition, working memory, and cognitive flexibility. We also tested whether our model demonstrated construct validity with related domains including behavioral inhibition and activation as well as impulsivity. Finally, we examined the utility of this model in predicting later measures of substance use, psychopathology and peer relationships in early adolescence.

Several findings were observed. First, an exploratory LCA approach identified support for a four class solution of the experience of SAD symptoms and EF in a sample of early adolescent participants. The largest class demonstrated low probability of any past or present SAD symptom endorsement or current EF impairment. Next, we found subgroups that demonstrated elevated probability of experiencing SAD symptoms alone, or elevated probability of EF impairment alone. Finally, we observed a subgroup that demonstrated elevated probability of both experiencing SAD symptoms as well as EF impairment.

We also observed that class membership was predicted by key demographic variables, including sex, race, and household income. That is, most participants in

each class were White, male, and upper SES. This finding may be related to characteristics of the sample. A closer look at the participants who remained at the time of follow up revealed a similar pattern; that is, most individuals were White, male, and upper SES at time 2. Future work should consider exploring whether this pattern is both clinically meaningful and consistent in samples with greater representation of demographic characteristics. Further discussion of this finding can be found below in Limitations.

Our model was partially supported by tests of construct validity; that is, classes were significantly different on measures of behavioral inhibition, domains of behavioral activation (i.e., drive, fun-seeking), and domains of impulsivity (i.e., negative urgency, positive urgency). Prediction of distal outcomes was generally null: we found that classes were only distinguished from one another on measures of later internalizing symptoms of psychopathology. Notably, the classes were not meaningfully different from one another on measures of later substance use, externalizing symptoms, or peer relationships.

Research and clinical implications

This study has important implications for future research and clinical work. Most notably, there may be several avenues to explore for understanding why generally, the proposed model did not demonstrate statistically significant relations with future outcomes of interest. Regarding predictions of substance use outcomes, this is likely related to characteristics of the sample. Indeed, in this non-clinical sample, the presence of past or present symptoms of SAD were low. Similarly, rates of later substance use were also low. Taken together, the restricted range of these

variables limits our ability to detect patterns of heterogeneity. Future work should consider identifying a sample with greater variation in SAD symptoms and substance use to enhance our understanding of these two variables. See limitations for further discussion of the implications of the sample characteristics.

At the level of model construction, selected indictors of working memory, cognitive flexibility, and inhibition were included as representatives of a higher order construct of EF consistent with the tripartite model (Miyake et al., 2000). Indeed, this model of EF has been supported across development and study samples (e.g., Best & Miller, 2010; Friedman et al, 2016). However, some studies have also failed to replicate this structure with more youthful populations (van der Ven et al., 2013). Because EF as a cognitive domain is quite heterogeneous as well, alternative models are worth consideration. For example, research has found support for a model that identifies a unitary, or common EF factor, which serves as a broadband control mechanism, in addition to the individual components (Miyake & Friedman, 2012). In fact, one study has found that the common EF factor was predictive of substance use behaviors in later adolescence, over and above the individual components (Gustavson et al., 2018). Considering that only two of the three EF indicators in the model demonstrated variation, the current study may be consistent with this line of thought, that highlights the importance of capturing the broadband factor of EF, rather than specific domains. Future work should explore the contrast between a more modular style of EF measurement, alongside a more global variable of EF when modeling SAD heterogeneity and predictors of substance use.

A second way to structure EF involves "hot" and "cold" dimensions, which describes EF processes that are mobilized in either emotionally salient contexts (i.e., hot) or more neutral situations that are decontextualized from social or affective factors (i.e., cold; Zelazo & Carlson, 2012). Cold EF skills may include working memory, inhibition, and cognitive flexibility. Hot EF skills include decision making in uncertain situations, delay of gratification, and perception of emotions in others (Garcia et al., 2021). Importantly, work has failed to identify support for cold EF skills relating to substance use patterns (e.g., Groenman et al., 2015). Furthermore, additional work has found that impairments in hot EF skills are strongly associated with inattentive-overactive behaviors, while cold EF skills are uniquely associated with academic achievement in an early childhood sample (Willoughby et al., 2011). Similar trends were observed in an adolescent sample as well, such that impairments in hot EF skills in adolescence are associated with emotional problems (Poon, 2018). Additional work has found that cold EF skills improve earlier in childhood, while hot EF skills improve more gradually and later in adolescence (Poon, 2018; Principe et al., 2011). Considering that the current study used traditionally cold EF tasks, variation in performance may have been limited, due to the steeper and earlier trajectory of improvement in this age group. Importantly, cold EF may not exert influence on risk taking behaviors; indeed, adult work has found that individuals with substance use disorders demonstrate poor performance on hot EF tasks (Bartzokis et al., 2000; Bechara & Damasio, 2002). Future work should consider inclusion of more emotionally activating tests of EF to understand whether this alternative model is more likely to be associated with adolescent substance use behaviors.

