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Living in the Fast Lane: The Role of Temporal Processing in ADHD Risk-taking Behaviors

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Abstract

Background: Attention Deficit/Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder, prevalent in the college student population, that is associated with temporal processing deficits and functional impairments, namely engagement in risky behaviors (ERB; e.g., binge drinking). An existing theoretical framework purposes that aberrant temporal processing and subjective experience of time passing slowly, experienced in individuals with a fast internal clock (e.g., individuals with ADHD), increases the likelihood of ERB. The primary aim of this project is to improve our understanding of the relationship between objective temporal processing deficits and the subjective experience of time passage among people with elevated ADHD symptoms.

Method: The present study used the Wittmann and Paulus (2008) theoretical framework to examine (a) relationships between objective and subjective temporal processing and ADHD symptoms and (b) associations between these variables and ERB. A novel measure of temporal processing (the Time Management and Estimation Scale, TiME) was revised from a pilot study and assessed via factor analysis and tested for reliability and validity to be used as a predictor variable in subsequent analyses. College student participants (*N*=215) completed measures of current ADHD symptoms, objective measures of temporal processing, ERB, the TiME, and relevant covariates (e.g., delay aversion, impulsivity). Linear regressions analyzed the associations between ADHD symptoms, objective temporal processing, and subjective (self-report) temporal processing, and negative binomial regressions analyzed the associations between these variables and ERB.

Results: Factor analysis indicated a four-factor structure of the TiME. The TiME demonstrated good reliability to be used in subsequent analyses, but validity was only partially established for the TiME. Concurrent validity with the TiME and procrastination, but not objective measures of temporal processing or ADHD, was established. Overall, objective and subjective measures of temporal processing were not significantly associated with ADHD symptoms. ADHD symptom severity and temporal processing self-report were significantly associated with greater engagement in academic risk behaviors (e.g., missing class, not completing assignments). Time estimation accuracy was associated with lower engagement in risky sexual behavior (e.g., condomless sex) and aggressive behavior (e.g., hitting someone). No other significant associations were found between the predictor variables and ERB. The interaction between ADHD symptoms and subjective temporal processing was not associated with ERB.

Discussion: The present study established preliminary evidence for the reliability of a novel self-report measure of temporal processing, yet there was a lack of concurrent validity evidence supporting associations between ADHD symptoms and subjective and objective temporal processing skills in college students. Objective time estimation accuracy was associated with decreased engagement in sexual or aggressive risky behaviors. Future research should continue to investigate if temporal processing deficits are present in college students with ADHD and clinically significant impairments associated with these deficits.

Keywords: ADHD, attention deficit / hyperactivity disorder, time perception, temporal processing, risky behaviors

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Attention deficit / hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by elevated levels of inattention and hyperactivity/impulsivity (Klein et al., 2012; Wood et al., 2021). ADHD is associated with impairments in temporal processing (Nejati & Yazdani, 2020; Zheng et al., 2020) as well as increased engagement in risky behaviors (ERB) (Pollak et al., 2019). ADHD is a highly heterogenous and prevalent disorder, with an estimated 5 - 9.1% prevalence in the general United States child population (Danielson et al., 2018; Visser et al., 2014). Although there is a long history of interest in ADHD, there is still much to be elucidated about temporal processing in ADHD (Weissenberger et al., 2021), the subjective experience of time in ADHD (Weissenberger et al., 2021), and the underlying mechanisms driving ERB in the ADHD population (Pollak et al., 2019). This study aims to improve our understanding of these associations.

What follows is a review of the current literature on the heterogeneity of ADHD including the temporal processing pathway, the variety of risky behaviors (RBs) that are highly correlated with ADHD, a theoretical framework that may explain ERB as a function of aberrant temporal processing in ADHD, and the importance of examining these aspects of ADHD in the college student population.

ADHD in College Students

Once considered to be a childhood-delimited disorder that subsides in adulthood (Hill & Schoener, 1996), more recent literature has detailed the persistence of ADHD symptoms and related impairments into college-aged students. There estimated prevalence of ADHD in the college student population is between 2-11% prevalence (American College Health Association, 2020; DuPaul et al., 2009), and one-quarter of all college students receiving campus disability services have an ADHD diagnosis (DuPaul et al., 2009). Similar to childhood ADHD, ADHD in college students is associated with core symptoms of inattention and hyperactivity/impulsivity as well as associated features of emotion dysregulation and executive dysfunction (DuPaul et al., 2009; Dvorsky & Langberg, 2019a). Importantly, college students with ADHD exhibit functional impairments that include poor academic performance (Arnold et al., 2020; Murphy & Barkley, 2007; Weyandt et al., 2013), occupational difficulties (Goffer et al., 2020), greater psychosocial impairments (Nugent & Smart, 2014; Weyandt & Dupaul, 2008), and a widespread pattern of ERB (Nugent & Smart, 2014). The high prevalence of ADHD in the college population and wide range of significant functional impairments necessitate increased focus on the processes underlying ADHD in college students.

ADHD can be considered both dimensionally (e.g., measurement of ADHD symptoms/characteristics on a continuous scale) and categorically (e.g., ADHD or not ADHD). The use of a dimensional model to ADHD has many merits in research as it permits a more nuanced consideration of the relationships between ADHD symptoms and other study variables (Marcus & Barry, 2011). Because of its ability to capture ADHD on a continuum, some in the field of ADHD research recommend use of the dimensional model in studies (Elton et al., 2014; Marcus & Barry, 2011). In addition to utilizing a dimensional model to study the heterogeneity of college students with ADHD, the Triple Pathway Theory of ADHD (Sonuga-Barke et al., 2010) offers a theoretical basis to understanding the heterogeneity of ADHD in college students.

The Triple Pathway Theory of ADHD

The Triple Pathway Theory of ADHD posits that there are three main pathways that contribute to the heterogeneity of ADHD: the delay averse pathway, the inhibitory control pathway, and the temporal processing pathway (Sonuga-Barke et al., 2010). The delay averse pathway refers to individual responses towards waiting for rewards (e.g., individuals with ADHD exhibit an aversion towards waiting for rewards) (Sonuga-Barke, 2003). The inhibitory control pathway refers to the ability to withhold a prepotent response, and ADHD-related deficits in this pathway are denoted by difficulty in suppressing behaviors or responses (Sonuga-Barke, 2003). The temporal processing pathway refers to one's ability to perceive the passage of time (e.g., individuals with ADHD over-estimate time intervals, indicative of the subjective experience of time passing more slowly) (Sonuga-Barke et al., 2010). Although deficits in these three pathways are common in ADHD (de Zeeuw et al., 2012), delay aversion, inhibitory control, and temporal processing are clearly distinct constructs. According to the Triple Pathway Theory, each of these three domains represent a unique neuropsychological deficit and etiology of ADHD (Sonuga-Barke et al., 2010).

Though possible to display impairments in multiple pathways, which is indicative of greater ADHD severity and functional impairments, the majority of individuals with ADHD exhibit deficits in only one of the three pathways (de Zeeuw et al., 2012; Sonuga-Barke et al., 2010). Since the conception of the Triple Pathway Theory, there has been empirical evidence that delay aversion, inhibitory control deficits, and temporal processing deficits are distinct in ADHD via performance on cognitive tasks measuring these constructs (Coghill et al., 2014; Fair et al., 2012; Sjöwall et al., 2013) and neuroimaging data showing discrete neural underpinnings for the three pathways (Stevens et al., 2018). Despite the strong empirical support for the Triple Pathway Theory of ADHD (de Zeeuw et al., 2012; Fair et al., 2012; Stevens et al., 2018), research has historically focused far more on the delay averse and inhibitory control pathways and much less on the temporal processing pathway (Weissenberger et al., 2021).

The delay averse and inhibitory control pathways are directly related to dimensions of impulsivity – a defining characteristic of ADHD – and were, thus, identified earlier than temporal processing pathway in a predecessor of the Triple Pathway Theory (Sonuga-Barke, 2003). However, temporal processing deficits have been consistently reported in ADHD, and a recent review of the literature argued that temporal processing impairments should be recognized as a focal symptom of ADHD, alongside inattention and hyperactivity/impulsivity (Weissenberger et al., 2021). There is an increased interest in the prevalence and topography of temporal processing deficits in ADHD (Weissenberger et al., 2021), yet the ecological manifestations of these deficits and their clinical relevance are presently far less well known.

The Temporal Processing Pathway

The temporal processing pathway of ADHD broadly refers to the way individuals perceive time (Sonuga-Barke et al., 2010). Temporal processing is a multifaceted construct that includes the estimation of time intervals, discrimination between different time intervals, reproduction of time, temporal self-regulation (e.g., the ability to regulate behavior to manage time), and the subjective experience of time (e.g., how subjectively fast time feels to be passing) (Grondin, 2010). Indeed, temporal processing is a fascinating and complex construct, and the importance of temporal processing is underscored by the centrality of clock time in today's society (e.g., appointments are scheduled for a particular *time*, strict *time* deadlines, managing *time* throughout the day). Aberrant temporal processing is thought to have broad implications for psychopathology (Moreira et al., 2016; Paasche et al., 2019; Zheng et al., 2020) and negatively impacts functioning in everyday situations that require time management skills (Houghton et al., 2011; Labrell et al., 2016). For example, procrastination is an everyday behavioral act that relates to inefficient time management (among other processes, such as intentional delay of a task), which is contingent on completing work by a time-oriented deadline, and thus is related to temporal processing abilities (Francisco et al., 2013). (These clinical and ecological implications of time perception will be discussed in greater detail in a subsequent section below.)

Temporal Processing Theory

A well accepted theoretical model for temporal processing is the attentional-gate model. The attentional-gate model describes temporal processing as a complex process that involves an internal clock (or "pacemaker"), attention, working memory, and decision making skills (Block, 1990; Zakay & Block, 1997). The basis of the attentional-gate theory is derived from the well-accepted scalar expectancy theory (SET) of temporal processing behavior; SET proposes that individuals have an internal clock that generates pulses akin to the ticks of a mechanical clock (Gibbon, 1977). A stimulus that signals the start of a time interval leads to the opening of a gating mechanism to allow the pulses of the internal clock (which represent elapsed time) to come into consciousness skills. When the gating mechanism opens, the pulses are stored in an accumulator, which relies on working memory skills. The accumulation of pulses is processed in working memory and denote elapsed time skills.

The attentional-gate model importantly expands the SET by including an attentional explanation for the gating mechanism (Block, 1990; Zakay & Block, 1997). Stimuli that elicit selective attention to time are more likely to open the gating mechanism to allow for the time pulses of the internal clock to be consciously monitored and create an explicit representation of time duration skills (Block, 1990; Zakay & Block, 1997). For example, an 80-minute in-class exam that must be completed before the end of the class period would draw a college student's attention to time. Yet, many behaviors or events do not necessitate a realistic representation of time (e.g., eating dinner, a party on a Friday night), and therefore, do not open the gates even though the internal clock in still functioning at an unconscious level. As such, the perception of time can be thought of as a trait-construct in terms of the base-speed of our internal clock, though states (e.g., emotional experiences, stimulating activities, conscious attention drawn to time) can open our attentional gates and influence time perception (Di Lernia et al., 2018).

Temporal Processing in ADHD

The integral role of working memory and attention in temporal processing highlights the multidimensional nature of temporal processing (Grondin, 2010) and predicts the occurrence temporal processing deficits in ADHD. Time perception is assessed via tasks that generally fall into one of two paradigms: 1) the prospective paradigm, where the participant is informed that they must make a temporal judgement prior to the presentation of the stimulus (e.g., participants are first instructed that they will be hear a sound and will be asked to estimate its duration, then a sound is presented and they are asked to estimate how long they heard the sound for), or 2) the retrospective paradigm, where the presentation of the stimulus precedes the instructions to make a temporal judgement (e.g., a sound is presented and, after the sound has played, participants are asked to estimate how long they heard the sound for) (Block et al., 2018).

The prospective paradigm requires selective attention to open the gating mechanism as the explicit task instructions prime the individual to estimate, discriminate, or reproduce a time interval (Matthews & Meck, 2016). Attentional deficits are a core feature of ADHD, and greater levels of inattentive symptoms are correlated with greater variability and inaccuracy on prospective temporal processing tasks (Hurks & Hendriksen, 2011). Working memory is implicated in the retrospective paradigm because the explicit cue to estimate or reproduce a time interval is presented following the stimulus (Zakay & Block, 2004). College students with ADHD display significant working memory deficits (Gropper & Tannock, 2009), and performance on working memory tasks and processing speed has been positively correlated with performance on retrospective temporal processing tasks in the ADHD population (Barkley & Fischer, 2019; Walg et al., 2017).

Temporal processing impairments in ADHD are noted across the lifespan and in multiple domains and task types, including duration discrimination (Smith et al., 2002; Valko et al., 2010; Yang et al., 2007), time estimation (Zheng et al., 2020), time reproduction (Nejati & Yazdani, 2020), and everyday time management (Houghton et al., 2011). Cognitive tasks to measure time perception in ADHD typically use auditory stimuli (e.g., auditory time reproduction where an original tone is presented and then a second tone starts and the participant must stop the tone when it lasts for the same duration as the original tone); however, these tasks can also be presented with visual stimuli or involve a motor component (Toplak et al., 2006). Although not yet investigated in college students, higher time discrimination thresholds are seen in children and adults with ADHD, such that they need a greater temporal duration difference to be able to perform accurately on duration discrimination tasks (Smith et al., 2002; Valko et al., 2010; Yang et al., 2007). On tasks of time estimation, individuals with ADHD provide larger and more variable estimations of time (Barkley et al., 2001; Prevatt et al., 2011; Smith et al., 2002; Sonuga-Barke et al., 1998; Walg et al., 2017). Individuals with ADHD commit more errors on time reproduction tasks, and these time reproductions tend to be shorter compared to the actual time duration (Barkley et al., 1997, 2001; Barkley & Fischer, 2019; Smith et al., 2002; Taş Dölek et al., 2021).

Recently, two meta-analyses concluded that the temporal processing deficits in ADHD are persistent, regardless of the modality of stimuli (e.g., auditory, visual) or the task type (e.g., time estimation, time reproduction) (Nejati & Yazdani, 2020; Zheng et al., 2020). Individuals with ADHD consistently commit more errors on temporal processing tasks, over-estimate time intervals, and under-reproduce time intervals (Nejati & Yazdani, 2020; Zheng et al., 2020). Age was shown to moderate temporal processing deficits in youth with ADHD, such that older adolescents with ADHD demonstrated less temporal processing deficits compared to children (Zheng et al., 2020). However, errors in time reproduction and estimation persist into adulthood, even in cases where ADHD symptoms have largely abated (Barkley & Fischer, 2019; Prevatt et al., 2011; Valko et al., 2010). Interestingly, the effects of stimulant medication, the most common medication treatment for ADHD, on temporal processing impairments is inconsistent. Some studies report that methylphenidate reduces variability on time estimation, reproduction, and tapping tasks (Rubia et al., 2003; Toplak et al., 2006) whereas others find no effect of ADHD medication on temporal processing (Barkley et al., 1997; Hurks & Hendriksen, 2011).

Despite the evidence in child and adult samples, to date only one study has examined time perception in college students with ADHD (Prevatt et al., 2011). Prevatt and colleagues (2011) found that college students with ADHD over-estimate time intervals and are less accurate on time estimation tasks compared to their non-ADHD peers. The findings from Prevatt and colleagues (2011) align with the general pattern of temporal processing deficits seen in ADHD, yet more research is needed to solidify the existence and pattern of temporal processing deficits in college students with ADHD.

In sum, across the lifespan, individuals with ADHD tend to display greater variability and less accuracy on temporal processing tasks and, more specifically, over-estimate and under-reproduce time intervals. This pattern of over-estimation and under-reproduction of time intervals signifies that individuals with ADHD have a faster internal clock – indicative of the subjective experience of time passing more slowly (Coghlan, 2009; Rubia et al., 2009). The leading ADHD theory, the Triple Pathway Theory, suggests that temporal processing deficits like those noted above are etiologically relevant to ADHD and the inherent heterogeneity of the condition. However, despite all of the above, temporal processing deficits remain vastly understudied relative to the other two ADHD pathways (delay aversion, inhibitory control), especially in college students.

Likewise, the current gold-standard for assessing temporal processing is cognitive tasks administered in a clinic or research setting (Block et al., 2018). In fact, despite the existence of scales designed to assess the subjective experience of time, *no* extant studies have assessed this dimension of temporal processing in college students with ADHD (Weissenberger et al., 2021). A reliable and valid subjective self-report measure of temporal processing would help further temporal processing research and allow for greater clinical utility via enhanced feasibility. Better understanding the subjective experience of time in ADHD is an imperative step to elucidating how cognitive temporal processing deficits in ADHD impact the everyday experience of time passing and the real-world implications of atypical time perception in ADHD (Di Lernia et al., 2018), including difficulties with meeting deadlines, managing busy schedules, and potentially ERB. The present study is an important incremental first step in this larger programmatic line of research.

Risky Behaviors in ADHD

In addition to temporal processing deficits, individuals with ADHD exhibit a greater likelihood of ERB. RBs are behaviors that, despite a degree of uncertainty in their outcome, have an increased probability of undesirable or harmful consequences (Boyer, 2006). Examples include binge drinking (i.e., ≥ 4 [women] or ≥ 5 [men] drinks over two-hours) (Linden-Carmichael & Lanza, 2018), condomless sex, physical aggression and sex while intoxicated.

Although there is significant heterogeneity in these RBs, each is conceptually linked by the common knowledge that these behaviors pose serious risk in the future (e.g., binge drinking contributes to poor health outcomes), but are also associated with potential reinforcement in the present (e.g., relief from stress when drinking alcohol).

There is substantial evidence in the literature that ADHD is associated with a wide range of ERB throughout the lifetime (Shoham et al., 2019). The transition to college and the developmental period of young adulthood (i.e., age 18-25) is associated with a particularly high rate of ERB in both the general and ADHD populations compared to other developmental periods (Maggs, 1997). College students experience greater autonomy, less parental supervision, and more exposure to similar aged peers. These contextual factors contribute to an increase in ERB during this developmental period (Fromme et al., 1993). Likewise, despite knowledge of potential risks, college students with (Shoham et al., 2016, 2020) and without ADHD (Fromme et al., 1997) both overvalue the potential benefits of ERB, making them most susceptible to ERB. Because individuals with ADHD exhibit increased ERB compared to the general population across the lifetime (Pollak et al., 2019; Shoham et al., 2019) and college students engage in more RBs compared to other life stages (Maggs, 1997), young adult college students with ADHD – the proposed sample for this study – may be at a particularly increased risk for ERB.