Despite the many null findings, this model was associated with concurrent measures of positive and negative urgency. Urgency, as a component of behavioral impulsivity, describes the tendency to act quickly and without planning (Anestis, Selby, & Joiner, 2007). Negative urgency refers to rash decision making when experiencing negative emotional states (e.g., distress, anger, fear); in contrast, positive urgency refers to rash decision making in response to emotions such as happiness or joy (Billieux et al., 2021). The observation of our model relating to these facets of impulsivity is particularly interesting for several reasons. In young adult samples, increased urgency is associated with a variety of maladaptive behaviors including drinking to cope (Anestis, Selby, & Joiner, 2007). Recent work has also identified that the combination of elevated anxiety and elevated urgency is associated with risky sexual behaviors, cannabis use, and alcohol problems in young adult samples (Keough, et al., 2018; Menary et al., 2015; Rahm-Knigge, Prince & Conner, 2018). Importantly, work with early adolescents found that negative urgency mediated the relationship between social anxiety symptoms and expectations towards alcohol use (Marmorstein, 2016). Work has also found that increased negative urgency is associated with increased generalized anxiety disorder symptoms, as well as increased threatening interpretations of ambiguous social situations in adults (Malivoire et al., 2019a; Malivoire et al., 2019b). Taken together, these findings highlight the importance of urgency as a relevant trait in variation of social anxiety and deleterious outcomes. Given that the behavioral trait of urgency is related yet still distinct from facets of EF, future work should consider whether variation in urgency

may co-vary in adolescent social anxiety, alongside measurements of EF, in efforts to predict substance use related outcomes.

Furthermore, our model was able to significantly predict one of several future outcomes: internalizing pathology. This finding is consistent with a longstanding body of work that suggests that childhood experiences of social anxiety are associated not only with future social anxiety but with other internalizing concerns as well. Recent work has found that childhood symptoms of SAD serves as a risk factor for future diagnosis of depression in adolescence (Guidetti et al., 2024). Taken together, these findings signal that even in late childhood, identifiable risk factors for future negative outcomes are instantiated. Indeed, one study found that children younger than 11 years who are diagnosed with SAD are at increased risk for depression later in adulthood (Beesdo, Bittner, & Pine, 2007). Future work should examine the extent to which this model predicts outcomes beyond early adolescence; that is, does such a framework identify which children are at risk for developing internalizing concerns in later adolescence or even adulthood? Of note, our SAD indicators collapsed across past and present. This suggests that children who previously experienced symptoms but are not currently endorsing these experiences are still at risk for future internalizing problems. As such, these children warrant continued clinical monitoring, beyond returning SAD related concerns. Clinical monitoring is especially meaningful in SAD populations, given that by adulthood, most individuals with SAD are not seeking treatment (Grant et al., 2007).

This study also introduces a unique question for future consideration of clinical applications. In the context of our current treatment practices of SAD,

cognitive behavioral therapy (CBT) is well supported in the treatment of childhood SAD (Scaini, et al., 2016). CBT typically includes components related to cognitive restructuring, a skill that relies on using flexibility to address maladaptive thoughts and inhibition of any urges to avoid potentially frightening social exposures (Herbert et al., 2009). The current study emphasized the utility of our model in the prediction of negative outcomes. However, should future studies replicate support for this model, additional work should also examine the extent to which treatment outcomes are meaningfully associated with classes in this model. Additionally, bodies of work have previously highlighted the role of the school context in both social anxiety and EF. That is, social anxiety symptoms may be elicited by negative performance or peer experiences at school (Blöte et al., 2015). The current study found peer experiences of aggression or victimization were not predicted by the model. Yet little is known about how this model may relate to other aspects of social functioning including loneliness or social competence. EF is also strongly linked to academic achievement outcomes (e.g., Titz & Karbach, 2014). As such, when extending this model with a school context in mind, understanding academic success or impairment will also be key in future work.

Limitations

The findings of our study should be interpreted with the following limitations in mind. Below we discuss the implications of construction of the ABCD study, impact of attrition, and measurement of key constructs in tempering the conclusions drawn from this study.

Sample characteristics.

Participants in the ABCD study were recruited at ages 9 and 10. The age of this baseline sample can be useful in understanding trends of early emergence of psychopathology more broadly. Furthermore, specific to our aims surrounding SAD, pre-adolescent children are indeed being diagnosed with SAD and receiving subsequent intervention (Hirshfeld-Becker et al., 2010), suggesting this age group warrants a closer look. However, as mentioned earlier, examination of the sample found an overall low manifestation of SAD symptoms. This low prevalence is consistent with longstanding SAD research that indicates the typical "spike" in SAD symptoms occurs later in adolescence (e.g., age 14; Kessler et al., 2005). Similarly, the follow up wave of substance use behavior data was collected at age 12, also yielding a low base rate of any substance use behavior at all. Again, substance use behaviors have been documented as early as age 12, but tend to increase later in adolescence as well (Dodge et al., 2009; Kaplow, Curran, & Dodge, 2002). Although using these time points improves our ability to understand the development of early trends towards variation in SAD, EF, and substance use in a more nationally representative sample of children, the overall reduced representation of these domains in any form consequently limits our ability to detect patterns of heterogeneity. Future work should consider exploring whether this model of SAD and EF can be generalized to participants more squarely in the adolescent phase of development. Alternatively, regardless of age, examining a sample that is already enriched for problems in SAD, EF, or substance use behaviors (e.g., targeted recruitment efforts

from clinical settings) may allow for higher frequency of these behaviors, and therefore, better capture underlying variation.

Attrition.

Consistent with longitudinal study design, attrition of participants was observed from the baseline sample to the follow up time point. However, attrition was especially high at a nearly 40% loss of participants. Although the study was designed to recruit a sample large enough at baseline that was robust to expected attrition at later waves, the differences in the baseline sample and follow up sample were many. These findings demand consideration. Significant differences included key demographic variables such as sex, race, and household income, as well as measures of our variables of interest (i.e., SAD and EF). Taken together, this prompts the question of whether individuals who were lost to follow up may have experienced barriers related to these differences. That is, did systemic barriers associated with access to resources (i.e., household income) or pervasive experiences of marginalization (e.g., sexism, racism) influence which participants returned for assessment? Alternatively, were participants who were experiencing increased social anxiety or reduced EF skills less represented in follow up samples, due to the functional impacts of their own impairments? Taken together, the sample of substance use behavior data may be limited in its generalizability to the sample that was used to initially construct the model, in part due to significant differences on key variables. In addition to continuing well-powered longitudinal studies, future work should consider cross-sectional designs to augment our understanding of how

variation in SAD and EF may both manifest as a model and relate to concurrent outcomes.

*Measurement of construct***s.**

To accommodate for the complexity of the ABCD study design while also maintaining a broad span of measured variables, many constructs in the study were measured with one instrument or informant. For example, SAD symptoms were assessed through a symptom based measure. This method is useful in determining how participants may meet diagnostic criteria. However, this limits the scope of SAD related experiences that are not necessarily part of diagnostic criteria such as somatic experiences, cognitions related to predicted outcomes, specific beliefs about performance, or avoidance behaviors. Furthermore, this measure was only through self-report; literature suggests that SAD may vary across settings such as school, home, or with peers (Deros et al., 2018; Hur et al., 2020). In sum, soliciting additional informants or leveraging more detailed instruments may provide a rich amount of data that demonstrates variation in SAD experience. In fact, with increased specificity of SAD experience, future work could examine relations between domains of SAD, such as physical, cognitive, and behavioral experiences, and whether this meaningfully co-varies with EF.

EF was also measured with laboratory tasks from the NIH Toolbox, the validity of these measures having been recently established. This approach allowed for samples of multiple domains of cognition, without demanding extensive time that typically is associated with comprehensive evaluations of EF and other cognitive domains. That being said, a body of research has identified disagreement between

performance on laboratory tasks of EF and day-to-day EF (Herbrich et al., 2019; Howlett et al., 2022; Kallweit et al., 2020). That is, empirical work has demonstrated that children may perform well on laboratory tasks of EF, but per self and parent report, struggle with implementing these skills in their typical environment, complete with complex demands. This suggests that not all measures are created equal, in that administration and format may be capturing distinct manifestations of EF. Interestingly, recent work with an adult sample took a two-pronged approach to measuring EF and found that substance use was related to scores on self-report measures of EF, rather than performance measures (Hagen et al., 2016). Future work would benefit from supplementing performance measures of EF with subjective reports from participants and/or caregivers to capture a more comprehensive and ecologically valid assessment of EF. Considering how the instrument of choice may capture a different facet of EF, careful selection of EF measurement will be useful in examining specific relations between EF domains and outcomes of interest.

Similarly, substance use was measured with a detailed interview that assessed a wide span of behaviors and substances. This data was ultimately reduced to a dichotomous variable to improve power to detect effects due to the low base rate of substance use behaviors at the follow up time point. As previously discussed, these findings might relate to the age of the sample; that being said, when examining substance use related constructs in more youth, non-clinical populations, inclusions of measures related to attitudes or beliefs about substances could augment our understanding with antecedents that precede problematic behaviors.