One specific RB associated with ADHD that may be of particular concern for college students is problematic alcohol use (e.g., binge drinking, drinking and concurrently using substances). College students with ADHD are significantly more likely to binge drink than college students without ADHD, with research finding a 40-70% greater occurrence of binge drinking in students with ADHD (Baker et al., 2012; Garcia et al., 2020; Mochrie et al., 2020).

Compared to college students without ADHD, those with ADHD are more likely to use alcohol and other substances – especially cannabis – at the same time (Baker et al., 2012; Petker et al., 2021). Importantly, college students with ADHD are also more likely to experience negative alcohol-related consequences, including driving while intoxicated and engaging in unplanned and/or unprotected sex while intoxicated, compared to those without ADHD (Elmore et al., 2018).

Engaging in sexual behaviors that confer greater risks (e.g., condomless sex, sex while intoxicated, casual sex) of poor sexual health outcomes (e.g., sexually transmitted infections [STIs]) is another risky behavior of particular concern to college students with ADHD. Earlier debut of sexual activity, increased occurrence of condomless sex, sex while intoxicated, and greater number of past sexual partners are correlated with ADHD symptoms in adolescents and young adults (Berry et al., 2020; Flory et al., 2006; Huggins et al., 2015; Isaksson et al., 2018). College students with ADHD report greater prevalence of STIs compared to college students without ADHD (Rohacek et al., 2022). Overall, adolescents and young adults with ADHD engage in more sexual behaviors that are likely to confer risk (Berry et al., 2020; Flory et al., 2006; Huggins et al., 2015; Isaksson et al., 2018) and exhibit poorer sexual health (Argenyi & James, 2021; Rohacek et al., 2022) compared to those without ADHD.

One final, notable risky behavior relevant to ADHD in college students is aggressive behavior. Compared to college students without ADHD, those with ADHD are more likely to engage in confrontational aggression (e.g., verbal arguments, physical alterations) in social situations (Weyandt & DuPaul, 2006; Weyandt & Dupaul, 2008), aggressive driving (Richards et al., 2006), and criminal or delinquent activities (Pratt et al., 2002). All of these aggressive behaviors pose physical, social, and legal consequences that are likely to cause harm to the individual, thus making these behaviors risky.

There is clear empirical evidence that ADHD is associated with a wide range of RBs, including binge drinking, aggressive behaviors, and sexual risk behaviors. The increased probability of undesirable or harmful consequences from engaging in these behaviors rightly classifies each as a RB. Despite potentially different motivations for engaging in these specific RBs, these behaviors are all associated with potential reinforcement (e.g., binge drinking or casual sex reinforced by pleasure). Though these principles of operant conditioning may help to conceptually link motivations for ERB, these principles alone do not sufficiently explain the relationship between ADHD and ERB.

Further research is needed to understand the mechanism driving this wide-range of increased ERB in ADHD under a theoretical framework. The Triple Pathway Theory of ADHD identifies inhibitory control, delay aversion, and temporal processing deficits as factors that are etiologically relevant to ADHD and its inherent heterogeneity (Sonuga-Barke et al., 2010). Previous research has identified that inhibitory control deficits and delay aversion link ADHD to ERB, yet temporal processing has not been investigated as related to ERB (Pollak et al., 2018). The present study aims to fill this void and relies upon an existing theoretical framework for understanding potential association between temporal processing deficits and ERB.

Clinical Significance of Temporal Processing Deficits

Although relationships between ERB and temporal processing abilities are unexplored in ADHD, Wittmann and Paulus (2008) provide a theoretical framework for understanding potential association between ADHD and ERB. Though not developed for ADHD, Wittmann and Paulus (2008) propose that aberrant temporal processing abilities lead to impulsive decision making. Highly impulsive individuals (e.g., individuals with ADHD) perceive a subjective slowing in the passage of time (denoted by a fast internal clock, which is a well replicated objective finding in ADHD), and are, therefore, more likely to engage in exciting or stimulating activities (e.g., RBs) to subside boredom or abate the experience of slowed time. Indeed, some in the ADHD field have argued that impulsivity in ADHD is a function of aberrant time perception (Rubia et al., 2009).

Because 1) temporal processing deficits are one of the pathways implicated in ADHD (Himpel et al., 2009; Hurks & Hendriksen, 2011; Sonuga-Barke et al., 2010), 2) individuals with ADHD display a pattern of objective over-estimation and under-reproduction consistent with a subjective experience of time passing slowly (Coghlan, 2009; Zheng et al., 2020), 3) impulsivity is a core feature of ADHD, and 4) impulsive decision-making and ERB are both common in ADHD (Pollak et al., 2018; Shoham et al., 2019), the Wittmann and Paulus (2008) theoretical framework provides a potentially coherent basis for hypothesizing ERB in ADHD to be, in part, a function of aberrant temporal processing.

While not specific to ADHD, the Wittmann and Paulus (2008) framework has been applied to the understanding the relationship between impulsivity and ERB in multiple different forms of psychopathology. Abnormal performance on cognitive tasks of temporal processing, specifically the over-estimation of time intervals, is seen in individuals with substance use disorders (Paasche et al., 2019). A meta-analysis found that individuals with high trait impulsivity (e.g., those with a diagnosis of borderline personality disorder, substance use disorder, or pathological gambling) over-estimate the passage of time (Moreira et al., 2016). Problematic substance use and gambling are prevalent in ADHD (Shoham et al., 2019), as is impulsivity and the over-estimation of time intervals (M. E. Toplak et al., 2006; Zheng et al., 2020). Therefore, the Wittmann and Paulus (2008) framework may be useful to explain the connection between temporal processing deficits and the increased ERB in ADHD. The association between temporal processing deficits and ERB in ADHD warrants exploration as a potential clinically significant consequence of the temporal processing pathway of ADHD. In addition, procrastination is a clinically significant construct that may be related to deficits in the temporal processing pathway of ADHD.

Procrastination

Procrastination refers to delaying tasks that must be completed before a deadline, and procrastination is associated with deficits in time management skills (Francisco et al., 2013), which constitute a facet of temporal processing (Grondin, 2010). Although many factors (e.g., task aversion, motivation, anxiety) contribute to procrastination, poor time management skills, such as the inability to accurately estimate how long a task will take to complete and allocate adequate time for the task, predict procrastination (Häfner et al., 2014; Ocak & Boyraz, 2016). Moreover, ADHD symptoms in adults and college students are positively correlated with rates of procrastination (Ferrari & Sanders, 2006; Niermann & Scheres, 2014), and temporal processing and time management deficits in ADHD may contribute to increased levels of procrastination in this population. As such, procrastination is theoretically related to temporal processing and may serve as a useful variable to study the ecological manifestation or external validity of temporal processing deficits in ADHD.

Although the dimensions of temporal processing have been commonly investigated in ADHD, this literature is *entirely* based on experimental, laboratory-based cognitive tasks. To our knowledge, no studies have examined the self-reported subjective experience of time in ADHD or the potential ecological manifestations of ADHD-related temporal processing deficits in college students. The subjective experience of time is a particularly important dimension of temporal processing given the role it plays on individual interpretation of their connection to and passage of time (Shipp & Jansen, 2021) and its prominence in the Wittmann and Paulus (2008) framework. To advance the field, research is needed to directly measure the subjective experience of time via a valid and reliable self-report measure and elucidate the role of temporal processing deficits in clinically significant outcomes relevant to college students (e.g., ERB).

Existing Time Questionnaires

There is a variety of empirically supported objective laboratory measures (i.e., auditory or visual duration discrimination, time estimation, and time reproduction tasks) used to assess temporal processing deficits, yet these *objective* measures do not provide direct information about the *subjective* experience of time or perception of time in daily life (Block et al., 2018).. Currently, there is a dearth of psychometrically sound questionnaires available to assess temporal processing. The following is a review of the few existing questionnaires that assess temporal processing and related processes, with attention to why a novel self-report instrument is needed for use with college students.

Two instruments designed to measure time perception in children exist, including the Time Knowledge Questionnaire (TKQ) and Salience, Organization and Management of Time Scale (SOMTS). The TKQ measures aspects of children's time knowledge, including knowledge of temporal structures and sequences (e.g., there are 4 weeks in a month), time units, and awareness of important dates (Labrell et al., 2020). The SOMTS is a parent-report measure that expands beyond time knowledge to measure multiple domains of temporal processing in children using three subscales: verbalizing temporal structure (e.g., how often a child talks about the future), temporal self-regulation (e.g., ability to follow deadlines), and conceptualization of time (e.g., understanding units of time) (Houghton et al., 2011). Although these questionnaires have acceptable reliability (Houghton et al., 2011; Labrell et al., 2020) and may be promising tools to measure a child's knowledge of time, the TKQ and SOMTS provide limited information on the subjective experience of time. For example, the items on these questionnaires primarily measure the construct of time knowledge and provide only one item that targets subjective time via retrospective duration estimates. Finally, and importantly, TKQ and SOMTS are both measures developed for children and are not validated for use in the college student population.

The Sorrell-Canu Orientation To Time (SCOTT) is a self-report measure of temporal processing for adults that largely focuses on duration estimation and temporal self-regulation (Sorrell & Canu, 2018). The SCOTT has high face validity for measuring temporal processing (e.g., "I have difficulty estimating how much time it will take me to complete a task") and good internal consistency ($\alpha = .82$) (Sorrell & Canu, 2018). Despite these merits, there is no other information on the psychometrics of the SCOTT, and the measure is not currently being considered for further investigation (Canu, personal communication, March 18, 2021). Moreover, the SCOTT contains items to measure duration estimation and temporal self-regulation in an adult population but does not contain items measuring the subjective experience of time.

The Time Integration Questionnaire (TIQ) was constructed as a measure of the subjective experience of time by combining many dimensions of temporal processing (Drakulić et al., 2003). From its conception, however, the TIQ lacked a theoretical basis and attempted to capture the experience of time from a purely lexical approach – identifying words in the English language used to describe time (Drakulić et al., 2003). The atheoretical nature of this questionnaire is problematic, along with its focus on descriptive and metaphorical language that can be challenging to comprehend (e.g., “My life goes on in insufficiently connected periods”; “I feel that I am of full age”).

The Subjective Time Questionnaire (STQ) was developed to assess the difference in the subjective passing of time between older and younger adults (Wittmann & Lehnhoff, 2005). One subscale assesses personal time experience and asks the participant to rate how slowly time passes on a Likert scale from -2 to 2 (Wittmann & Lehnhoff, 2005). The subjective time experience subscale rates agreement to statements of time expansion (e.g. “I have a lot of time”) and time pressure (e.g. “I haven’t enough time to complete my tasks”) on a Likert scale from 0 to 4 (Wittmann & Lehnhoff, 2005). These questions have a high face validity for measuring the subjective experience of time, but, despite the use of the STQ is several later studies (Mioni et al., 2016; Wittmann et al., 2015), this questionnaire has not been psychometrically validated. Six items on the STQ involve time related metaphors (e.g., “time is a galloping horse”), which may introduce error as individuals interpret metaphors differently or have rigid thinking patterns and fail to understand metaphor, and the use of two different Likert scales on the questionnaire may be confusing. Although some items in the STQ demonstrate high face validity, the use of metaphors, multiple Likert scales, and lack of psychometrics are problematic.

Currently, there is not a psychometrically valid self-report questionnaire that can be used to reliably and validly assess multiple domains of temporal processing, including the subjective experience of time perception, time estimation abilities, and temporal self-regulation in college students. The TKQ only measures one dimension of temporal processing, time knowledge, in children. The SOMTS is a valid measure of temporal self-regulation but, similarly, is intended for use in children and does not measure subjective time experience. The SCOTT is a reliable measure of time estimation and temporal self-regulation for adults, but the SCOTT lacks evidence of validity or a way to assess subjective experience of time. Although the TIQ and STQ specifically measure the subjective experience of time, these measures lack evidence of reliability, rely on metaphorical language, and do not measure time estimation or temporal self-regulation. Moreover, none of these five scales have been tested for concurrent validity with objective, cognitive measures of temporal processing.

In sum, there are benefits to many of these assessments, and the SOMTS, SCOTT, and STQ contain promising items to assess time perception; however, none of the current assessments successfully measure the temporal processing constructs of interest in college students with ADHD. Therefore, there is a need for a psychometrically valid self-report questionnaire to measure multiple domains of temporal processing in college students.

Purpose of the Present Study

Many studies have independently examined ADHD-related performance on laboratory tasks temporal processing, albeit primarily in child samples. A sufficient body of literature exists on temporal processing deficits in ADHD that this domain is included in the leading ADHD theory (Triple Pathway Theory). At the same time, 1) these laboratory-based performance measures have not been directly correlated to the subjective experience of time, real world time management skills, or clinically significant outcomes of temporal processing deficits, 2) nor is there an existing reliable and valid self-report measure to evaluate these key constructs of temporal processing in college students. Although the relationship between the temporal pathway and increased ERB in ADHD is not well understood, the Wittmann and Paulus (2008) framework is a promising theoretical basis for understanding associations between ERB and temporal processing deficits in ADHD. Lastly, the existing body of literature suggests that

ADHD is associated with *objective* temporal processing deficits and a fast internal clock – indicative of the subjective experience of time passing slowly – but the self-reported *subjective* experience of time in ADHD has yet to be evaluated.

To address these gaps in the literature, the proposed study aims to 1) assess the reliability, concurrent validity, and discriminant validity of a novel self-report measure of temporal processing; 2) evaluate the relationship between ADHD severity, objective temporal processing performance, and subjective temporal processing in college students; and 3) evaluate the extent to which objective temporal processing performance and subjective report of temporal processing are associated with engagement in risky behavior. The hypotheses are as follows: 1) the novel self-report measure of temporal processing will have satisfactory internal consistency, demonstrate concurrent validity with the objective cognitive measures of temporal processing and with a conceptually relevant, related construct (procrastination), and demonstrate discriminant validity to distinguish between individuals with and without ADHD; 2) greater ADHD severity will be associated with greater objective temporal processing deficits and a subjective experience of time passing slowly; 3a) objective temporal processing deficits and a subjective experience of time passing more slowly will be associated with greater ERB; and 3b) ADHD severity will exacerbate the relationship between the subjective experience of time passing slowly and ERB.

Methods

Participants completed this study in one virtual 45-50 minute session, and data collection was completed between November 2021 – April 2022. The session was comprised of two objective cognitive temporal processing tasks and multiple self-report questionnaires to assess ADHD symptoms, subjective temporal processing, delay aversion, inhibitory control, ERB, and demographic information. Data analyses assessed the reliability and validity of the novel self-report measure of temporal processing and evaluated the extent to which ADHD was associated with objective temporal processing task performance, the subjective experience of time passing slowly, and ERB. This study was approved by the Institutional Review Board at Syracuse University (IRB #21-291).

Participants

A total of 275 participants were recruited from Syracuse University through the university's Psychology Research Participation System (SONA). SONA is an online system that allows students at Syracuse University to sign up for research studies and access virtually administered studies. The introductory level psychology course at Syracuse University introduces students to the SONA system, and research participation (through SONA or an alternative assignment) is a course requirement. All recruited participants met inclusion/exclusion criteria for this study.

Inclusion criteria for this study included (a) the ability to comprehend the English language because the instructions and scales were administered in English; and (b) access to a laptop or computer with a stable internet connection and functioning speakers. In addition, to participate in the study, interested individuals were required to be (c) currently enrolled full-time as a Syracuse University undergraduate student; and (d) between 18 and 25 years old.

Exclusion criteria included (a) deafness (study contains auditory stimuli); (b) psychiatric disorders (i.e., autism spectrum disorder) associated with temporal processing deficits (Isaksson et al., 2018); and (c) neurological conditions (i.e., concussion, traumatic brain injury) associated with temporal processing deficits (Bader et al., 2019). Given the extensive psychiatric comorbidity of ADHD, the current study did not screen out comorbid conditions beyond those noted above.

Of the 275 recruited and enrolled participants, 44 participants were removed for missing data, 12 were removed due to failed attention checks, and 4 were removed due to outliers (as detailed in the data inspection section below). A total of 215 participants were retained in the final sample.

The mean age of the 215 participants was 18.75 (*SD*=1.01). Most participants were in their first year of college (75.3%) and identified as White (62.8%) and female (55.7%). 7.9% of participants reported currently having ADHD, and 6.1% reported currently managing their ADHD through prescribed medication. Based on self-report of ADHD symptoms via the Adult ADHD Self-report Scale Six-item Screener (ASRS-6; *M*=11.44, *SD*=3.56), 15.8% of college students rated themselves as having a clinically elevated ADHD symptoms. All college students with a self-reported ADHD diagnosis also met the cut-off score for clinically elevated ADHD symptoms based on the ASRS-6. In addition, college students in our sample self-reported a normative, non-impairing level of depression, anxiety, and stress symptoms (*M*=18.17, *SD*=13.20), with 30.2% of students exhibiting clinically significant levels of depression based on the clinical cut-off scores on the DASS-21 (Beaufort et al., 2017). Full demographic information is presented in Table 3. Bivariate correlation matrices for descriptive variables and variables used for linear regressions can be found in Table 4 and Table 5, respectively.

A priori power analysis (detailed in the data analytic plan below) indicated that a sample size of 103 participants would be required to detect a medium effect size at the alpha level of .05 to evaluate hypotheses 2 and 3. Nevertheless, scale development guidelines indicate that a sample size that is five times larger than the number of items on a proposed scale is sufficient for psychometric analyses (Anthoine et al., 2014). The novel subjective temporal processing measure developed for this study contains 20 items, indicating 200 participants were needed to obtain sufficient power. Therefore, the sample size (*N*=215) of this study was adequately powered to detect medium strength associations and conduct reliability and validity analyses on a novel 20-item scale.