Chapter 6: Concluding remarks

The longstanding link between social anxiety disorder (SAD) and substance use has yet to be fully understood, in part due to the notable heterogeneity in the manifestation of SAD. One model of SAD variation suggests a subtype of SAD that co-occurs with behavioral dysregulation, including impulsivity, anger, and risk-taking behaviors. Examination of this subtype also revealed an understudied area of research; little is known about the cognitive processes that may underlie these behaviors, specifically executive functioning. Because of this, we sought to apply a person-centered modeling approach to the ABCD study in order to test whether variation in social anxiety symptoms was systematically associated with an understudied variable of interest: executive functioning (EF). The ABCD study offered rich opportunity to examine our research question in a large, nonclinical sample and make predictions about future outcomes such as substance use. We identified emerging support for a four class solution that captured variation in experience of SAD symptoms and EF performance (i.e., no SAD symptoms or EF problems, SAD symptoms only, EF problems only, and combined SAD symptoms and EF problems). Demographic variables predicted class membership, and class membership meaningfully differed along behavioral inhibition, activation, and impulsivity. However, the model did not predict future substance use, peer functioning, or externalizing behaviors. We encourage future work to replicate this model with additional samples, including older adolescents, as well as examine alternative means of measuring SAD, EF, and substance use.

Tables

Table 1

Demographics of sample at baseline and Year 3 follow-up

Demographic Characteristic	*Baseline sample (n = 10090)*	*Year 3 sample (n =5384)*
Mean age in months (SD)	119.02 (7.51)	154.93 (7.76)
Sex (%)		
Male	5424 (52.4%)	2797 (52%)
Female	4924 (47.6%)	2857 (48%)
Race (%)		
White	5567(53.8%)	3161 (58.7%)
Black	1400 (13.5%)	505 (9.4%)
Hispanic	2080 (20.1%)	1059 (19.7%)
Asian	220 (2.1%)	133 (2.5%)
Other	1081 (10.4%)	526 (9.8%)
Combined annual household income (%)		
Less than 50 K	2394 (23.7%)	1115 (20.7%)
50 -100 K	2534 (25.1%)	1419 (26.4%)
Greater than 100 K	4212 (41.7%)	2415 (44.9%)
No response	950 (9.4%)	435 (8.1%)

Table 2

Means (Standard Deviations) for Baseline Measures of Inhibition, Activation, and Impulsivity (n = 10090)

Instrument	*Subscale*	*Mean (SD)*
BIS/BAS	BIS	5.54 (2.82)
	BAS: Reward responsiveness	8.82 (2.38)
	BAS: Drive	4.13 (3.05)
	BAS: Fun seeking	5.71 (2.64)
UPPS-P Short Form	Negative Urgency	8.47 (2.64)
	Lack of planning	7.73 (2.37)
	Sensation Seeking	9.78 (2.68)
	Positive urgency	7.96 (2.95)
	Lack of perseverance	7.03 (2.24)

Note. **BIS/BAS** = Behavioral Inhibition and Behavioral Activation Scale; **UPPS-P** = Short Form = Urgency-Premeditation-Perseverance-Sensation Seeking-Positive Urgency Short Form

Table 3

Frequency of Year 3 substance use behaviors (n = 5384)

Substance use endorsement	*n (%)*
Any substance use	729 (13.5%)
Any alcohol use	675 (12.5%)
Any nicotine use	117 (2.2%)
Any marijuana use	47 (0.9%)
Any other drug use (e.g., opiates, stimulants, hallucinogenic, etc.)	10 (0.2%)

Table 4

Means (Standard Deviations) for Year 3 Measures of Psychopathology and Peer Relations
(n = 5384)

Instrument	*Subscale*	*Mean (SD)*
BPM	Internalizing problems	1.92 (2.29)
	Externalizing problems	2.00 (1.92)
RPEQ	Relational victimization	4.67 (1.90)
	Overt victimization	3.51 (1.15)
	Relational aggression	3.89 (1.26)
	Overt aggression	3.22 (0.72)

Note. **BPM** = Brief Problem Monitor; **RPEQ** = Revised Peer Experience Questionnaire

Table 5

SAD diagnoses and symptoms in original sample (n = 11877)

	Diagnosis/Symptom	*n (%)*
Diagnoses	Social anxiety disorder - Present	59 (0.5%)
	Social anxiety disorder - Past	48 (0.4%)
	Other specified social anxiety disorder - Present	73 (0.6%)
	Other specified social anxiety disorder - Past	103 (0.9%)
Symptom endorsement	Fear of social situations – Present	180 (1.5%)
	Fear of social situations – Past	570 (4.8%)
	Avoidance of feared social situations - Present	93 (0.8%)
	Avoidance of feared social situations - Past	273 (2.3%
	Fear of embarrassment – Present	70 (0.7%)
	Fear of embarrassment – Past	375 (3.6%)

Note. **SAD** = Social Anxiety Disorder

Table 6

Point Biserial Correlations of Indicators

Indicator	***1***	***2***	***3***	***4***	***5***	***6***
1. SAD (1)	--					
2. SAD (2)	.69**	--				
3. SAD (3)	.87***	.67**	--			
4. TF	-.02	.01	-.01	--		
5. TLSWMT	-.05**	-.02*	-.05**	.18**	--	
6. DCCS	-.03**	-.001	-.03**	.23**	.24**	--

Note. **SAD (1)** = Fear of Social Situations; **SAD (2)** = Worry Cognitions; **SAD (3)** = Avoidance or Endurance of Feared Social Situations; **TF** = Toolbox Flanker; **TLSWMT** = Toolbox List Sorting Working Memory Test; **DCCS** = Dimensional Change Card Sort; * = p < .05; ** = p <.01; *** = p <.0001

Table 7

Model Fit Indices for One to Five Class Solutions for SAD-EF Profiles

	BIC	Adj. BIC	AIC	BLMR-LR	Entropy	Pearson $\chi2$	Likelihood Ratio $\chi2$
1 class	42588.64	42569.57	42545.32	--	--	82906.59***	5252.85***
2 classes	37763.37	37722.05	37669.52	4815.19***	0.99	580.15***	474.58***
3 classes	**37452.78**	37389.23	37308.4	**369.39*** **	0.74	**111.34*** **	**99.46*** **
4 classes	37458.22	**37372.41**	**37263.29**	58.20	0.78	38.22	40.36
5 classes	37516.90	37408.86	37271.45	5.76	**0.83**	35.22	34.51

Note. **BIC**=Bayesian Information Criterion; **Adj. BIC**=Sample Size Adjusted Bayesian Information Criterion; **AIC**=Akaike Information Criterion; **BLMR-LR**=Bootstrapped Lo-Mendell Rubin Likelihood Ratio. *p<.05, **p<.01, ***p<.001

Table 8

Frequency of indicators within Four Class Solution

Class	**SAD(1)**	**SAD (2)**	**SAD (3)**	**TLSWMT**	**TF**	**DCCS**
CI Class *n = 134*	131 (97.76%)	57 (42.54%)	107 (79.85%)	120 (89.55%)	45 (33.58%)	134 (100%)
SAI Class *n* = 380	380 (100%)	232 (61.05%)	349 (91.84%)	101 (26.58%)	23 (6.05%)	68 (17.89%)
NI Class *n = 8125*	73 (0.9%)	0 (0%)	0 (0%)	1734 (21.34%)	425 (5.23%)	1694 (20.85%)
EFI Class *n = 1451*	0 (0%)	0 (0%)	1 (0.07%)	1241 (85.53%)	459 (31.63%)	1450 (99.93%)

Note. **SAD (1)** = Fear of Social Situations; **SAD (2)** = Avoidance or Endurance of Feared Social Situations; **SAD (3) =** Fear of Embarrassment; **TF** = Toolbox Flanker; **TLSWMT** = Toolbox List Sorting Working Memory Test; **DCCS** = Dimensional Change Card Sort. Also note that N's of each class differ from previously reported due to minor fluctuation associated with probability of assignment.

Table 9

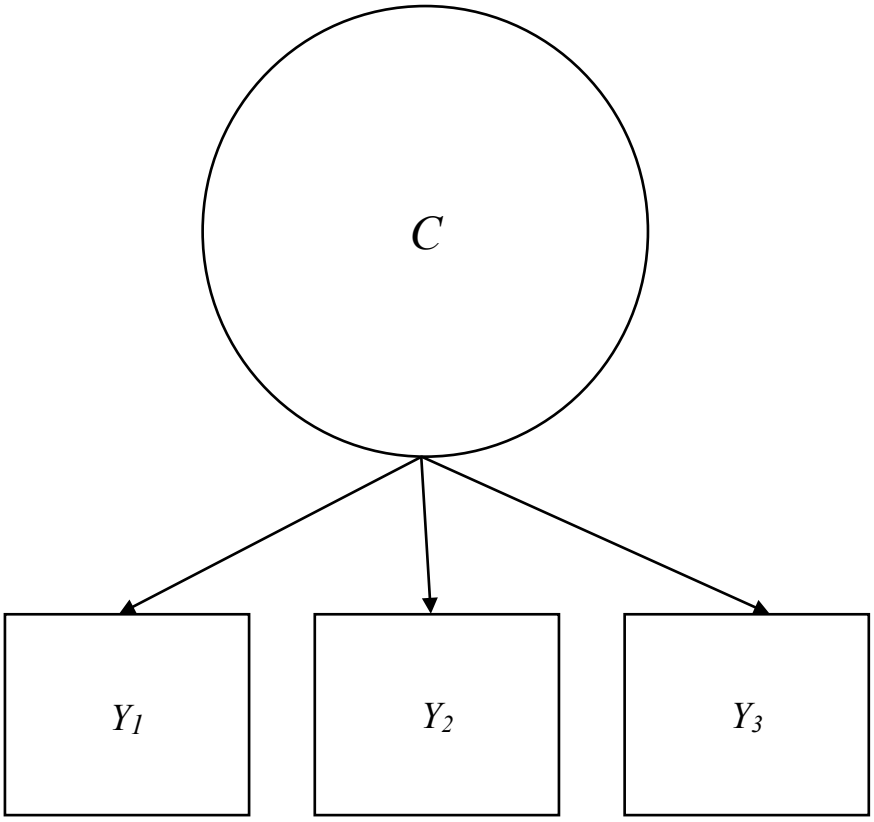
Mean Differences of BIS/BAS and UPPS-P; Estimated Means (Standard Deviation)