Procedure

All measures were completed virtually through Qualtrics. Participants received instructions to complete this study on a computer or laptop, in a quiet environment with no distractions, as though they “were taking an online test for one of their courses”. Participants were instructed to not use a phone or watch during the completion of this study.

After obtaining electronic informed consent, participants completed an ADHD symptom inventory on Qualtrics. Following completion of this first measure, participants were automatically directed to InquisitWeb to complete the two computerized cognitive tasks of objective temporal processing. InquisitWeb provided each user with unique login information to record data. Any session left idle for 30 minutes was automatically terminated by the system. Following completion of the two InquisitWeb tasks, participants were automatically redirected back to Qualtrics to complete the remaining self-report questionnaires. All participants were asked to provide sociodemographic data at the end of the study in an effort to make ADHD symptoms the most salient individual difference variable. Following all measure and task completion, participants were debriefed and compensated (1 SONA credit).

Four attention check items (e.g., “Please select 5 for this item”) were dispersed within the self-report measures to ensure participants are fully reading and answering questions. One validity item (i.e., “Did you encounter internet connectivity issues that interfered with your completion of this study?") was presented at the end of the study to check validity related to internet use. In addition to the validity check item, InquisitWeb contains validity features that allowed the researcher to view errors during the administration of the cognitive tasks, such as the use of a phone to complete the cognitive tasks or internet connection errors. Participants who failed $\geq$ 2 attention check items or failed any validity item were not included in analyses. All measures were administered in one session and took approximately 45 minutes to complete.

Measures

All measures were directly embedded into the Qualtrics survey and presented in the order listed in Table 1. ADHD symptom measures were administered first to increase the salience of ADHD symptoms. Following the ADHD symptom measures, participants were provided instructions about the automatic transition between the survey (Qualtrics) and InquisitWeb platforms for user ease. InquisitWeb tasks were administered second to allow for objective temporal processing performance to be measured when participants were not mentally taxed from long self-report items. The novel self-report measure of temporal processing was purposefully presented several measures away from the objective temporal processing tasks to allow for greater separation when answering these self-report items intended to be based on general experiences with time perception rather than the recent experience with the objective, experimental task. Demographic items were administered at the end of the survey to mitigate any stereotype threat that may impact self-report or performance on previous measures in the study.

ADHD Symptoms

The Adult ADHD Self-report Scale Six-item Screener (ASRS-6) is a self-report scale that consists of 6 items across two sub-scales (inattention and hyperactivity-impulsivity), and past 6-month frequency of ADHD symptoms are rated on a 5-point Likert scale (0 – never, 4 –

very often) with greater frequency indicating greater symptom severity (Adler et al., 2006). The ASRS-6 is a psychometrically valid self-report measure of ADHD, with high internal consistency and test-retest reliability, and is strongly correlated with clinical diagnoses of ADHD (Adler et al., 2006; Kessler et al., 2007). This measure has been validated in the college student population for ADHD screening (Gray et al., 2014). A score of 14 or higher on the ASRS-6 is indicative of a clinically elevated level of ADHD symptoms (Adler et al., 2006). This clinical cut-off score was utilized in the current study to create ADHD (e.g., ASRS-6 score ≥ 14) vs. non-ADHD groups (e.g., ASRS-6 score < 14). Cronbach's alpha for the ASRS-6 in the current study was 0.71, indicating acceptable internal consistency.

The following four questions were asked immediately following the ASRS administration in order to assess if participants have a previous history of ADHD diagnosis and/or a history of taking ADHD medication: 1) Have you ever been diagnosed with Attention-Deficit/Hyperactivity Disorder (ADHD) *or* Attention Deficit Disorder (ADD) by a medical or mental health professional? 2) Have you ever been prescribed medication for ADHD? 3) Do you currently take medication for ADHD? 4) Did you take your medication for ADHD today? The first three questions were used to describe the sample and support the external validity for the ADHD group created based on the ASRS-6 scores. The fourth question was used as a covariate in analyses.

Objective Temporal Processing

Immediately following the ASRS, objective temporal processing was measured using two tasks: a prospective time estimation task and a temporal reproduction task. These tasks are available on InquisitWeb and were directly embedded into the study. A prospective time estimation task and a prospective temporal reproduction task were chosen because time estimation and temporal reproduction task performance has been shown to discriminate ADHD from non-ADHD (Walg et al., 2017), such that individuals with ADHD consistently over-estimate and under-reproduce time intervals (Walg et al., 2017; Zheng et al., 2020). Furthermore, prospective time estimation and temporal reproduction are both implicated in the Wittmann and Paulus theoretical framework, such that individuals with a fast internal clock (denoted by over-estimating and under-reproducing time interval) are posited to exhibit greater ERB (Wittmann & Paulus, 2008).

The prospective time estimation task follows the procedure detailed in Wittmann and colleagues (2007). Prior to starting the task, participants received task instructions that they will need to estimate the interval of time between the start stimulus (i.e., a green dot appearing on screen, accompanied by an alarm ring) and the end stimulus (i.e., a red dot appearing on screen, accompanied by an alarm ring). After reading the instructions, participants completed two practice trials prior to become familiar with the task. Participants completed 3 trials of the time estimation task for time intervals of 10 seconds, 35 seconds, and 135 seconds, presented in a random order. Participants reported the estimated duration of the time interval on a visual scale of 0 minutes to 3 minutes, with each bar representing 1 second. Performance was recorded in InquisitWeb and automatically stored. The mean accuracy (estimated duration – real duration of stimulus) across the 3 trials was utilized in analyses.

The prospective temporal reproduction task also followed the procedure described in Wittmann and colleagues (2007). Participants heard a standard tone play for a given duration, and then were asked to reproduce the duration. To reproduce the duration, participants were presented with a tone and asked to interrupt this tone when it has played for the same duration as the previous tone. The tone is interrupted by pressing their computer’s space bar. After reading the instructions, participants completed 3 practice trials. Each participant completed 30 trials of this task for durations of 1 second, 2 seconds, 3 seconds, 4 seconds, and 5 seconds. Each duration was presented 6 times in a random order. Mean duration of reproduced intervals, the coefficient of variation (SD/Mean), and the mean accuracy ((reproduced duration – actual duration)/number of trials) will be calculated for the six trials of each duration. Because the durations measured were all under 5 seconds, and to reduce Type I errors that can be introduced by running many analyses, as recommended by others (Nejati & Yazdani, 2020), the total mean accuracy and coefficient of variation across all time intervals was used for analyses.

Delay Aversion

The Quick Delay Questionnaire (QDQ) is a 10-item self-report measure of responses to delay in adults (Clare et al., 2010). The QDQ is comprised of two subscales, delay aversion ("I hate waiting for things") and delay discounting ("I often give up on things that I cannot have immediately"), and has good test-rest reliability (range: r = .80 - .81) and acceptable internal consistency (range: α = .68 - .79) (Clare et al., 2010). ADHD symptoms are significantly correlated (r = .416, p <0.01) with self-report on the QDQ (Clare et al., 2010), and there is established discriminant validity to differentiate individuals with an ADHD diagnosis from a nonclinical population (Thorell et al., 2017). Cronbach's alpha for the QDQ in the current study was 0.78, indicating acceptable internal consistency reliability. The total raw score from the QDQ were used to control for delay aversion when testing hypotheses 2 and 3.

Inhibitory Control

The Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency, Impulsive Behavior Scale (UPPS-P) measures five facets of impulsivity (Lynam et al., 2006). The UPPS-P is a well-accepted measure of impulsivity, demonstrating high internal consistency and adequate test–retest validity (Magid & Colder, 2007). The lack of premeditation, positive urgency, and negative urgency subscales demonstrate discriminant validity to differentiate between individuals with and without ADHD (Geurten et al., 2021), and these three subscales adequately measure inhibitory control (a dimension of impulsivity) (Whiteside & Lynam, 2001). The combined score from lack of premeditation, positive urgency, and negative urgency subscales was used to control for inhibitory control when testing hypotheses 2 and 3. Cronbach's alpha for the UPPS-P combined scores in the current study was 0.89, indicating good internal consistency reliability.

Subjective Experience of Time

The Time Management and Experience Scale (TiME) is the novel self-report measure that was developed for this study to provide a comprehensive self-assessment of temporal processing. The measure is comprised of 20 items pertaining to one's subjective experience of time passing and one's ability to manage time in daily life during the past 6-months. Participants rate agreement with the statements on a 6-point Likert scale (1 – strongly disagree; 3 – slightly disagree, 4 – slightly agree, 6 – strongly agree). An extensive description of the development of the TiME is detailed in the TiME Pilot Testing and Development section. As part of hypothesis 1 testing, psychometric analyses (e.g., exploratory factor analysis, reliability, validity) were completed for the TiME, and internal consistency was analyzed for each subscale identified. TiME total score was used in analyses for hypotheses 2 and 3.

Risky Behaviors

The Cognitive Appraisal of Risky Events Questionnaire (CARE) measures the perceived risk, benefit, and past frequency of engagement in risky behaviors (Fromme et al., 1997). Risky behaviors are categorized into 6 domains on the CARE: risky sexual behavior, heavy drinking, illicit drug use, aggressive and illegal behaviors, irresponsible academic/work behaviors, and high risk sports (Fromme et al., 1997). Past frequency of engagement in risky behaviors was reported as a numerical estimate of the number of times the participant engaged in a given behavior in the past 6 months (Fromme et al., 1997). The CARE has good internal reliability (α range: .81 - .84) and test–retest reliability and strong construct validity based on significant correlations with impulsivity and sensation seeking (Fromme et al., 1997). The CARE was selected for this study because: 1) the CARE was developed and normed in a college student population, and 2) external validity was established in a clinical substance use disorders sample (Fromme et al., 1997). In addition, the CARE represents risky behaviors with potentially severe outcomes (e.g., binge drinking, condomless sex) as well as those with still serious, but less severe consequences (e.g., irresponsible academic behaviors). These domains of risky behaviors coincide with the domains of risky behaviors that are associated with ADHD. For the purposes of this study, the subscale pertaining to high risk sports was not be included as it is not of clinical interest or related to the aims of this project. One additional item was added at the end of the CARE drug use subscale: "ever used stimulant medication in a way that was not prescribed". This item will be included to assess for NMU of stimulants, a risky behavior that has been associated with ADHD (Clemow & Walker, 2014) but not assessed in the CARE. Each of the included frequency of past engagement subscale scores (e.g., risky sexual behavior, heavy drinking, drug use, aggressive behaviors, irresponsible academic/work behaviors) were used in analyses.

Procrastination

The Tuckman Procrastination Scale (TPS) measures self-reported procrastination and tendency to procrastinate (Tuckman, 1991). The TPS contains 16 items with good internal reliability (α=.86) and was normed and intended for use in the college student population (Tuckman, 1991). The TPS was used to test concurrent validity of the TiME because procrastination has demonstrated to have medium correlations with measures of time management, which is a dimension of temporal processing (Ocak & Boyraz, 2016). Cronbach's alpha for the TPS in the current study was 0.81, indicating good internal consistency reliability.

Depression, Anxiety, and Stress

The Depression, Anxiety, and Stress Scale (DASS-21) measures anxiety, stress, and depression and is commonly used as a general measure of psychological distress (Henry & Crawford, 2005). The DASS-21 contains 21 items with excellent internal reliability (α=.93) and is normed for use in the general adult population (Henry & Crawford, 2005). The DASS-21 was used to describe the overall level of psychological distress in the sample. Participants reported levels of psychological distress that are typical of non-clinical adult populations (Henry & Crawford, 2005), indicating no need to control for psychological distress in analyses. Cronbach's alpha for the DASS-21 in the current study was .94, indicating excellent internal consistency reliability

Demographics/Background

A brief demographic questionnaire will collect information about participants' age, gender, race, ethnicity, and year in college. These variables were used to describe the sample.

TiME Pilot Testing and Development

Initial Item Pool Development

Twenty-five items (see Appendix A) were generated to address three conceptually distinct domains of temporal processing: 1) time estimation abilities; 2) temporal self-regulation; and 3) subjective time perception. The items were generated based on face-validity to measure one of the three domains of temporal processing, and several items covered similar content and phrasing as the SCOTT, with permission of the its developers (Canu, personal communication, March 18, 2021). The format, instructions, and item phrasing (i.e., first-person) of the TiME were based on previous measures used to assess procrastination and time management in college students (Sorrell & Canu, 2018; Tuckman, 1991).

Pilot Testing Results

These initial 25-items were pilot tested on a sample of 71 undergraduate college students from Syracuse University, recruited from the SONA research participation pool. As is recommended best-practice in scale development research (Boateng et al., 2018), this initial pilot testing was conducted to eliminate poorly worded, very low-performing items to provide preliminary evidence of feasibility and reliability of the scale. Based on the initial calculated KMO of 0.502, five items were deleted from the original set of items. These five items were selected for removal due to low correlation with the overall test score and low inter-items correlation. Overall KMO was recalculated after the removal of items. Overall KMO was 0.648, indicating suitability for factors analysis. Principle factor analysis (PFA) and root mean square error of approximation (RMSEA) were then completed on the remaining 20 items. Results from the PFA and RMSEA indicated a four-factor structure. The resulting four factors were subjective experience of time, temporal self-regulation, time orientation, and time pressure. Internal consistency for the pilot instrument was acceptable for the subjective experience of time (α=.74) and temporal self-regulation (α=.69) subscales, but poor for the time orientation (α=.20) and time pressure (α=.17) subscales. See Appendix B for steps of item removal and factor analysis from pilot testing.

Revising Item Pool

The acceptable reliability of the subjective experience of time and temporal self-regulation subscales from this pilot sample provides evidence that these two subscales may be a reliable and useful self-report measure of temporal processing in college students. Although the pilot testing participant sample was underpowered, this initial pilot testing was utilized to simply remove significantly low-performing items to ensure the items on the TiME are easily comprehensible and have preliminary evidence of ability to measure temporal processing, as is typical of pre-testing in scale development (Boateng et al., 2018). Because of the poor performance of the temporal self-regulation and time orientation items, five of the lowest performing items (i.e., lowest correlation with other items, lowest factor loading) from these two subscales were removed from the TiME. Five items hypothesized to load onto the subjective experience of time and temporal self-regulation scales were then added to make the current iteration of the TiME to be used in this project. These five new items were generated based on face validity for assessing subjective experience of time and temporal self-regulation, using existing measures (e.g., SCOTT, STQ) as reference (Sorrell & Canu, 2018; Wittmann & Lehnhoff, 2005). See Appendix C for a table of the item pool revisions for the final TiME.

Selecting Validity Constructs

Several measures were selected to assess validity of the TiME. While concurrent validity with an existing measure that assesses temporal processing is typically recommended, none of the extant temporal processing self-report scales have been assessed for validity (Langberg et al., 2011; Sorrell & Canu, 2018; Wittmann & Lehnhoff, 2005). Thus, a scale (i.e., TPS) that assesses a theoretically relevant and conceptually similar construct to temporal processing (i.e., procrastination) was selected to test concurrent validity of the TiME. Because objective, cognitive tasks are hallmark in testing temporal processing (Matthews & Meck, 2014), a time estimation and time reproduction task were selected to test concurrent validity of the TiME, as well. Finally, the ASRS was selected to test discriminant validity of the TiME because 1) temporal processing deficits are consistently noted in individuals with ADHD compared to those without ADHD (Nejati & Yazdani, 2020; Zheng et al., 2020); and 2) the ASRS is a psychometrically valid and commonly used tool to assess for ADHD symptoms in college students (Gray et al., 2014). Given the evidence that prescribed stimulant medication does not significantly impact time perception in individuals with ADHD, stimulant medication use was not included as a correlate with the TiME (Barkley et al., 1997; Hurks & Hendriksen, 2011).

Data Analytic Plan

Power Analyses

Power analyses to complete psychometric analyses for the TiME followed scale development guidelines, which suggest a sample size that is five times greater than the number of items on a proposed scale (Anthoine et al., 2014). The TiME contains a total of 20 items, and, therefore, 200 participants are needed for sufficient power to complete psychometric analyses.

A priori power estimates using effect sizes from previous research examining temporal processing and risk-taking in ADHD were calculated using G*Power. Previous ADHD studies demonstrate medium to large effect sizes between ADHD severity and temporal processing deficits (Nejati & Yazdani, 2020; Zheng et al., 2020), medium to large effect sizes between ADHD and ERB (Shoham et al., 2019), and medium effects between temporal processing deficits and ERB (Cáceda et al., 2020; Paasche et al., 2019). Given the dearth of literature on the subjective experience of time in ADHD, a medium effect size was presumed. Assuming 80%

power to detect significant associations, an alpha level of .05, a moderate effect size (f^2=.15), and 7 predictors, a sample size of 103 was needed to attain adequate statistical power.

Pre-Analytic Data Management

Before conducting analyses, data was assessed for missingness, reliability, and normality. Initially, 44 participants were removed from analyses due to excess missingness (e.g., missing all InquisitWeb data due to technical errors). After the removal of excess data loss due to InquisitWeb failures, remaining data were also analyzed for missingness. Data were missing completely at random as per Little's MCAR test (χ^2(1015, N = 219) = 1050.933, *p*=.21) and less than 3% of the total data were missing. Thus, multiple imputation was used to handle remaining missing data.

Attention check items were included for reliability of data, and 12 participants were removed for failing 2 or more attention check items. The remaining data were analyzed for normality and multicollinearity. Skewness and kurtosis analysis of all variables except the CARE met the assumptions of normality (Mishra et al., 2019). The CARE data was assessed for outliers, and as suggested by (Tabachnick & Fidell, 2007), outlier data points above/below 2SD from the mean of on each item were removed. This removed the ability of outlier to unduly influence statistical significance through Type I or Type II errors. A total of four cases were removed due to outliers. After removal of outliers, the CARE data remained skewed due to excess reporting of zeros (32.6 - 50.7% zeros). However, this data is consistent with the most recent national data, which demonstrates 44% of college students report engaging in cannabis use and 56% report engaging in alcohol use (NIDA, 2021). Therefore, zero-reporting on these items is typical of the general college student population and does not warrant a zero-inflated correction. Based on the inflated variance compared to the mean on the CARE count data

(Erdman & Sinko, 2008; Wagner et al., 2015), a negative binomial regression was selected to complete the hypothesis 3 analyses using the CARE.