Instrument	*Subscale*	*CI Class*	*SAI Class*	*NI Class*	*EFI Class*
BIS/ BAS	BIS	11.88 $(0.52)_{NI}$	11.40 $(0.23)_{NI}$	9.41 $(0.05)_{CI, SAI}$	9.42 (0.18)
	Drive	5.62 (0.39)	4.59 (0.19)	3.83 (0.04)	5.41 (0.15)
	Reward Responsiveness	11.59 (0.33)	11.46 (0.17)	10.91 (0.04)	11.33 (0.14)
	Fun Seeking	6.42 (0.32)	6.39 $(0.17)_{NI}$	5.54 $(0.04)_{SAI}$	6.30 (0.13)
UPPS-P	Negative Urgency	9.94 $(0.32)_{NI}$	9.35 $(0.17)_{NI}$	8.30 $(0.04)_{CI, SI}$	9.04 (0.13)
	Positive Urgency	9.51 (0.37)	8.85 $(0.20)_{NI}$	7.69 $(0.04)_{SAI, EFI}$	9.04 (0.14) $_{NI}$
	Planning	7.43 (0.29)	7.79 (0.16)	7.72 (0.03)	7.82 (0.12)
	Perseverance	8.03 (0.31)	7.03 (0.14)	6.95 (0.03)	7.36 (0.12)
	Sensation Seeking	9.74 (0.36)	9.8 (0.17)	9.84 (0.04)	9.48 (0.13)

Note. **CI** = Combined Impairment; **SAI** = Social Anxiety Impairment; **NI** = No Impairment; **EFI** = Executive Function Impairment; **BIS/BAS** = Behavioral Inhibition and Behavioral Activation Scale; **UPPS-P** = Urgency-Premeditation-Perseverance-Sensation Seeking-Positive Urgency Short Form. Subscript indicates individual z-tests determining which pairwise means significantly differed Bonferroni corrected $p<.0004$ (i.e., a subscript of CI indicates a significant difference from the mean in the Combined Impairment Class, an SAI indicates a significant difference from the mean in the Social Anxiety Impairment Class, a subscript of NI indicates a significant difference from the mean in the No Impairment Class, and a subscript of EFI indicates a significant difference from the mean in the Executive Function Impairment Class.

Figures

Figure 1
Illustration of latent variable and indicator relations



Note. **C** = Latent variable; **Y** = Measured/observed indicators; arrows indicate causality

Figure 2
Sample selection

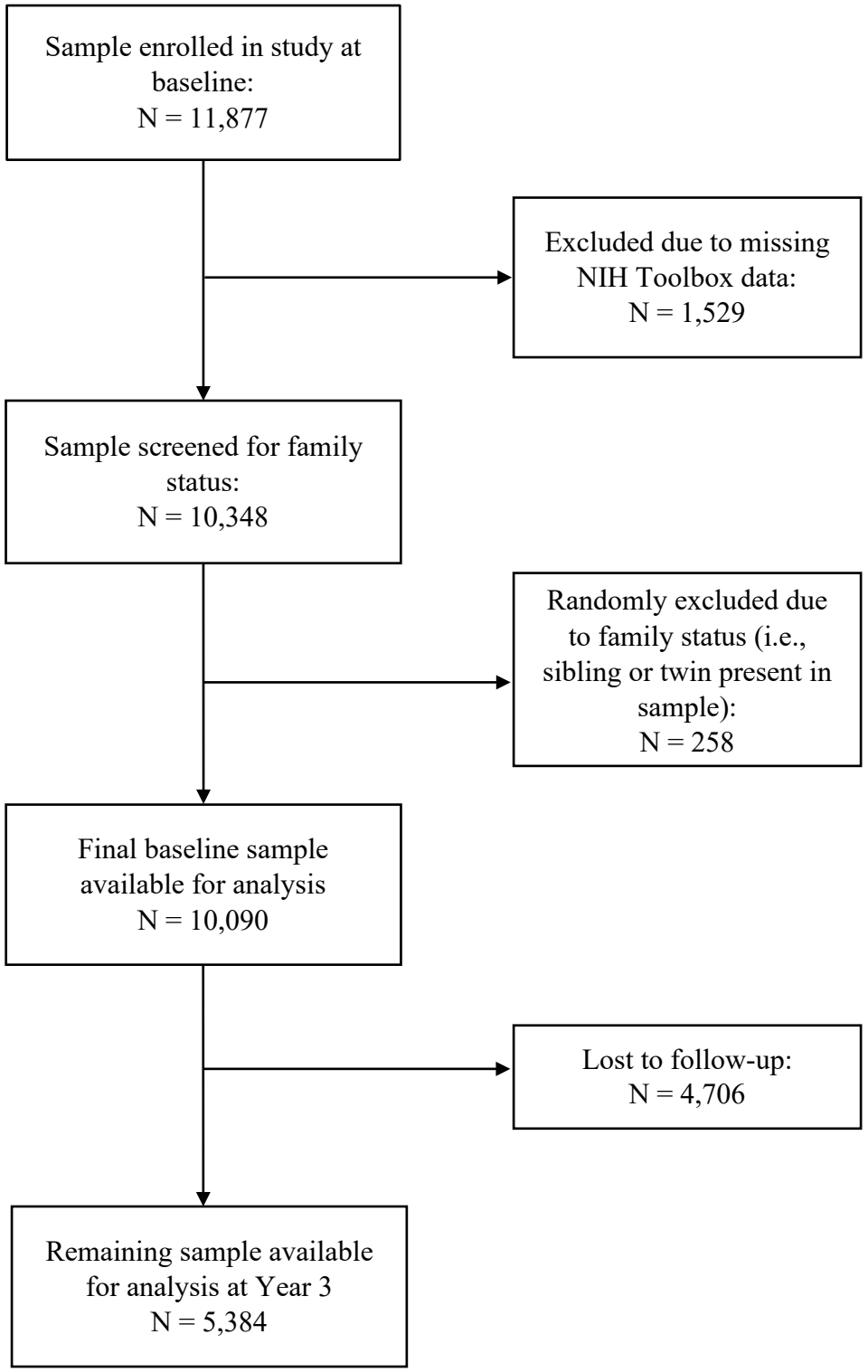
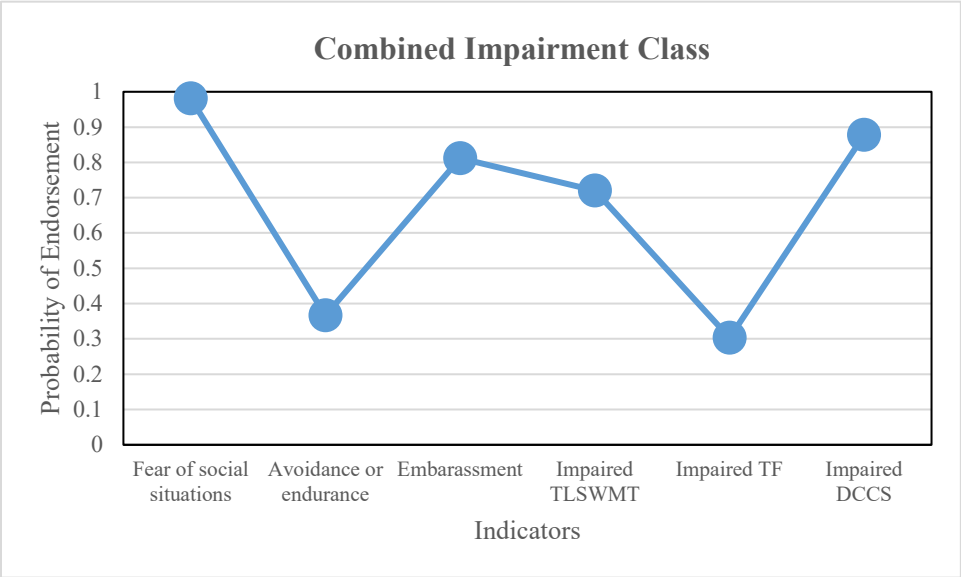
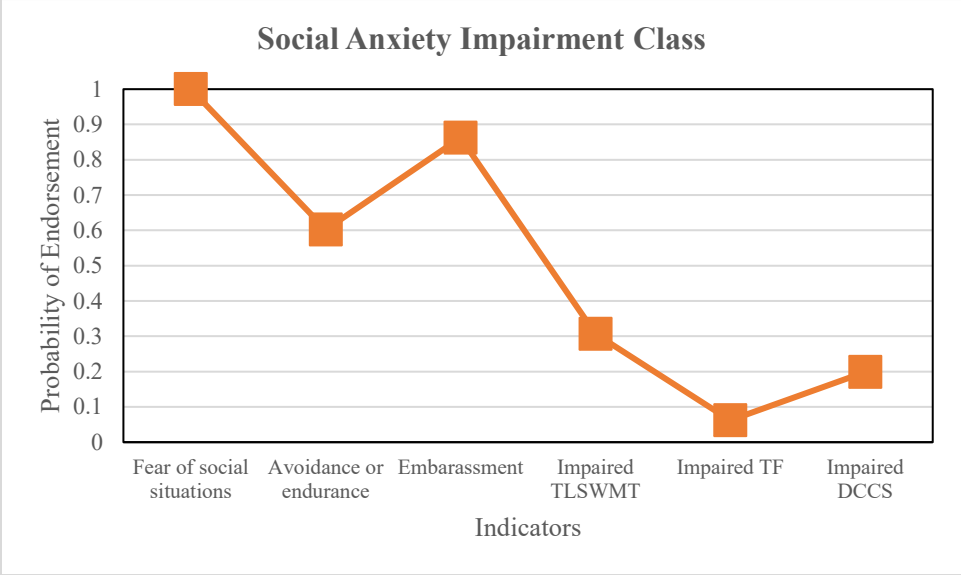
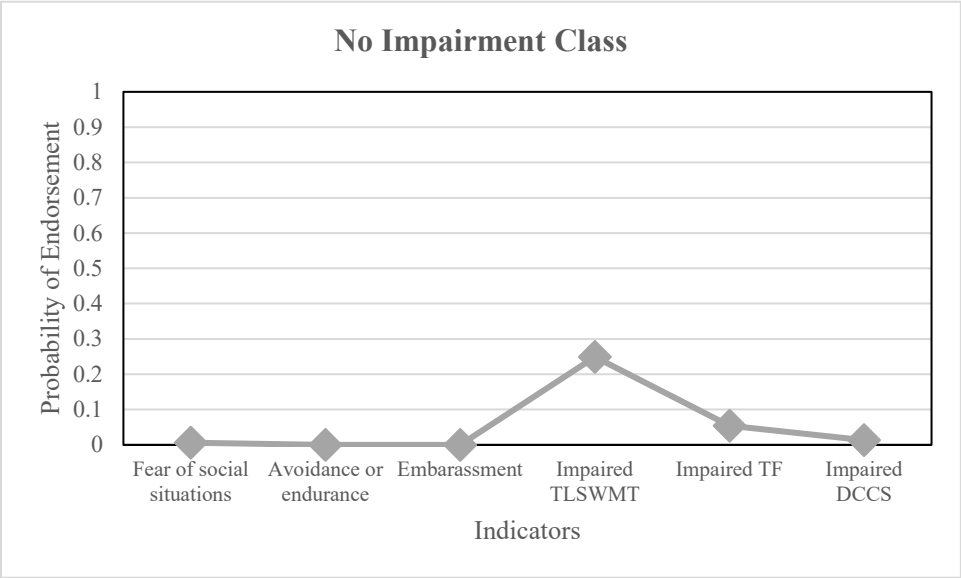
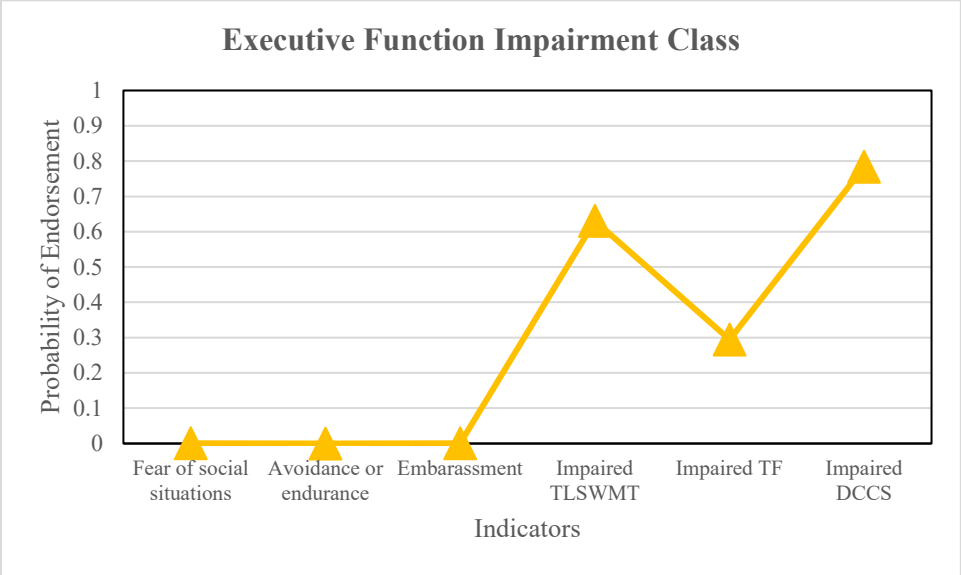


Figure 3
Probability plots of 4 class solution






No Impairment Class
Probability of Endorsement
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Fear of social situations
Avoidance or endurance
Embarassment
Impaired TLSWMT
Impaired TF
Impaired DCCS
Indicators


Executive Function Impairment Class
Probability of Endorsement
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Fear of social situations
Avoidance or endurance
Embarassment
Impaired TLSWMT
Impaired TF
Impaired DCCS
Indicators

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