Factor Structure Analyses

In order to test hypothesis 1, factor analyses on the TiME were completed. Bartlett's test of sphericity and a Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) for the TiME was used to determine if factor analysis could be used to reliably identify factors, wherein a significant Bartlett's test of specificity and a KMO above 0.50 indicate that factor analysis is appropriate (Watkins, 2018). Parallel analysis and a scree plot was used to determine the minimum eigenvalue necessary for inclusion for each factor (Glorfeld, 1995), and any factor where the initial eigenvalue eigenvalues >1 and exceeds the average from the parallel analysis were included (Hayton et al., 2004). Factors that could be linked to an existing theoretical rationale were retained, and factors that could not be linked to any existing theories of temporal processing were removed.

Items that loaded at least moderately (≥ 0.40) onto only one factor were included. Items that loaded between 0.40 and 0.30 on one factor or that loaded moderately (≥ 0.40) on more than one factor were examined for inclusion on the basis of theoretical rationale (Osborne, 2014), and items that loaded below 0.30 were excluded (Watkins, 2018). The maximum likelihood method was used to extract factors, as assumptions of normality were met, because this method allowed for easier computation for goodness of fit tests and significance testing of factor loadings. Direct oblimin rotation was used because the facets of temporal processing (e.g., subjective experience of time, temporal self-regulation) are theorized to be correlated with each other. Model fit was examined through a significant chi-square test and a root mean square error of approximation (RMSEA) value less than or equal to .06 (Chen et al., 2008).

Primary Analyses

To test hypothesis 1 (novel measure will possess adequate psychometric properties), a factor analysis, as detailed above, was completed to evaluate the hypothesized two factor structure of the TiME (revised from the initial pilot data). Cronbach's alpha was used to determine internal reliability of the TiME, and a Cronbach's alpha in the acceptable range ($\alpha \geq 0.71$) on the TiME total score and each factor was required to accept hypothesis 1 (TiME is a reliable measure). Concurrent validity of the subjective TiME was determined based on the correlation between performance on objective temporal processing tasks, the TPS, and the TiME. A strong correlation ($r \geq .50$) between performance on the TiME and objective temporal processing tasks and between the TiME and TPS was required to accept hypothesis 1 (TiME is a valid measure of temporal processing). Discriminant validity of the TiME was determined based on the correlation between self-report on the TiME and self-report on the ASRS. A strong correlation ($r \geq .50$) between TiME and ASRS was required to support the discriminant validity of the TiME for differentiating ADHD from non-ADHD.

To test hypothesis 2, multiple linear regression analysis was conducted to evaluate the association between ADHD symptoms (Y), objective temporal processing performance (X_1), and subjective temporal processing self-reports (X_2). The criterion for statistical significance was set to an alpha level of 0.05. To accept hypothesis 2, objective temporal processing performance and subjective experience of time self-reports were expected to be significantly associated with ADHD severity.

To test hypotheses 3a and 3b, a negative binomial regression analysis (selected based on findings in the pre-analytic data management section) were conducted to evaluate the prediction of ERB (Y) from ADHD symptom severity (X_1), objective temporal processing performance

(X_2), and temporal processing self-reports (X_3). The analysis included delay aversion, inhibitory control, age, and ADHD medication use as covariates. The criterion for statistical significance was set to an alpha level of 0.05. ADHD symptom severity, objective temporal processing performance, and temporal processing self-reports were expected to be significantly associated with ERB and explain significantly more variance in the model than the covariates. The interaction term between ADHD symptom severity and temporal processing self-report was entered into the negative binomial regression model, and the interaction effect was expected to be significant for ERB, demonstrating the moderating effect of ADHD severity on ERB. See Table 2 for a summary of analyses conducted.

Results

Factor Analysis

The overall Kaiser-Meyer-Olkin Test for Sampling Adequacy (KMO =.84) and Bartlett's Test of Sphericity ($\chi^2(190) = 1631.01$, $p < .001$) indicated that the TiME data was appropriate for factor analysis. The KMO for each item was greater than .50 (range: .58 – .91), justifying retaining all 20 items in the scale. See Table 6 for inter-item correlation matrix for all 20 items on the TiME.

Six factors with eigenvalues >1 were identified (λ = 1.276 - 3.446). However, the scree plot of eigenvalues (see Figure 1) of the reduced correlation matrix showed a marked drop from the fourth eigenvalue to the fifth, with no appreciable difference between the fifth and sixth or sixth and seventh eigenvalues, suggesting the presence of four latent factors. Additionally, the five and six-factor solutions were not meaningfully interpretable due to low number of items loading onto each factor and substantial cross-loading. Comparatively, the four-factor solution allowed for a more even number of items loading onto each factor and limited cross-loadings. Of note, two items were removed from the scale when determining this factor solution. Item 4 and item 13 were removed due to low loading on all four factors, such that 18 items were retained in the final factor solution. Thus, the four-factor maximum likelihood solution provided the most meaningful solution in terms of consistency with theory and previous measures of time perception, resulting number of items per factor, and absence of cross-loadings.

Hypothesis 1: **TiME will be a reliable and valid self-report measure of temporal processing.**

The fit indices for the oblim rotated maximum likelihood, four-factor TiME solution were $\chi^2(87) = 156.57$, $p<.001$; RMSEA=0.061, indicating adequate model fit. Results of the oblim rotated maximum likelihood solution for the TiME four-factor solution are presented in Table 7. Rather than representing a two-factor solution of subjective experience of time and temporal self-regulation outcomes (per *a priori* hypotheses), the four factors represented the multi-faceted nature of time perception, including feelings of time pressure, awareness or orientation to time, ability to regulate oneself to time, and subjective experience of time. In total, the four extracted factors across 18 items accounted for 60% of the total variance. Cronbach's alpha for the total TiME score was .80, indicating good internal consistency. Six items loaded onto the first factor, which was considered to reflect *Temporal Self-Regulation* (α=.86). Four items loaded onto the second factor, which was considered to reflect *Time Pressure* (α=.68), the third factor, which was considered to reflect *Orientation to Time* (α=.78), and the fourth factor, which was considered to reflect *Subjective Experience of Time* (α=.69).

The TiME demonstrated concurrent validity with a measure of procrastination, such that the TiME total was strongly correlated with the TPS (r=.64, p<.001). No significant associations were found between the TiME total or individual factors on the TiME and any other measure of external validity (see Table 8). The TiME was not significantly correlated with the objective measures of temporal processing, specifically mean time reproduction accuracy ($r = -.04$, $p = .654$) and mean time estimation accuracy ($r = -.01$, $p = .778$). Similarly, the TiME total was not significantly correlated with ADHD symptoms, specifically ASRS total ($r = .06$, $p = .230$), ASRS inattention ($r = .01$, $p = .628$), or ASRS hyperactivity score ($r = .11$, $p = .058$). Moreover, no significant between group differences on the TiME were found. Participants in the ADHD group did not report any significant differences on the TiME total score or subscales compared to college students in the no ADHD group. See Table 9 for between group comparisons on the TiME.

In sum, the hypothesis that the TiME will be a reliable and valid self-report measure of temporal processing was partially accepted. The TiME total score ($\alpha = .80$) met *a priori* standards (i.e., $\alpha \geq .71$) for accepting the TiME as an internally consistent measure. The TiME is partially accepted as a valid measure of temporal processing, as it demonstrated concurrent validity with procrastination but not with objective measures of temporal processing. The TiME failed to demonstrate adequate discriminant validity for ADHD. Additionally, given that the internal consistency of the *Subjective Experience of Time* subscale was in the questionable range, and the lack of evidence suggesting external validity for this subscale on its own, the *Subjective Experience of Time* subscale was not independently included in subsequent analyses. Rather, the overall TiME score was utilized to capture subjective temporal processing self-report in subsequent hypothesis testing.

Hypothesis 2: Greater ADHD severity will be associated with greater objective temporal processing deficits and a subjective experience of time passing slowly.

T-tests were utilized to investigate between group differences on objective temporal processing tasks. No significant differences were found between college students in the ADHD compared to no ADHD group on the time estimation task. On the time reproduction task, college students in the ADHD group were overall more inaccurate ($t(213)=3.151$, $p=.002$, $d=.333$) and displayed greater variation in their reproductions ($t(213)=1.509$, $p=.025$, $d=.432$) compared to college students in the no ADHD group. Specifically, college students in the ADHD group were more inaccurate reproducing time intervals of 1 second ($t(213)=1.582$, $p=.016$, $d=.400$), 2 seconds ($t(213)=2.489$, $p=.005$, $d=.629$), 3 seconds ($t(213)=2.599$ $p=.014$, $d=.657$), and 5 seconds ($t(213)=2.661$, $p=.042$, $d=.673$), compared to college students in the no ADHD. See Table 9 for full results of between group comparisons on objective temporal processing tasks.

A hierarchical linear regression was carried out to test if performance on temporal processing tasks and total TiME scores predicted ADHD symptoms when controlling for impulsivity and delay aversion. The first block of the model included the covariates of impulsivity (measured on the UPPS-P), delay aversion (measured on the QDQ), and self-report of ADHD medication use. Results for the first block of the model were non-significant. The second block of the model included objective temporal processing performance and subjective experience of time. Results for the second block of the model yielded a moderate effect size, yet were non-significant ($R=.891$, $\Delta R^2=.546$, $F=2.189$, $p=.234$). Of note, the temporal reproduction coefficient of variation was the only predictor approaching significance ($p=.053$). Please see Table 10 for linear regression results.

The hypothesis that temporal processing, as measured by objective temporal processing tasks and the TiME, would be associated with ADHD symptoms beyond impulsivity and delay aversion was rejected. No significant associations between these variables were detected.

Hypothesis 3a: Objective temporal processing deficits and a subjective experience of time passing more slowly will be associated with greater ERB

A negative binomial regression analysis was conducted to evaluate the prediction of ERB from ADHD symptom severity, objective temporal processing performance, and temporal processing self-reports. Age, ADHD medication use, delay aversion (as measured on the QDQ), and impulsivity (as measured on the UPPS-P) were included as covariates for each regression. As is detailed in the data inspection section above, a negative binomial regression was selected for this analysis due to the high level of variance in the count data from the CARE, which can be handled through negative binomial regression. Separate binomial regressions were completed for each of the five CARE subscales (e.g., risky sexual behavior, heavy drinking, drug use, aggressive behaviors, irresponsible academic/work behaviors) due to the heterogeneity in the risky behaviors measured on the CARE.

No variables significantly predicted heavy drinking or drug use as measured on the CARE. ADHD symptom severity (OR=1.133; 95% CI: 1.030, 1.247; p=.010) and TiME self-report (OR=1.054; 95% CI: 1.010, 1.101; p=.015) were significantly associated with greater engagement in irresponsible academic/work behaviors (e.g., missing class, not completing assignments). In terms of sexual risk behaviors, age (OR=1.217; 95% CI: 1.038, 1.426; p=.015) was significantly associated with greater engagement in sexual behaviors that may confer risk (e.g., unprotected sex, sex with a stranger) while objective time estimation accuracy (OR=.988; 95% CI: .979, .996; p=.006) was associated with lower engagement in these sexual behaviors.

Objective time estimation accuracy (OR=.989; 95% CI: .980, .998; *p*=.018) was also associated with lower engagement in aggressive behavior (e.g., hitting someone, causing a scene in public). No other variables were significantly associated with ERB as measured on the CARE. See Table 11 for full negative binomial regression results.

Hypothesis 3b: ADHD severity will exacerbate the relationship between the subjective experience of time passing slowly and ERB

An interaction term (ADHD severity x TiME) was created and added to the negative binomial regressions to assess the moderation of the subjective experience of time by ADHD severity. Results for the effect of the interaction term (ADHD severity x TiME) were non-significant for each of the five CARE subscales. The hypothesis that ADHD severity would moderate the relationship between subjective experience of time and ERB was rejected. See Table 11 for negative binomial regression moderation results.

Discussion

The present study developed a novel self-report measure of temporal processing and evaluated the associations between ADHD symptoms, objective temporal processing, and subjective temporal processing in college students. Further, this study utilized the Wittmann and Paulus (2008) theoretical framework to investigate the relationship between ADHD symptoms, temporal processing abilities, and ERB. This study expanded on past literature on temporal processing in ADHD by measuring temporal processing in a college student population (an under-represented population in this line of research), implementing a self-report measure of temporal processing, and considering clinically significant outcomes (e.g., ERB) that may be associated with temporal processing deficits. Table 12 provides a summary of the support for each hypothesis based on the results of the present study.

Supported Hypotheses

The primary significant findings from this study are (1) the TiME demonstrates reliability and some concurrent validity as a novel self-report measure of temporal processing, (2) ADHD symptom severity and temporal processing self-report (via the TiME) were positively associated with greater engagement in academic risk behaviors, and (3) time estimation accuracy was negatively associated with lower engagement in risky sexual behavior and aggressive behavior. These findings indicate that the TiME may be a useful measure to assess temporal processing, and some dimensions of temporal processing may be related to ERB.

TiME Reliability and Validity

Compared to existing self-report scales for temporal processing, such as the SOMTS, SCOTT, or STQ, the TiME is the first to include items pertaining both to temporal self-regulation and the subjective experience of time, thus offering a potentially more comprehensive assessment of temporal processing. The TiME total score demonstrates adequate internal consistency (α=.796) whereas many previous self-report scales for temporal processing have yet to be evaluated for reliability (Drakulić et al., 2003; Wittmann & Lehnhoff, 2005) or fail to provide a thorough assessment of many aspects of temporal processing (Houghton et al., 2011; Labrell et al., 2020; Sorrell & Canu, 2018).

The four-factor solution, consisting of Temporal Self-Regulation, Orientation to Time, Time Pressure, and Subjective Experience of Time subscales, is consistent with the multidimensional model of temporal processing (Grondin, 2010). Two of the four TiME subscales, Temporal Self-Regulation (α=.86) and Orientation to Time (α=.78), met standards for reliability. Although the other two subscales, Time Pressure (α=.61) and Subjective Experience of Time (α=.69), demonstrated reliability in the questionable range, they did not substantially decrease the overall TiME total score reliability and contributed theoretically important information about the subjective experience of time, and were thus retained. This lower reliability in the Time Pressure and Subjective Experience of Time subscales may indicate that these dimensions of temporal processing are more heterogeneous and difficult to measure. Indeed, previous research has found that there are notable individual differences in how people experience time and interpret time passage, leading to difficulties in measuring subjective time perception (Matthews & Meck, 2014). These two subscales also demonstrated weak correlation with each other and the other two subscales, indicating that these two constructs are unique facets of temporal processing. This notion is supported by past research (Matthews & Meck, 2016).

In terms of validity, the TiME exhibited a strong, positive correlation with the TPS, thus demonstrating concurrent validity with a theoretically related construct, procrastination. It is unsurprising that the TiME was positively correlated with the TPS given that some of the items on the TiME pertaining to Temporal Self-Regulation (e.g., “I often find it difficult to complete assignments on time,” and “I usually give myself enough time to complete my work before the deadline.”) relate to allocating adequate time to completing a task – a behavior that is conceptually similar to procrastinating. Nevertheless, concurrent validity with procrastination, a construct that is related to temporal processing (Francisco et al., 2013) and relevant to real-world behavior (Häfner et al., 2014; Ocak & Boyraz, 2016), is an important first step in providing evidence that the TiME is truly measuring temporal processing skills.

ADHD, Subjective Temporal Processing, and Risky Academic Behaviors

The positive relationship between ADHD symptoms and irresponsible academic behaviors is also unsurprising. Children and adolescents with ADHD are more likely to procrastinate on school work (Ferrari & Sanders, 2006; Niermann & Scheres, 2014) and have missing homework assignments (Langberg et al., 2016) and poorer attendance (Kent et al., 2011). This study's results confirm these past findings of risky academic behaviors in pediatric ADHD and indicate that college students who reported greater temporal processing deficits endorsed greater engagements in irresponsible or "risky" academic behaviors. Interestingly, in a recent qualitative study on academic impairments in college students with ADHD, a college student with ADHD remarked that they attributed their irresponsible academic behaviors, in part, to their poor perception of time (Lagacé-Leblanc et al., 2022).

While irresponsible academic behaviors are associated with less severe consequences than condomless sex or binge drinking, these behaviors are still highly relevant to college students with ADHD. This study demonstrates that temporal processing deficits are associated with academic risky behaviors, which, in turn, are associated with long-term academic impairments, such as lower GPAs and withdrawal from courses (Kent et al., 2011). Thus, the association between the TiME and risky academic behaviors is an important addition to burgeoning research demonstrating the relationship between academic impairments and temporal processing (Lagacé-Leblanc et al., 2022).

Objective Time Estimation and Risky Aggressive and Sexual Health Behaviors

A particularly novel finding from this study is the negative relationship between objective time estimation accuracy and engagement in aggressive behavior and behaviors that can confer risk to sexual health (e.g., condomless sex). The finding that better time estimation accuracy contributes to decreased engagement in particular risky behaviors provides additional support for the Wittmann and Paulus (2008) framework. According to Wittmann and Paulus (2008), individuals who exhibit a fast-internal clock (which can be denoted by the overestimation of time intervals) are more likely to engage in behaviors that are “risky” yet stimulating. Although aggressive and sexual behaviors are distinct in many ways, these types of behaviors can be considered highly stimulating (Prause et al., 2008; Rohlfs & Ramírez, 2006), and thus fit into the conceptualization of outcome behaviors that are predicted by the Wittmann and Paulus (2008) framework. Others have similarly reported that individuals who overestimate and are less accurate on time estimation tasks engage in more aggressive behaviors (Dougherty et al., 2007).

No studies to date have specifically examined the associations between temporal processing and sexual behaviors that confer greater risk to sexual health. However, sensation seeking is associated with condomless sex and non-monogamous sex in college students (Gullette & Lyons, 2005; Lalasz & Weigel, 2011). Likewise, sensation-seeking has been associated with aggressive behaviors (Wilson & Scarpa, 2011). Following the Wittmann and Paulus (2008) framework, it is possible that college students who overestimate time intervals have a faster internal clock, causing a subjective experience of time slowing and increased boredom, and are more likely to engage in “sensation-seeking” activities or risky sexual experiences to abate their feelings of slowed time.

Unsupported Hypotheses

While several hypotheses were supported by the results of this study, several other hypotheses were not supported including: (1) the TiME did not demonstrate concurrent validity with objective measures of temporal processing nor demonstrate discriminant validity for ADHD, (2) temporal processing ability, as measure on both objective and self-report measures, were not associated with ADHD symptom severity, (3) ADHD symptoms and temporal processing were not associated with risky drug or alcohol use, and (4) the interaction between ADHD symptoms and temporal processing was not related to ERB.

TiME Concurrent and Discriminant Validity

This study was the first to attempt to establish concurrent validity between a self-report measure of temporal processing and objective measures of temporal processing. However, neither the TiME total score nor any of the subscales were correlated with performance on objective time estimation and time reproduction tasks. There are several potential explanations for this finding. Foremost, a meta-analysis reported a weak correlation exists between psychological test results and self-report rating scales ($r = .19$) (Toplak et al., 2013). Relatedly, there is a subset of the ADHD field that argue against the use of performance-based measures of executive functions and other cognitive processes (Barkley & Murphy, 2010). Performance-based measures often lack ecological validity, such that these tasks do not capture the sustained, goal-directed behaviors that support daily functioning (Barkley & Murphy, 2010; White et al., 2022). Finally, error variance due to the lack of experimental control in the objective temporal processing tasks (described in greater detail below) may have artificially reduced the association between these two measures.

Regarding discriminant validity, the TiME was weakly correlated with ADHD symptoms. This result is surprising given that time management difficulties, which were measured on the Temporal Self-Regulation and Orientation to Time subscales, are well established in college students with ADHD (Gray et al., 2016; Wood et al., 2021). The present study utilized a non-clinical sample of college students, which may play a role in the overall lack of associations found between ADHD and subjective and objective temporal processing deficits, because the existing literature has primarily utilized clinical samples (Prevatt et al., 2011; Weissenberger et al., 2021). Past research has indicated that, compared to other young adults with ADHD, college students with ADHD are higher functioning, such that they exhibit less academic and vocational impairments (Kuriyan et al., 2013; von Wirth et al., 2022). Moreover, many colleges and universities explicitly teach time management skills and explain the importance of meeting deadlines in first-year seminar classes, thus the primarily first-year students in our study may have been taught time managements skills and experience increased salience of time due to the nature of college. Therefore, college students with ADHD may exhibit less impairments in temporal processing compared to community samples of adults with ADHD (Ptáček et al., 2022; Taş Dölek et al., 2021), thus reducing the correlation between ADHD symptoms and temporal processing in the present study. he weak correlation beTtween ADHD symptoms and temporal processing could be driven by heterogeneity in the presentation of core deficits in ADHD (Murray, 2006; Sonuga-Barke et al., 2010).

According to the Triple Pathway Theory, temporal processing deficits are not present in all individuals with ADHD symptoms (Sonuga-Barke et al., 2010), so it is to be expected that significant temporal processing deficits would not exist in most individuals in this sample (as the majority did not report diagnosed ADHD, and of those that did, only a portion would be expected to have temporal processing deficits). The combination of these points – the use of a non-clinical sample, the higher functioning of college students with ADHD compared to other young adults with ADHD (Kuriyan et al., 2013; von Wirth et al., 2022) and the lack of temporal processing deficits in all individuals with ADHD (Sonuga-Barke et al., 2010) – may explain the lack of associations found between temporal processing and ADHD symptoms found in this study.

ADHD and Temporal Processing

Contrary to previous research, this study did not find an association between ADHD and objective temporal processing performance. Most past research on temporal processing in

ADHD has focused on children and adolescents with ADHD (Nejati & Yazdani, 2020; Zheng et al., 2020) or adults with ADHD (Ptacek et al., 2019) and used clinical samples of individuals with diagnosed ADHD (Ptacek et al., 2019; Zheng et al., 2020). The one previous temporal processing study in college students (Prevatt et al., 2011) also relied upon a clinical sample. Use of a non-clinical college student in the present study likely increased the heterogeneity of the objective temporal processing performances and may explain why temporal processing deficits, which are well established in youth with ADHD (Nejati & Yazdani, 2020), were not found in this sample. In fact, a meta-analysis on temporal processing deficits in youth with ADHD found that age moderated temporal processing performance, such that older adolescents exhibited less temporal processing deficits than younger children (Zheng et al., 2020). In fact, some research has indicated that children, in general, are less sensitive to time and exhibit greater difficulty estimating and judging time compared to older adolescents and adults (Droit-Volet, 2013). This finding may indicate that most adults have adequate temporal processing skills based on cognitive tasks, and it is possible that children with ADHD simply are delayed in developing temporal processing skills, though these ADHD-related impairments in temporal processing subside by adulthood. In addition, adult ADHD symptom severity has been reported to not be related to temporal processing deficits (Ptáček et al., 2022). Thus, temporal processing deficits may be less prominent in adults with ADHD.

Another possibility is that a threshold effect exists for temporal processing deficits in adults with ADHD wherein a particular threshold of ADHD symptom severity may need to be eclipsed before deficits are noticed (Salum et al., 2014). Because of the nonclinical sample utilized in the present study, despite a normal distribution of ASRS scores, this threshold may not have been met to demonstrate marked temporal processing deficits related to ADHD.

Finally, the intervals selected for this study were chosen due to their frequency of use in prior ADHD temporal processing research where individuals with ADHD exhibited deficits at these intervals (Hurks & Hendriksen, 2011; Toplak et al., 2006; Walg et al., 2015). While representing the gold-standard in the field, the range of time intervals used in the present study (time reproduction: 1-5s, time estimation: 10s, 35s, 135s) may explain the lack of temporal processing deficits associated with ADHD symptoms in college students with ADHD. For example, the research regarding which time intervals individuals with ADHD are most impaired is mixed, with some studies finding that ADHD-specific temporal processing impairments are seen only in the range of milliseconds ($\geq$3000ms) rather than seconds (Anobile et al., 2022; Radonovich & Mostofsky, 2004). It is possible that ADHD symptoms may be associated with temporal processing deficits in the millisecond, rather than second, range for college students with ADHD.

ADHD and TiME Interaction on Risky Behaviors

Because only weak associations were found between ADHD symptoms and the TiME, along with the lower reliability of the TiME subscale related to subjective experience of time (implicated in the framework linking temporal processing to ERB), a lack of interaction between ADHD and self-report of temporal processing on ERB was not surprising. The hypothesis that greater temporal processing deficits would differentially impact those with greater ADHD severity in ERB was based partially on the notion that greater self-reported temporal processing deficits would be associated with greater ADHD symptoms (which was not found in the present study).

Related to ERB as an outcome in the present study, the data in this study were collected during the COVID-19 pandemic at a point where some social distancing measures and disease prevention measures (e.g., regular COVID-19 testing, online classes, regulations preventing large gatherings) were still enacted in the area the study was conducted. The mean frequency of CARE drug and alcohol use in our sample was slightly lower than those reported in college student samples collected prior to the pandemic (Copeland et al., 2009; Slavin, 2013). Research has indicated that drug and alcohol use in college students has decreased during the pandemic (Benschop et al., 2021; Firkey et al., 2021; White et al., 2020). This relatively restricted range of substance use variables may have potentially reduced the associations between study variables (e.g., ADHD symptoms, temporal processing) and ERB.

Clinical Implications

This study increases our understanding of temporal processing in college students. While still very much a nascent topic, two potential clinical implications may be worthy of consideration.

Utility of the TiME

The adequate internal consistency and preliminary concurrent validity of the TiME is promising and suggests the potential for further refinement of this instrument to fill an existing clinical void. Although computerized cognitive tasks for temporal processing are well-accepted for use in ADHD research, these tasks have yet to be utilized for clinical practice. Self-report measures are preferable for use in clinical practice because they are more time efficient, more easily administered in clinical settings, and are more predictive of impairments compared to performance-based measures (Barkley & Murphy, 2010; Kamradt et al., 2014; Knouse et al., 2013). As such, the TiME provides a potentially unique niche in clinical screening.

The TiME currently is not a valid measure to screen for ADHD. However, the TiME was significantly associated with irresponsible academic behaviors, which are associated with academic impairments (Kent et al., 2011; Langberg et al., 2016) Therefore, the TiME may be a useful tool to identify students (regardless of ADHD status) who may benefit from preventative educational supports (Claessens et al., 2007) or clinical interventions targeting time management skills, such as cognitive behavior therapy (Mongia & Hechtman, 2012; Wang et al., 2017). Future TiME research should consider the TiME's predictive validity for clinically significant outcomes (e.g., GPA, class retention, other risky behaviors) or differential diagnoses beyond ADHD (e.g., autism spectrum disorder, learning disorders) that are known to be associated with temporal processing difficulties.

Temporal Processing Deficits May Be Less Pronounced in College Students

Objective and subjective temporal processing was unrelated to ADHD symptoms in the present college student sample. It is possible that temporal processing deficits are less pronounced in college students or adults with ADHD compared to children with ADHD, who reliably exhibit such deficits (Zheng et al., 2020). This finding generates a more in-depth picture of how ADHD presents in college students and how temporal processing deficits present in adults with ADHD. Clinicians should be aware of the potential existence of temporal processing deficits in college with ADHD but may choose to put less emphasis on remediating temporal processing deficits in college students with ADHD compared to youth with ADHD.

Limitations and Future Directions

These results need to be considered in the context of several methodological limitations.

Continued Validation of TiME and Ecological Validity of Temporal Processing

The psychometrics of the TiME assessed in this study were adequate and measured using sound methodology, yet continued validation of the TiME is necessary to establish the stability and utility of the measure. Best practices in scale development research recommend measuring test-retest reliability (Boateng et al., 2018), which was not completed in the present study due to logistical constraints with conducting longitudinal research to measure test-retest reliability. Future research should collect test-retest data on the TiME to gain stability of the measure over time. Establishing greater criterion validity for the TiME is another important step in validating the TiME, and measuring the correlation between self-report on the TiME and ecologically valid behaviors relevant to temporal processing, such as tardiness, late or missing work assignments (Langberg et al., 2011), may be particularly useful in determining the real-world utility of the measure. To date, no studies have directly examined the associations between temporal processing and academic outcomes in college students, though there is some evidence to suggest that temporal processing deficits may be linked to academic impairments. For example, temporal processing deficits in children are associated with greater academic difficulties, including mathematics (Hurks & van Loosbroek, 2014) and reading difficulties (Toplak et al., 2003; Zheng et al., 2022). Future research should consider the predictive validity of the TiME towards academic impairments.

Online versus In-person Research

Data were collected during the COVID-19 pandemic when university regulations required a halt to in-person data collection. Because of this, the present study was conducted fully online. Virtual studies have the merits of, at times, being more efficient and cost effective yet can pose challenges to experimental control, especially in designs using cognitive tasks (Hensen et al., 2021). Many steps were taken to maximize the validity of the data, including utilizing a university server that limits the number of bots that may access the study, providing clear instructions to participants about study procedures, adding attention check and validity check items to the study (Tiersma et al., 2022), and utilizing the data validity features of

InquisitWeb. Nonetheless, the virtual nature of the study meant there was no true experimental control over how participants completed the study. It is possible that during the objective temporal processing tasks participants were using the stopwatch on their phone or not utilizing the sound on their computers. These behaviors may reduce the quality of the objective temporal processing data, though these effects are likely to be random (e.g., no more likely to occur in one type of demographic of participant compared to others). In-person research would have more stringent control over these factors, and future research should seek to continue assessing temporal processing in college students with ADHD in a laboratory setting. Another future direction for maximizing validity in remote research utilizing cognitive tasks may be to observe cognitive tasks remotely, such that participants complete the cognitive tasks over Zoom with a researcher present to proctor the administration of the exams. This hybrid model may allow for the researcher to minimize the use of phones or other distractions during remote administrations of cognitive tasks.

Measurement of ADHD

One limitation of the present study that informs a future direction of research is the measurement of ADHD symptoms. Due to an error in the upload of measures to Qualtrics, two items were unintentionally left off of the ASRS: "How often do you have difficulty waiting your turn in situations when turn taking is required?" and "How often do you interrupt others when they are busy?" These two items are part of the Hyperactivity/Impulsivity subscale of the ASRS, and more specifically, measure impulsivity (Kessler et al., 2007). Of note, a perplexing result in this study was the lack of associations between delay aversion (measured on the QDQ), impulsivity (measured on the UPPS-P), and ADHD symptoms. Because the items left off the ASRS were measuring ADHD-related impulsivity (Kessler et al., 2007), it is possible that the correlation between these measures were artificially reduced due to the error. Thus, the results from this study may underestimate the relationship between Hyperactive/Impulsive ADHD symptoms and other study variables. Nevertheless, the ASRS in the analyses demonstrated strong internal consistency, and contained all items on the Inattention subscale. Additionally, the ASRS-6, which is the short-form of the ASRS that contains the items that are most strongly predictive of a clinical diagnosis of ADHD (Kessler et al., 2005) does not contain these two items. Future research should be sure to assess ADHD symptoms using the full ASRS measure and implement both the categorical and dimensional approach to studying ADHD. Although the dimensional approach has gained traction in the field of ADHD research (Marcus & Barry, 2011), the categorical approach (ADHD vs. non-ADHD) is still quite common in research. The use of both the categorical and dimensional approach may be the best practice to gain a more holistic understanding of the heterogeneity of ADHD (Elton et al., 2014).

ADHD-related Cognitive Processes and Temporal Processing

As a highly heterogeneous disorder, ADHD has been associated with executive functioning (Dvorsky & Langberg, 2019b) and processing speed deficits (Kibby et al., 2019) in college students. Both working memory (Zakay & Block, 2004) and processing speed (Barkley & Fischer, 2019; Walg et al., 2017) have been implicated in cognitive models for temporal processing, affecting the internal "storage" of elapsed time. Direct associations between ADHD symptoms and temporal processing were not found in the present study, and it is possible that these related skills (e.g., processing speed, working memory) may be more strongly associated with ADHD in college students than temporal processing ability itself. Investigating the manifestation of these other cognitive processes along with temporal processing in college students with ADHD may elucidate a greater understanding of the disorder and factors that most contribute to impairments.

Conclusion

Overall, this study provided preliminary support for the reliability and some concurrent validity of a novel self-report measure of temporal processing. In addition, results supported a positive association between temporal processing self-report (via the TiME) and greater engagement in academic risk behaviors. The lack of associations between ADHD symptoms and temporal processing abilities may indicate that temporal processing deficits are less pronounced in the college student population. Future research should continue to investigate if temporal processing deficits are present in college students with ADHD and how best to measure temporal processing in a clinical setting.

Tables and Figures

Table 1

Order of Included Measures

Measure	Construct	Use
ADHD Adult Rating Scale	ADHD symptom frequency/severity	Hypothesis 1 - discriminant validity Hypothesis 2 – outcome variable Hypothesis 3 – predictor variable
Time Estimation	Objective temporal processing	Hypothesis 1 – concurrent validity Hypothesis 2 – predictor variable Hypothesis 3 – predictor variable
Temporal Reproduction	Objective temporal processing	Hypothesis 1 – concurrent validity Hypothesis 2 – predictor variable Hypothesis 3 – predictor variable
Quick Delay Questionnaire	Delay aversion	Hypothesis 2 – covariate Hypothesis 3 – covariate
UPPS-P* (composite of lack of premeditation, positive urgency, and negative urgency subscales)	Inhibitory control	Hypothesis 2 – covariate Hypothesis 3 – covariate
Time Management and Experience Scale	Subjective temporal processing - Subjective experience of time - Temporal self-regulation	Hypothesis 1 – scale development Hypothesis 2 – predictor variable Hypothesis 3 – predictor variable
Cognitive Appraisal of Risky Events	Engagement in risk behavior	Hypothesis 3 – outcome
Tuckman Procrastination Scale	Procrastination	Hypothesis 1 – concurrent validity
Demographics	Demographic items	Descriptive

Note. Measures were presented in the order listed on this table. The time estimation and time reproduction tasks were directly embedded into the online study through InquisitWeb. The remaining measures were directly embedded into the online study as Qualtrics surveys.

*UPPS-P - Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency, Impulsive Behavior Scale

Table 2

List of Included Measures and Use in Hypothesis Testing

Hypothesis	Measures Included	Analyses
H1	ADHD Adult Rating Scale Temporal Reproduction Task Time Estimation Task Time Management and Experience Scale Tuckman Procrastination Scale	Factor analysis of TiME Cronbach's alpha of TiME and subscales Bivariate correlation matrix of TiME, ASRS, TPS, time estimation, and temporal reproduction
H2	ADHD Adult Rating Scale Age Quick Delay Questionnaire Reported ADHD Medication Use Temporal Reproduction Task Time Estimation Task Time Management and Experience Scale UPPS-P* Composite	Hierarchical linear regression Step 1: Covariates (age, reported ADHD medication use, QDQ, UPPS-P) → Y (ASRS) Step 2: X1 (time estimation accuracy) + X2 (temporal reproduction accuracy) + X3 (temporal reproduction coefficient of variation) + X4 (TiME) → Y (ASRS)
H3	ADHD Adult Rating Scale Age Cognitive Appraisal of Risky Events Quick Delay Questionnaire Reported ADHD Medication Use Temporal Reproduction Task Time Estimation Task Time Management and Experience Scale UPPS-P* Composite	Negative binomial regression X1 (time estimation accuracy) + X2 (temporal reproduction accuracy) +X3 (temporal reproduction coefficient of variation) + X4 (TiME) + X5 (ASRS) + Covariates (age, reported ADHD medication use, QDQ, UPPS-P)→ Y (CARE subscale*) For H3b, interaction term (ASRS x TiME) is added as a predictor variable to the above model

Note: ASRS, ADHD Adult Rating Scale; CARE, Cognitive Appraisal of Risky Events; QDQ, Quick Delay Questionnaire; TiME, Time Management and Estimation Scale; UPPS-P - UPPS-P - Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency, Impulsive Behavior Scale

*Separate regressions will be run for each include CARE subscale (e.g., risky sexual behavior, heavy drinking, illicit drug use, aggressive and illegal behaviors, irresponsible academic/work behaviors)

Table 3

Demographic Characteristics and Descriptive Variables

	ADHD (*n*=17)	No ADHD (*n*=198)	Total Sample (*N*=215)
	n (%)	n (%)	n (%)
Year in School	1.23 (0.60)	1.40 (0.81)	
Year 1	12 (70.6)	150 (75.8)	162 (75.3)
Year 2	2 (11.8)	30 (15.2)	32 (14.9)
Year 3	1 (5.9)	12 (6.1)	13 (6.0)
Year 4	1 (5.9)	5 (2.5)	6 (2.8)
Year 5	1 (5.9)	1 (0.5)	2 (0.9)
Gender			
Female	8 (47.1)	116 (58.6)	124 (55.7)
Male	8 (47.1)	80 (40.4)	88 (40.9)
Nonbinary	0 (0)	1 (0.5)	1 (0.5)
Genderfluid	1 (5.9)	0 (0)	1 (0.5)
Other not listed	0 (0)	1 (0.5)	1 (0.5)
Race			
White	7 (41.2)	128 (64.4)	135 (62.8)
Asian	4 (23.5)	24 (12.1)	28 (13.0)
Biracial	2 (11.8)	17 (8.6)	19 (8.8)
Black	2 (11.8)	12 (6.1)	14 (6.5)
Hispanic	0	12 (6.1)	12 (5.6)
Native American	1 (5.9)	3 (1.5)	4 (1.9)
Other not listed	1 (5.9)	1 (0.5)	2 (0.9)
Middle Eastern	0 (0)	1 (0.5)	1 (0.5)
	M (SD)	M (SD)	M (SD)
Age	18.54 (0.66)	18.77 (1.04)	18.75 (1.01)
ADHD Self Report Scale 6-item Screener**	15.08 (1.93)	11.21 (3.52)	11.45 (3.55)
Depression Anxiety Stress Scale-21*	22.69 (17.52)	17.88 (12.88)	18.17 (13.20)
Tuckman Procrastination Scale	50.08 (8.29)	50.41 (9.27)	50.39 (9.19)
UPPS-P Composite			
Lack of Premeditation	23.31 (5.81)	23.47 (4.40)	23.46 (4.48)
Positive Urgency	30.69 (6.05)	29.30 (5.43)	29.39 (5.47)
Negative Urgency	28.28 (5.96)	28.46 (6.07)	28.45 (6.05)
Quick Delay Questionnaire	32.08 (3.23)	31.24 (3.50)	31.29 (3.46)
Cognitive Appraisal of Risky Events			
Drug Use	19.62 (36.21)	27.55 (117.73)	27.07 (114.49)
Alcohol Use	16.31 (24.21)	10.57 (18.34)	10.92 (18.63)
Irresponsible Academic Behavior	31.67 (40.63)	31.02 (40.94)	31.29 (40.51)
Risky Sexual Behavior	8.69 (12.66)	8.52 (18.34)	8.54 (18.02)
Aggressive Behavior	9.77 (12.22)	9.31 (21.74)	9.33 (21.24)

Note: *$p<.05$, **$p<.001$ADHD, attention deficit/hyperactivity disorder; UPPS-P, Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency, Impulsive Behavior Scale

Table 4

Bivariate Correlation Matrix of Descriptive Variables

	Variable	1	2	3	4	5	6	7	8	9	10
1	Age	1.0									
2	Year in School	.79***	1.0								
3	ASRS v1.1 total	.00	-.04	1.0							
4	ADHD Inattention	-.05	-.09	.92***	1.0						
5	ADHD Hyperactivity/Impulsivity	.05	.04	.89***	.64**	1.0					
6	DASS-21	.17*	.14*	.04	.01	.06	1.00				
7	Quick Delay Questionnaire	.14*	.20*	.08	.07	.08	.06	1.0			
8	UPPS-P Positive Urgency	-.03	-.01	-.001	.04	-.05	.31**	.08	1.0		
9	UPPS-P Negative Urgency	.08	.04	.08	.07	.08	.51**	.23**	.30**	1.0	
10	UPPS-P Lack of Premeditation	.14*	.11	.08	.08	.07	.01	.02	.30**	.59**	1.0

Note: *p<.05,** p<.01;p<.001 ADHD, Attention Deficit/Hyperactivity Disorder; ASRS, Adult ADHD Self-report Scale; DASS-21, Depression, Anxiety and Stress Scale - 21 Items; UPPS-P, Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency, Impulsive Behavior Scale

Table 5

Bivariate Correlation Matrix of Linear Regression Variables

	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	ASRS v1.0	1.0														
2	ASRS Inattention	.92***	1.0													
3	ASRS H/I	.89***	.64**	1.0												
4	ADHD Medication Use	-.10	-.14	-.04	1.0											
5	Time Estimation Accuracy	.10	.16*	.002	.25	1.0										
6	Time Reproduction Accuracy	.06	.06	.04	.06	.002	1.0									
7	Time Reproduction CV	.01	-.01	.04	-.31	-.03	.23**	1.0								
8	TiME Total	.08	.03	.13	.40	.01	-.04	-.06	1.0							
9	UPPS-P	.09	.08	.09	-.13	-.02	.03	.07	.29**	1.0						
10	Quick Delay Questionnaire	.08	.08	.07	-.10	-.05	-.01	.11	.06	.19**	1.0					
11	CARE Drug Use	.07	.01	.12	-.38	-.09	-.02	-.03	.06	.12	.19**	1.0				
12	CARE Alcohol Use	.10	.12	.05	-.15	-.02	-.09	.001	-.06	.09	-.04	.25**	1.0			
13	CARE Academic Risk	.03	.01	.05	-.11	-.11	-.02	.06	-.13	-.13	-.06	.15*	.11	1.0		
14	CARE Risky Sex	.03	.02	.04	-.22	-.05	-.05	-.03	.04	.10	-.01	.25**	.62**	.09	1.0	
15	CARE Aggressive Behaviors	.11	.09	.11	.25	-.05	.46**	.15*	-.11	-.06	-.05	.06	.26**	.28**	.33**	1.0

Note: **p*<.05, ***p*<.01, ****p*<.001; ADHD, Attention Deficit/Hyperactivity Disorder; ASRS, Adult ADHD Self Report Scale; CARE, Cognitive Appraisal of Risky Events, CV, coefficient of variation; H/I, Hyperactivity/Impulsivity; TiME, Time Management and Experience Scale; UPPS-P, Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency, Impulsive Behavior

Table 6

Inter-item Correlation Matrix of TiME Scale

Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1.0																			
2	.50**	1.0																		
3	.30**	.65**	1.0																	
4	.23**	.26**	.04	1.0																
5	.38**	.46**	.45**	.14*	1.0															
6	.38**	.59**	.43**	.12	.42**	1.0														
7	-.129	-23**	-.19**	-.19**	-.24**	-.23**	1.0													
8	.31**	.38**	.31**	.38**	.34**	.42**	-.40**	1.0												
9	-.09	-.09	-.08	-.08	.40	-.18**	-.31**	-.14*	1.0											
10	.54**	.36**	.25**	.09	.24**	.30**	-.21**	.21**	-.10	1.0										
11	.34**	.37**	.33**	.11	.15*	.27**	-.02	.20**	-.04	.38**	1.0									
12	.60**	.41**	.29**	.22**	.40**	.41**	-.23**	.38**	-.06	.62**	.39**	1.0								
13	.11	.23**	.17*	.002	.09	.13	.01	.07	.03	.03	.15*	.06	1.0							
14	.13	.23**	.19**	.14*	.36**	.25**	-.21**	.34**	.18**	.13	-.04	.23**	.10	1.0						
15	.19**	.25**	.22**	.17*	.43**	.29**	-.16*	.37**	.09	.09	.04	.30**	.09	.46**	1.0					
16	.06	.07	.09	.17*	.15*	.20**	-.14*	.29**	-.16*	-.04	-.01	.20**	-.12	.21**	.39**	1.0				
17	.01	.12	.15*	.09	.22**	.19**	.08	.15*	.07	.16*	.08	.15*	-.06	.38**	.38**	.23**	1.0			
18	-.17*	-.24**	-.12	-.31**	-.26**	-.29**	.54**	-.47**	.28**	-.14*	.07	-.20**	.04	-.26**	-.32**	-.24**	.05	1.0		
19	.40**	.57**	.36**	.35**	.42**	.55**	-.24**	.42**	-.17*	.28**	.32**	.44**	.16*	.34**	.44**	.35**	.24**	-.39**	1.0	
20	.35**	.72**	.50**	.25**	.40**	.58**	-.16*	.32**	-.03	.23**	.25**	.29**	.23**	.22**	.13	.08	.08	-.16*	.50**	1.0

Note: *$p<.05$, **$p<.01$; TiME, Time Management and Experience Scale

Table 7
Factor Structure and Description of TiME Scale

	M(SD)	Factors				
		Self-Regulation	Time Pressure	Orientation to Time	Subjective Experience	h^2
2. I allow myself enough time to complete my work and assignments before the deadline.[R]	3.24 (1.38)	**.874**	.039	.065	-.039	.826
3. I often find myself completing assignments at the last minute.	4.28 (1.34)	**.675**	-.025	.014	.028	.470
5. I am often pressed for time.	3.81 (1.26)	**.339**	-.337	.139	-.053	.408
6. I often find it difficult to complete assignments on time.	3.08 (1.42)	**.529**	-.148	.120	-.132	.502
19. I have trouble managing my daily schedule.	3.08 (1.44)	**.418**	-.335	.127	-.166	.550
20. I usually give myself enough time to complete my work before the deadline. [R]	3.21 (1.41)	**.853**	.058	-.072	.002	.640
14. I rarely have enough time in a day.	3.57 (1.40)	.104	**-.581**	-.015	.-018	.384
15. I find that it usually takes me longer to complete tasks than I originally predicted.	3.86 (1.35)	.024	**-.767**	.032	-.016	.618
16. I rarely know how much time is left in class without looking at a clock.	3.58 (1.28)	-.052	**-.468**	-.014	-.150	.247
17. It usually feels like time is passing too quickly.	3.62 (1.29)	.022	**-.527**	.041	.216	.299
1. I am a punctual person. [R]	2.84 (1.40)	.145	.018	**.639**	-.039	.537
10. I typically arrive to class on time. [R]	2.12 (1.11)	-.073	.057	**.784**	-.053	.560

	M(SD)	Self-Regulation	Time Pressure	Orientation to Time	Subjective Experience	h^2
11. I follow a set routine when getting ready in the morning. [R]	2.87 (1.49)	.210	.110	**.447**	.141	.312
12. I am rarely ready to leave on time.	2.82 (1.39)	-.116	-.194	**.849**	-.052	.740
7. It usually feels like time is moving slowly. [R]	3.93 (1.29)	-.032	.042	-.056	**.661**	.479
8. I often lose track of time. [R]	3.52 (1.27)	.177	-.311	.128	**.374**	.447
9. I usually feel like I have too much time on my hands. [R]	4.27 (1.27)	-.024	-.189	-.035	**.466**	.231
18. It takes a long time to get through the day.	3.77 (1.25)	-.030	.252	.053	**.724**	.647

		Factors			
	Total TiME	Self-Regulation	Time Pressure	Orientation to Time	Subjective Experience
Eigenvalue		5.818	2.019	1.673	1.297
% total VAF	60.041	32.320	11.219	9.297	7.205
Cronbach's Alpha	0.796	0.861	0.675	0.775	0.688
		Correlations Among Factors			
Self-Regulation	.869**	1.0	.407**	.555**	-.121
Subjective Experience	.631**		1.0	.191**	.010
Time Orientation	.735**			1.0	-.024
Time Pressure	.157*				1.0

Note: **p*<.05, ***p*<.01; [R] denotes reverse scored items; TiME, Time Management and Experience Scale

Table 8
TiME Scale Correlations with Validity Constructs

		Factors			
	Total TiME	Self-Regulation	Time Pressure	Orientation to Time	Subjective Experience
ASRS v1.1	.06	.09	.12	.04	-.10
ASRS Inattention	.01	.05	.06	-.02	-.06
ASRS Hyperactivity/Impulsivity	.11	.13	16*	.10	-.13
Tuckman Procrastination Scale	.64**	.65**	.52**	.36**	-.11
Time Reproduction Accuracy	-.04	-.01	-.07	-.03	-.05
Time Estimation Accuracy	.01	.11	-.03	-.08	-.05

Note: **p*<.05, ***p*<.01 ASRS, Attention Deficit/Hyperactivity Disorder Self Report Scale; TiME, Time Management and Experience Scale

Table 9

Temporal Processing Abilities Among College Students with and without ADHD

	ADHD M (SD)	No ADHD M (SD)	*df*	*t*	*p*	*Cohen's d*
TiME Scale						
Temporal Self-Regulation	22.64 (4.96)	20.55 (6.42)	213	1.315	.190	.332
Time Pressure	14.59 (2.85)	14.63 (3.86)	213	.045	.964	.011
Orientation to Time	10.47 (3.34)	10.66 (4.25)	213	.180	.857	.046
Subjective Experience of Time	14.71 (2.44)	15.55 (2.62)	213	1.273	.204	.322
TiME Total Score	62.41 (9.72)	61.38 (11.52)	213	.357	.722	.090
Time Estimation						
5s	13.00 (3.87)	12.96 (6.96)	213	.025	.060	.006
35s	37.50 (11.48)	39.42 (14.99)	213	.490	.092	.130
135s	146.75 (24.87)	134.11 (37.8)	213	1.560	.160	.393
Time Reproduction						
1s	1.65 (1.79)	1.25 (0.92)	213	1.582	.016	.400
2s	2.65 (1.87)	1.99 (0.95)	213	2.489	.005	.629
3s	3.27 (1.57)	2.62 (0.93)	213	2.599	.014	.657
4s	3.90 (2.34)	3.16 (0.95)	213	2.631	.017	.665
5s	4.53 (2.41)	3.75 (0.99)	213	2.661	.042	.673
Coefficient of variation	0.31 (0.30)	0.23 (0.17)	213	1.509	.025	.432

Note: ADHD, attention deficit/hyperactivity disorder; TiME, Time Management and Experience Scale

Table 10

Hierarchical Linear Regression for Hypothesis 2

Model	Variable	β	t	R	ΔR^2	ΔF	*p*-value
1	Overall Model			.497	.247	1.433	.492
	Quick Delay Questionnaire	.066	.955				.341
	UPPS-P	.083	1.198				.232
	ADHD Medication Use	-.099	-.318				.759
2	Overall Model			.891	.546	2.635	.234
	TiME Total	.606	2.079				.106
	Time Estimation Accuracy	1.299	1.707				.163
	Time Reproduction Accuracy	-.659	-1.719				.161
	Time Reproduction CV	1.025	2.714				.053

Note: TiME, Time Management and Estimation Scale; UPPS-P - UPPS-P - Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency, Impulsive Behavior Scale

Table 11

Negative Binomial Regressions for Hypothesis 3

Drug Use

Variable	*B*	*SE*	*p*	OR	95% CI
Age	-.466	12.345	.148	.627	(.334, 1.180)
ADHD medication use	1.765	1.554	.256	5.844	(.278, 12.746)
Quick Delay Questionnaire	.097	.714	.892	1.101	(.272, 4.467)
UPPS-P	.039	.099	.696	1.039	(.856, 1.261)
ASRS	.068	.086	.427	1.071	(.905, 1.268)
TiME	-.103	.056	.069	.902	(.808, 1.008)
Time Estimation Accuracy	.060	.119	.613	1.062	(.841, 1.342)
Time Reproduction Accuracy	-1.976	3.096	.523	.139	(.045, 9.856)
Time Reproduction CV	-4.120	6.173	.504	.016	(.009, 25.029)
ASRS*TiME	.024	.0108	.208	1.024	(1.003, 1.046)

Alcohol Use

Variable	*B*	*SE*	*p*	OR	95% CI
Age	-.097	.087	.263	.722	(.319, 1.637)
ADHD medication use	-.325	.418	.436	.908	(.766, 1.076)
Quick Delay Questionnaire	.001	.024	.976	1.001	(.955, 1.049)
UPPS-P	.016	.009	.063	1.016	(.999, 1.034)
ASRS	.003	.009	.727	1.003	(.986, 1.020)
TiME	.007	.007	.336	1.007	(.993, 1.021)
Time Estimation Accuracy	-.002	.005	.685	.998	(.989, 1.007)
Time Reproduction Accuracy	.066	.063	.299	1.068	(.943, 1.208)
Time Reproduction CV	-.689	.485	.155	.502	(.194, 1.298)
ASRS*TiME	-.026	.0159	.107	.975	(.945, 1.006)

Academic Risk

Variable	*B*	*SE*	*p*	OR	95% CI
Age	-.440	.349	.207	.644	(.325, 1.276)
ADHD medication use	2.508	1.452	.084	12.275	(.713, 21.208)
Quick Delay Questionnaire	-1.124	.634	.076	.325	(.094, 1.125)
UPPS-P	.130	.091	.150	1.139	(.954, 1.360)
ASRS	.125	.049	.010	1.133	(1.030, 1.247)
TiME	.053	.022	.015	1.054	(1.010, 1.101)
Time Estimation Accuracy	.201	.113	.074	1.223	(.981, 1.524)
Time Reproduction Accuracy	-3.595	3.070	.242	.027	(.062, 11.270)
Time Reproduction CV	-.537	6.458	.934	.585	(.008, 12.857)
ASRS*TiME Interaction	.005	.0085	.079	1.005	(.988, 1.022)

Sexual Risk

Variable	*B*	*SE*	*p*	OR	95% CI
Age	.196	.081	.015	1.217	(1.038, 1.426)
ADHD medication use	.387	.452	.392	1.473	(.607, 3.572)
Quick Delay Questionnaire	.044	.026	.089	1.044	(.993, 1.098)
UPPS-P	.011	.008	.160	1.011	(.996, 1.027)
ASRS	-.009	.009	.322	.991	(.974, 1.009)

	Variable	*B*	*SE*	*p*	OR	95% CI
	TiME	.004	.008	.552	1.004	(.990, 1.019)
	Time Estimation Accuracy	-.012	.004	.006	.988	(.979, .996)
	Time Reproduction Accuracy	.138	.085	.105	1.148	(.972, 1.356)
	Time Reproduction CV	.085	.499	.865	1.088	(.409, 2.894)
	ASRS*TiME Interaction	-.003	.0116	.779	.997	(.974,1.020)
Aggressive Behaviors						
	Variable	*B*	*SE*	*p*	OR	95% CI
	Age	.110	.089	.215	1.117	(.938, 1.330)
	ADHD medication use	-.469	.4147	.258	.626	(.278, 1.411)
	Quick Delay Questionnaire	-.027	.0225	.229	.973	(.931, 1.017)
	UPPS-P	.006	.0084	.468	1.006	(.990, 1.023)
	ASRS	.001	.0088	.879	1.001	(.984, 1.019)
	TiME	-.005	.0081	.506	.995	(.979, 1.011)
	Time Estimation Accuracy	-.011	.0046	.018	.989	(.980, .998)
	Time Reproduction Accuracy	.140	.0882	.113	1.150	(.968, 1.367)
	Time Reproduction CV	-.333	.4963	.503	.717	(.271, 1.896)
	ASRS*TiME Interaction	-.039	.0158	.140	.962	(.933, .992)

Note: ASRS, Attention Deficit/Hyperactivity Disorder Adult Self-report Scale; CI, confidence interval; CV, coefficient of variation; OR, odds ratio; TiME, Time Management and Estimation Scale; UPPS-P - UPPS-P - Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency, Impulsive Behavior Scale

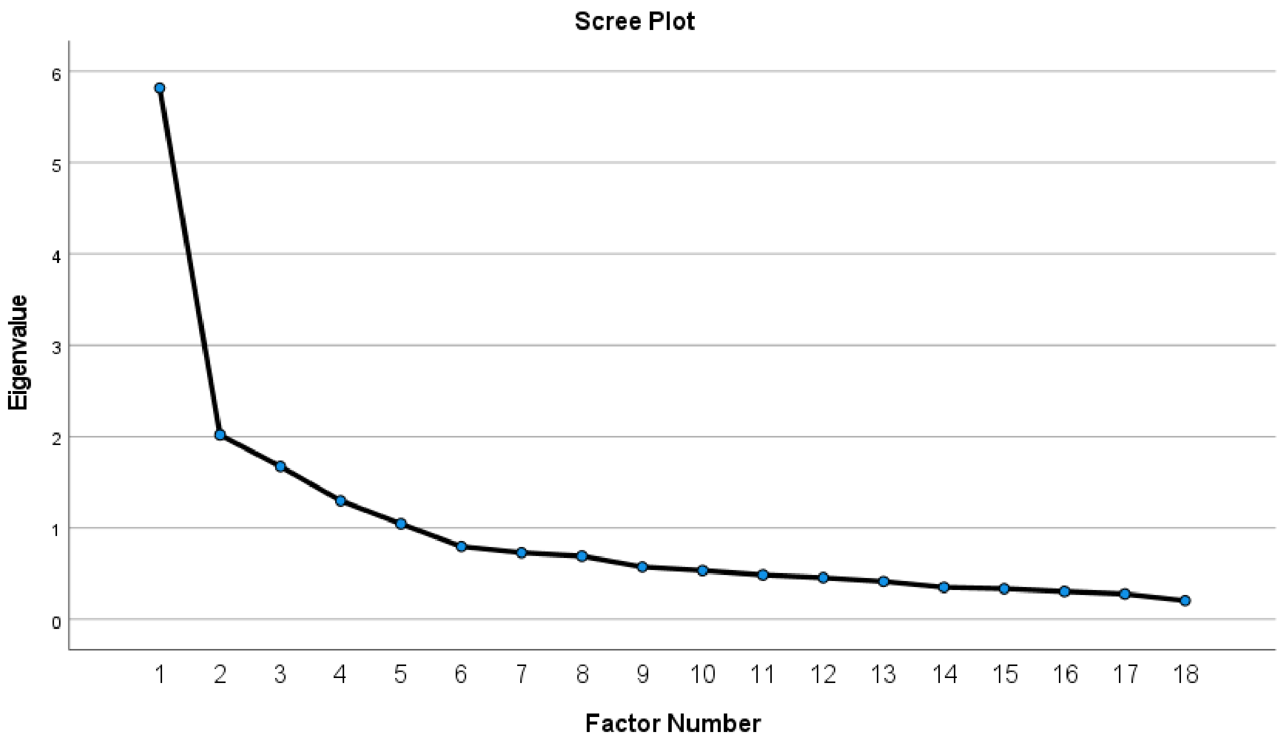
Table 12
Support for Hypotheses

Hypothesis		***Support Determination***	
H1	The TiME will have satisfactory internal consistency, concurrent validity with the objective cognitive measures of temporal processing and with a conceptually relevant, related construct (procrastination), discriminant validity for ADHD	Partially Supported	TiME is reliable and demonstrated adequate internal consistency (α=.74). TiME exhibited concurrent validity with procrastination (r=.64), but no validity with objective temporal processing or ADHD.
H2	Greater ADHD severity will be associated with greater objective temporal processing deficits and a subjective experience of time passing slowly	Not Supported	ADHD symptoms were not significantly associated with objective temporal processing deficits nor subjective, self-report of temporal processing.
H3a	Objective temporal processing deficits and a subjective experience of time passing more slowly will be associated with greater ERB	Partially Supported	Subjective temporal processing was associated with greater engagement in irresponsible academic behavior. Accurate objective time estimation performance was associated with decreased sexual risk and aggressive behavior.
H3b	ADHD severity will exacerbate the relationship between the subjective experience of time passing slowly and ERB	Not Supported	ADHD symptom severity did not moderate the relationship between subjective experience of time and ERB.

Note: ADHD, Attention Deficit/Hyperactivity Disorder; ERB, Engagement in Risky Behaviors

Figure 1

Scree Plot for Time Management and Estimation Scale Development



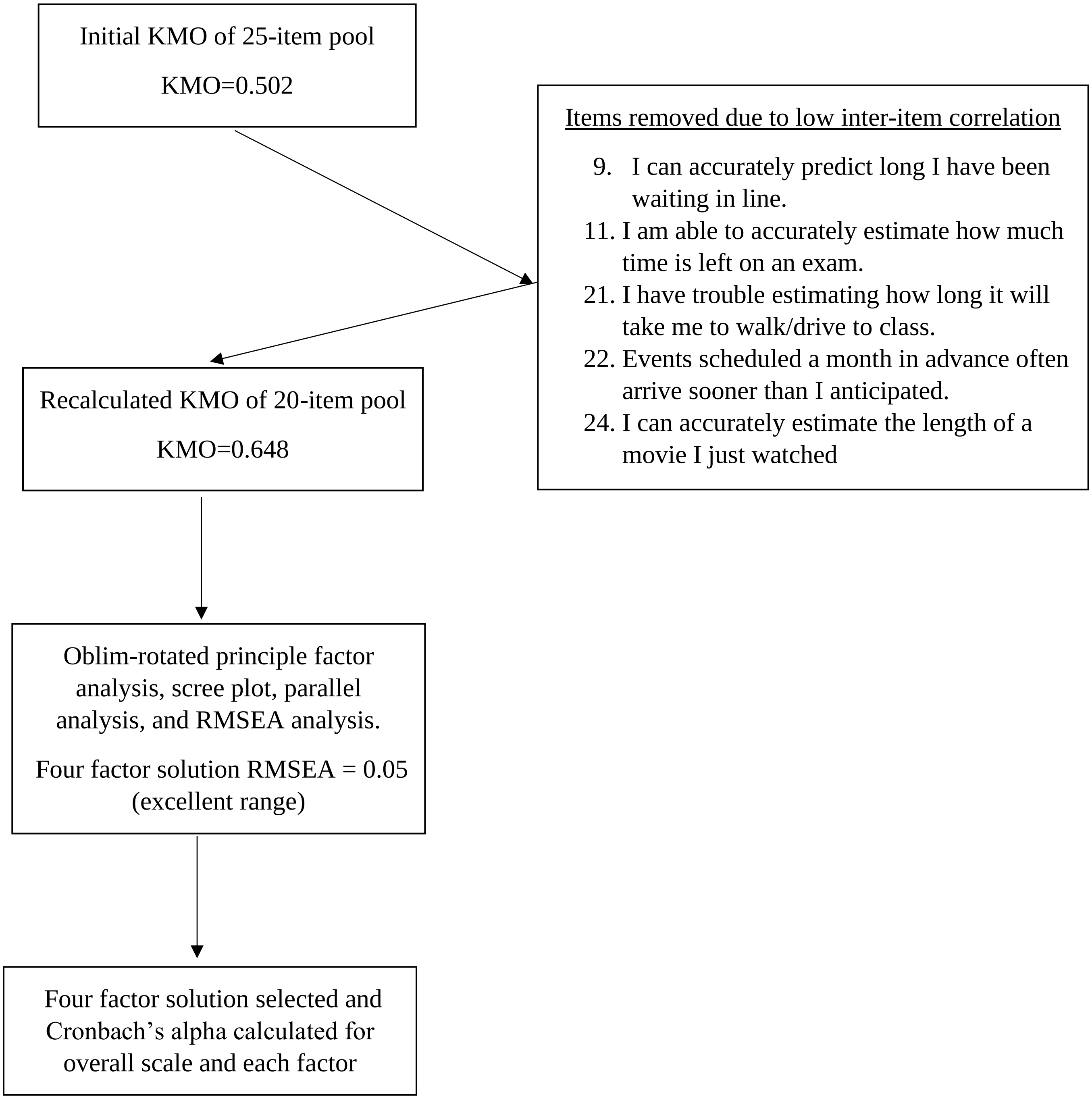
Appendices: TiME Pilot Testing and Measures

Appendix I: Time Management and Estimation (TiME) Scale Initial Item Pool

Instructions: Please read the following statements carefully and rate your agreement with how much each statement describes you using the following scale: 1 – Strongly Disagree, 2 – Disagree, 3 – Slightly Disagree, 4 – Slightly Agree, 5 – Agree, 6 – Strongly Agree

1. I am a punctual person.
2. I am able to determine how much time it will take me to complete my homework.
3. I often find myself completing assignments at the last minute.
4. I usually have an accurate idea of what time it is without looking at a clock.
5. I don’t know what to do with my time.
6. I often find it difficult to complete assignments on time.
7. In class, it feels like time is moving very slowly.
8. I rarely know how much time is left in class without looking at the clock.
9. I can accurately predict long I have been waiting in line.
10. I often lose track of time
11. I am able to accurately estimate how much time is left on an exam.
12. I usually feel like I have too much time on my hands.
13. I usually arrive to class on-time.
14. I follow a set routine when getting ready in the morning
15. I have difficulty getting ready to leave for class/work on time.
16. I wake up right before my alarm goes off in the morning
17. I rarely have enough time in a day.
18. I find that it usually takes me longer to complete assignments than I originally predicted.
19. I have trouble managing my daily schedule.
20. I feel like time is passing too quickly.
21. I have trouble estimating how long it will take me to walk/drive to class.
22. Events scheduled a month in advance often arrive sooner than I anticipated.
23. I don’t know what to do with my time.
24. I can accurately estimate the length of a movie I just watched
25. I have trouble managing my daily schedule.

Appendix II: Initial TiME Factor Analysis Steps



Appendix III: Initial TiME Factor Analysis Results

		Factors				
	M(SD)	Self-Regulation	Subjective Experience	Time Orientation	Time Pressure	h^2
1. I am a punctual person	4.01 (1.27)	**.863**	.066	.155	.150	.782
13. I usually arrive to class on-time	4.79 (1.04)	**.675**	-.062	-.152	.056	.435
2. I usually arrive to class on time.	4.27 (1.04)	**.534**	-.079	-.307	-.174	.383
14. I follow a set routine when getting ready in the morning	4.1 (1.28)	**.512**	.469	.003	.149	.544
15. I have difficulty getting ready to leave for class/work on time. (R)	3.73 (1.39)	**.469**	.031	.259	-.194	.403
25. I have trouble managing my daily schedule. (R)	4.01 (1.15)	**.399**	.166	.328	-.308	.501
12. I usually feel like I have too much time on my hands. (R)	4.15 (1.16)	-.410	**.749**	-.121	.023	.592
23. I don't know what to do with my time. (R)	4.05 (1.11)	-.014	**.714**	.308	.011	.544
7. It feels like time is moving very slowly. (R)	4.27 (1.19)	-.018	**.568**	-.192	-.329	.488
17. I rarely have enough time in a day	3.75 (1.17)	.002	**.523**	-.216	.182	.385
10. I often lose track of time.	3.13 (1.25)	.051	.163	**0.837**	-0.213	.804
19. I rarely know how much time is left in class without looking at a clock.	3.34 (1.22)	-.014	-.063	**0.649**	-0.12	.435
20. I feel like time is passing too quickly.	4.21 (1.24)	.124	.229	**-0.503**	0.105	.363

4. I usually have an accurate idea of what time it is without looking at a clock.	3.62 (1.19)	-.016	-.053	**0.486**	0.142	.248
5. I am often pressed for time.	3.65 (1.25)	-.081	.117	-.096	**0.639**	.470
16. I wake up right before my alarm goes off in the morning.	3.17 (1.28)	.233	-.078	.118	**0.454**	.231
18. I find that it usually takes me longer to complete assignments than I originally predicted.	3.25 (1.22)	.066	-.080	.091	**-0.446**	.239
6. I often find it difficult to complete assignments on time.	3.04 (1.13)	-.332	-.008	.011	**0.443**	.363
3. I often find myself completing assignments at the last minute.	3.85 (1.34)	-.345	-.148	-.262	**0.364**	.445
		Factors				
		Self-Regulation	Subjective Experience	Time Orientation	Time Pressure	
Rotated Eigenvalue		2.852	2.251	2.449	1.932	
% total VAF		15.01%	11.85%	12.89%	10.17%	
Cronbach's Alpha		.770	.709	.196	.170	
		Correlations Among Factors				
Self-Regulation		-	0.154	0.109	-0.195	
Subjective Experience			-	-0.126	-0.037	
Time Orientation				-	-0.126	
Time Pressure					-	

Appendix IV: Revising TiME Item Pool

Items Removed from Initial TiME (20-item pool):

- I allow myself enough time to arrive at appointments.
- Events scheduled a month in advance take a long time to arrive.
- I have difficulty getting ready to leave for class/work on time.
- I have trouble completing assignments in the amount of time I originally predicted.
- Events scheduled a month in advance often arrive sooner than I anticipated.

Items Added to Revised TiME:

- I allow myself enough time to complete my work and assignments before the deadline.
- I am rarely ready to leave on time.
- I find that it usually takes me longer to complete tasks than I originally predicted.
- It takes a long time to get through the day.
- I usually give myself enough time to complete my work before the deadline.

Appendix V: ADHD Adult Self-report Scale

ADHD Adult Self-report Scale (ASRS)

Please answer the questions below, rating yourself on each of the criteria shown using the scale on the right side of the page. As you answer each question, select the option that best describes how you have felt and conducted yourself over the past 6 months on a scale of: 1 – Never, 2 – Rarely, 3 – Sometimes, 4 – Often, 5 – Very Often

1. How often do you have trouble wrapping up the final details of a project, once the challenging parts have been done?
2. How often do you have difficulty getting things in order when you have to do a task that requires organization?
3. How often do you have problems remembering appointments or obligations?
4. How often do you fidget or squirm with your hands or feet when you have to sit down for a long time?
5. When you have a task that requires a lot of thought, how often do you avoid or delay getting started?
6. How often do you feel overly active and compelled to do things, like you were driven by a motor?
7. How often do you make careless mistakes when you have to work on a boring or difficult project?
8. How often do you have difficulty keeping your attention when you are doing boring or repetitive work?
9. How often do you have difficulty concentrating on what people say to you, even when they are speaking to you directly?
10. How often do you misplace or have difficulty finding things at home or at work?
11. How often are you distracted by activity or noise around you?
12. How often do you leave your seat in meetings or other situations in which you are expected to remain seated?
13. How often do you feel restless or fidgety?
14. How often do you have difficulty unwinding and relaxing when you have time to yourself?
15. How often do you find yourself talking too much when you are in social situations?
16. When you're in a conversation, how often do you find yourself finishing the sentences of the people you are talking to, before they can finish them themselves?

Additional ADHD Items

Please answer the following questions about your history of ADHD diagnosis. Yes – 1, No – 2

1. Have you ever been diagnosed with Attention-Deficit/Hyperactivity Disorder (ADHD) *or* Attention Deficit Disorder (ADD) by a medical or mental health professional?
2. Have you ever been prescribed medication for ADHD?
3. Do you currently take medication for ADHD?
4. Did you take your medication for ADHD today?

Appendix VI: Quick Delay Discounting

Quick Delay Discounting

Please answer the questions below, rating yourself on each of the criteria shown using the scale on the right side of the page. As you answer each question, select the option that best describes you: 1 – Not like me at all, 2 – Somewhat unlike me, 3 – Neither like or unlike me, 4 – Somewhat like me, 5 – Very like me

1. Even if I have to wait a long time for something I won’t give up if it is important to me.
2. I am usually calm when I have to wait in queues.
3. I will often chooses a task because it is beneficial in the long term even if it doesn’t offer immediate reward.
4. I feel relaxed when waiting for things.
5. I often give up on things that I cannot have immediately.
6. I hate waiting for things.
7. I try to avoid tasks that will only benefit me in the long term and don’t have any immediate benefits.
8. I feel frustrated when I have to wait for someone else to be ready before I can do something.
9. Having to wait for things makes me feel stressed and tense.
10. The future is not important to me, I only consider the immediate consequences of my actions

Appendix VII: UPPS-P Scale

UPPS-P

Below are a number of statements that describe ways in which people act and think. For each statement, please indicate how much you agree or disagree with the statement, using the following scale: Strongly Disagree – 1, Disagree – 2, Agree – 3, Strongly Agree – 4

1. I have a reserved and cautious attitude toward life.
2. I have trouble controlling my impulses.
3. When I am very happy, I can't seem to stop myself from doing things that can have bad consequences.
4. My thinking is usually careful and purposeful.
5. I have trouble resisting my cravings (for food, cigarettes, etc.).
6. When I am in great mood, I tend to get into situations that could cause me problems.
7. I am not one of those people who blurt out things without thinking.
8. I often get involved in things I later wish I could get out of
9. When I am very happy, I tend to do things that may cause problems in my life.
10. I like to stop and think things over before I do them.
11. When I feel bad, I will often do things I later regret in order to make myself feel better now.
12. I tend to lose control when I am in a great mood.
13. I don't like to start a project until I know exactly how to proceed.
14. Sometimes when I feel bad, I can't seem to stop what I am doing even though it is making me feel worse.
15. When I am really ecstatic, I tend to get out of control
16. I tend to value and follow a rational, "sensible" approach to things.
17. When I am upset I often act without thinking.
18. Others would say I make bad choices when I am extremely happy about something.
19. I usually make up my mind through careful reasoning.
20. When I feel rejected, I will often say things that I later regret.
21. Others are shocked or worried about the things I do when I am feeling very excited
22. I am a cautious person.
23. It is hard for me to resist acting on my feelings.
24. When I get really happy about something, I tend to do things that can have bad consequences.
25. Before I get into a new situation I like to find out what to expect from it.
26. I often make matters worse because I act without thinking when I am upset.
27. When overjoyed, I feel like I can't stop myself from going overboard.
28. I usually think carefully before doing anything.
29. When I am really excited, I tend not to think of the consequences of my actions.
30. In the heat of an argument, I will often say things that I later regret.
31. I tend to act without thinking when I am really excited.
32. I always keep my feelings under control.

33. When I am really happy, I often find myself in situations that I normally wouldn't be comfortable with.
34. Before making up my mind, I consider all the advantages and disadvantages.
35. When I am very happy, I feel like it is ok to give in to cravings or overindulge.
36. Sometimes I do impulsive things that I later regret.
37. I am surprised at the things I do while in a great mood

Appendix VIII: Time Management and Experience Scale

Time Management and Experience (TiME) Scale

Please read the following statements carefully. As you answer each question, select the option that best describes how you have felt and conducted yourself over the past 6 months, using the following scale: 1 – Strongly Disagree, 2 – Disagree, 3 – Slightly Disagree, 4 – Slightly Agree, 5 – Agree, 6 – Strongly Agree

1. I am a punctual person.
2. I allow myself enough time to complete my work and assignments before the deadline.
3. I often find myself completing assignments at the last minute.
4. I usually have an accurate idea of what time it is without looking at a clock.*
5. I am often pressed for time.
6. I often find it difficult to complete assignments on time.
7. It usually feels like time is moving slowly.
8. I often lose track of time.
9. I usually feel like I have too much time on my hands.
10. I typically arrive to class on time.
11. I follow a set routine when getting ready in the morning.
12. I am rarely ready to leave on time.
13. I wake up right before my alarm goes off in the morning.*
14. I rarely have enough time in a day.
15. I find that it usually takes me longer to complete tasks than I originally predicted.
16. I rarely know how much time is left in class without looking at a clock.
17. It usually feels like time is passing too quickly.
18. It takes a long time to get through the day.
19. I have trouble managing my daily schedule
20. I usually give myself enough time to complete my work before the deadline.

*Items removed after factor analysis

Appendix IX: Tuckman Procrastination Scale

Tuckman Procrastination Scale (TPS)

Please read the following statements carefully and rate your agreement with how much each statement describes you using the following scale: 1 - Strongly Disagree, 2 - Disagree, 3 - Neither Agree nor Disagree, 4 - Agree, 5 - Strongly Agree

1. I needlessly delay finishing jobs, even when they're important
2. I postpone starting in on things I don't like to do.
3. When I have a deadline, I wait until the last minute.
4. I delay making tough decisions.
5. I keep putting off improving my work habits.
6. I manage to find an excuse for not doing something.
7. I put the necessary time into even boring tasks, like studying
8. I am an incurable time waster.
9. I'm a time waster now but I can't seem to do anything about it.
10. When something's too tough to tackle, I believe in postponing it.
11. I promise myself I'll do something and then drag my feet.
12. Whenever I make a plan of action, I follow it.
13. Even though I hate myself if I don't get started, it doesn't get me going.
14. I always finish important jobs with time to spare.
15. I get stuck in neutral even though I know how important it is to get started.
16. Putting something off until tomorrow is not the way I do it.

Appendix X: Cognitive Appraisal of Risky Events

Cognitive Appraisal of Risky Events (CARE)

Past Frequency

For each of the activities listed below, please indicate how many times you have participated in this activity in the past six (6) months.

	Number of Times in Past 6 Months
1. Tried/used drugs other than alcohol or marijuana	______________
2. Missed class or work	______________
3. Grabbed, pushed, or shoved someone	______________
4. Left a social event with someone I have just met	______________
5. Drove after drinking alcohol	______________
6. Made a scene in public	______________
7. Drank more than 5 alcoholic beverages in one hour	______________
8. Not studied for exam or quiz	______________
9. Drank alcohol too quickly	______________
10. Disturbed the peace	______________
11. Damaged/destroyed public property	______________
12. Sex without protection against pregnancy	______________
13. Left tasks or assignments until the last minute	______________
14. Hit someone with a weapon or object	______________
15. Sex without protection against sexually transmitted diseases	______________
16. Failed to do assignments	______________
17. Slapped someone	______________
18. Not studied or worked hard enough	______________
19. Punched or hit someone with fist	______________
20. Used cannabis	______________
21. How many different sexual partners have you had in the past 6 months?	______________
22. Mixed drugs and alcohol	______________
23. Got into a fight or argument	______________
24. Involved in sexual activities without my consent	______________
25. Played drinking games	______________
26. Sex with someone I have just met or don't know well	______________
27. Used stimulant medication in a way that was not prescribed	______________

Appendix XI: Demographics

Demographic Items

Please carefully read and answer the following questions.

1. How old are you?
2. What is your current year in college?
    1- Freshman
    2- Sophomore
    3- Junior
    4- Senior
    5- 5th year
3. What sex were you assigned at birth?
    1- Female
    2- Male
    3- Intersex
4. Which term do you use to describe your gender identity?
    1- Woman or female
    2- Man or male
    3- Trans woman
    4- Trans man
    5- Non-binary
    6- Genderfluid
    7- Intersex
    8- My identity is not listed above
5. How do you usually describe yourself?
    1- American Indian or Native Alaskan
    2- Asian or Asian American
    3- Black or African American
    4- Hispanic or Latino/a/x
    5- Middle Eastern/North African (MENA) or Arab Origin
    6- Native Hawaiian or Other Pacific Islander Native
    7- White
    8- Biracial or Multiracial
    9- My identity is not listed above

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Curriculum Vitae

Ashley Schiros, B.S.

Clinical Psychology Doctoral Student

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Syracuse, NY 13204

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Education

Doctoral Program, Clinical Psychology (APA accredited) 2020-present

Syracuse University, Syracuse, NY

Major Advisor: Kevin M. Antshel, Ph.D.

GPA: 4.000

Bachelor of Science, Neuroscience 2016-2019

Utica College, Utica, NY

Cumulative GPA: 3.960

Summa Cum Laude

Clinical Experience

Graduate Student Clinician, Syracuse University Psychological Services Center Present

Clinic Director: Afton Kapuscinski, Ph.D.

Supervisors: Katie Kidwell, Ph.D., Aaron Gleason, Ph.D., Leslie Gellis, Ph.D., Kevin Antshel, Ph.D.

- Provide individual psychotherapy using evidence-based cognitive behavioral treatments in an outpatient mental health clinic for children, adolescents, and adults
- Receive supervision in cognitive behavioral therapy and motivational interviewing
- Administer, score, and interpret psychological tests of cognitive and executive functioning, personality and symptom inventories, and behavioral assessments for adults, adolescents and children (e.g., WAIS-IV, WISC-V, WIAT-III, ADOS-2, MMPI-3, PAI, BASC-3,WHODAS, AUDIT, CUDIT, GAD-7, PHQ-9, PSS)

- Provide comprehensive verbal and written feedback to clients and their families, including diagnostic impressions and treatment recommendations through integrated reports

Registered Behavior Technician 2019 – 2020

*ADHD & Autism Psychological Services and Advocacy***,** *Utica, NY*

- Provided direct care to children aged 2-15 with ADHD and Autism Spectrum Disorder
- Implemented ABA treatment programs, including NET, DTT, and desensitization
- Completed documentation and data collection on patient symptoms, challenging behaviors, and adaptive skills
- Extended teaching of basic ABA techniques to parents and bridged clinic services with home-care

Research Experience

Graduate Research Assistant, ADHD Lifespan, Treatment, and Education Lab Present

Syracuse University, Syracuse NY

Principle Investigator: Kevin M. Antshel, Ph.D.

- Design a novel research study on cognitive and self-report measures of temporal processing in ADHD
- Analyze qualitative and quantitative data on impact of COVID-19 on adolescents with ADHD
- Present data and research projects related to ADHD at national conferences
- Participate in weekly laboratory meetings and journal club to stay up-to-date on current ADHD literature

Utica College, Utica, NY May 2016 – December 2019

Research Assistant to Dr. Amy Lindsey

- Involved in experimental design from literature review to IACUC and grant approval
- Calculated visual angle of salamanders in a prey-capture model of vision
- Observed circadian rhythm of sighted, blind, and hybrid Mexican tetras
- Conducted assessments of visual acuity in Mexican tetras with optomotor drum
- Utilized MatLab to create sinusoidal gratings and contrast sensitivity functions
- Analyzed data and created graphs using Microsoft Excel and SPSS

Utica College, Utica, NY January 2018 – March 2019

Research Assistant to Dr. John Schwoebel

- Involved in experimental design from literature review to IRB approval
- Examined the efficacy of implementing a teaching method to reduce cognitive biases in decision-making
- Created a classroom lecture that defined cognitive biases and exemplified their prevalence in daily life
- Designed an assessment to measure the presence of cognitive bias in decision-making
- Analyzed data and created graphs using Microsoft Excel and SPSS

Presentations

Rohacek, A., Firkey, M.K., Woolf-King, S.E., Ansthel, K.M. (2022). Sex, Drugs, and ADHD: Sexual Health and Moderators of Risk in College Students. Poster presented at the American Professional Society of ADHD and Related Disorders Conference. Tucson, AZ.

Rother, Y., **Rohacek, A.,** Stevens, A.E., Willcutt, E.G., Flory, K., Canu, H., & Antshel, K.M. (2022). College during COVID-19: The pandemic's effect on college adjustment in first year students with and without ADHD. Presented at the 56th annual meeting of the Association for Behavioral and Cognitive Therapies, New York City, NY.

Taylor, L., Orantes, D.M., **Rohacek, A.**, Antshel, K.M. (2021). Understanding and Improving ADHD Symptom Recall: An Investigation of Temperament and Childhood Symptom Recall Over Time. Poster presented at the American Academy of Child and Adolescent Psychiatry Virtual Annual Meeting.

Jhawar, N., **Rohacek, A.**, London, A., & Antshel, K. (2021). A mixed-methods analysis of the impact of COVID-19 on adolescents with ADHD and their families. Poster presented at the American Professional Society of ADHD and Related Disorders Virtual Conference.

Rohacek, A., Smith, B., & Lindsey A. (2019). Psychophysical assessment of contrast sensitivity functions in surface and hybrid Mexican tetras. Poster presented at Vision Sciences Society Annual Meeting. St. Pete Beach, FL.

Rohacek, A. & Schwoebel, J. (2019). Your decisions matter! Teaching intervention improves decision making. Poster presented at Eastern Psychological Association Annual Meeting. New York City, NY.

Rohacek, A. (2018). Seeing our decisions anew. Round-table presentation at Northeast Regional Honors Conference. Providence, RI.

Rohacek, A. & Lindsey A. (2017). Terrestrial phase tiger salamanders have increased visual acuity compared to aquatic phase tiger salamanders. Poster presented at Association for Psychological Science Conference. Boston, MA.

Publications

Rohacek, A. M., Firkey, M. K., Woolf-King, S. E., & Antshel, K. M. (2022). Moderation of Risks to Sexual Health by Substance Use in College Students With ADHD. *The Journal of clinical psychiatry*, *83*(4), 21m14240. https://doi.org/10.4088/JCP.21m14240

Rohacek, A., Baxter, E. L., Sullivan, W. E., Roane, H. S., & Antshel, K. M. (2022). A Preliminary Evaluation of a Brief Behavioral Parent Training for Challenging Behavior in Autism Spectrum Disorder. *Journal of autism and developmental disorders*, 1–11. Advance online publication. https://doi.org/10.1007/s10803-022-05493-3

Publications (in press)

Rohacek, A., London, A. S., & Antshel, K.M. (2022). Gender Differences in Adults with ADHD. In J. L.Matson (Ed.), *Clinical Handbook of ADHD Assessment and Treatment Across the Lifespan*. Springer Nature.

Orantes, D.,* **Rohacek, A.**,* & Antshel, K.M. (2022). "Chapter 20: ADHD, Distractibility and ABA." Handbook of ABA for Children with Autism: Clinical Guide to Assessment and Treatment, edited by Matson, J.L., In press, Springer Nature.

*denotes equal contributions

Publications (under review)

Rohacek, A., Rother, Y. Wilcutt, E.G., Flory, K.H., Canu, W.H., & Antshel, K.M. (2021). College During COVID-19: The Pandemic's Effect on College Adjustment in First Year Students with ADHD. Under review, Department of Psychology, Syracuse University, Syracuse, New York.

Rohacek, A. & Antshel, K.M. (2022). Young, Restless, and Underrepresented: A Review of Psychosocial Interventions for Adolescent ADHD and Suggestions for Improving Treatment for Girls. In preparation, Department of Psychology, Syracuse University, Syracuse, New York.

Rohacek, A., & Antshel, K.M. (2022). The Relationship Between ADHD, Eating Disorders, and Suicidality Among College Students. In preparation, Department of Psychology, Syracuse University, Syracuse, New York.

Teaching Experience

Teaching Assistant, PSY395 Abnormal Psychology Fall 2021 – Current

Syracuse University, Syracuse, NY

- First point of communication for students in this course
- Managing course website, including uploading course materials and managing submission portals for student work
- Grading of all student work, including exams and research papers
- Assist in the development of lectures, exams, and assignments
- Hold exam review sessions and weekly office hours
- Meet with students during office hours and by appointment to facilitate learning

Guest Lecturer, PSY 395 Abnormal Psychology
Spring 2022

Syracuse University, Syracuse, NY

- Guest lecture (1) on clinical presentation, etiology, diagnosis and treatment of eating disorders
- Guest lecture (1) on psychotherapy and biological treatments of mental disorders

Guest Lecturer, PSY 395 Abnormal Psychology
Fall 2021

Syracuse University, Syracuse, NY

- Guest lectures (3) on diagnosis and treatment of neurodevelopmental and childhood disorders and trajectories in child psychology

Instructor of Record, PSY395 Abnormal Psychology
Summer 2021

Syracuse University, Syracuse, NY

- Presented instruction on key concepts of abnormal psychology and DSM-5 criteria for psychiatric diagnoses
- Facilitated class discussions, answered student questions, and provided active learning opportunities
- Developed a class syllabus and maintained course policies
- Prepared lectures, exams, and student assignments
- Graded student assignments and exams and provided feedback on written work

Guest Lecturer, PSY205 Introduction to Human Behavior Spring 2021

Syracuse University, Syracuse, NY

- Guest lecture on personality disorders

Teaching Assistant, PSY205 Introduction to Human Behavior Fall 2020 – Spring 2021

Syracuse University, Syracuse, NY

- Lectured and facilitated discussions on key concepts of introductory psychology
- Provided grading and feedback to students on all course assignments
- Assisted in creating recitation lectures and activities
- Enhanced student learning via office hours and frequent email communications

Service

Co-president, Psychology Action Committee (PAC) Summer 2021 - Current

Syracuse University, Syracuse NY

- Organize and run PAC meetings geared towards advocating for graduate student rights
- Host PAC introduction seminar at first-year student orientation
- Provide educational, general well-being, and professional development resources for psychology graduate students
- Hold elections for PAC leadership positions
- Strengthen department collaboration by organizing inter-area events and programming

Panelist, Utica College Spring 2021

Utica, NY

- Panelist for Clinical Pathways, a presentation on graduate programs and career trajectories in clinical psychology
- Provided insight on the application process and graduate school experience
- Offered mentorship on choosing and applying to clinical psychology doctoral programs

Secretary, Psychology Action Committee Fall 2020 - Spring 2021

Syracuse University, Syracuse NY

- Attended PAC meetings geared towards advocating for graduate student rights
- Maintained and disseminated meeting minutes

Programming Assistant, Womyn's Resource Center
2018-2019

Utica College, Utica NY

- Organized campus events promoting diversity, inclusion, and female empowerment
- Engaged in community outreach and service activities to support non-for-profits
- Disseminated information about sexual health, reproductive rights, domestic violence, racism,
- Worked to foster a safe-space for individuals to obtain resources when in need

Volunteer, NeuroCare Unit, Sitrin Healthcare Center
Summer 2017

New Hartford, NY

- Shadowed head neuropsychologist Dr. Lorin Williams on unit with HD and ALS patients
- Observed cognitive assessment tests be performed
- Scored cognitive assessment tests and learned basic psychometrics

Workshops, Certifications, and Trainings

- **Trauma-Focused Cognitive Behavior Therapy –** nationally accredited webinar and 3-day in-person training to conduct TF-CBT
- **Autism Diagnostic Observation Schedule-2 Training -** Sunfield Center for Autism,
- ADHD and Behavioral Health training to administer and score ADOS-2, 13.5 contact hours
- **National Register's Associate Certificate Program on Clinical Suicidology** – 4.5 contact hours
- **Body Project Training** – 6 contact hours, training on how to conduct Body Project groups and evidence base for Body Project effectiveness
- **Qb Training –** 3 hour training on evidence base, software, and administration of the Qb Test, continuous performance task for ADHD diagnosis
- **Safe Zone Workshop** – 2 hour training on LGBTQ+ identifies, improving inclusivity for LGBTQ+ individuals, and recognizing ways to be more effective advocates
- **Managing Biases Training** – 2 hour training on identifying biases and managing micro-aggressions in professional settings
- **Psychology Action Committee** - Co-president (Summer ’21 – present)
- **Psychological Action Committee** – Secretary (Fall ’20-Spring ’21)
- **American Professional Society of ADHD and Related Disorders** – Student Member
- **Psi Chi, the International Honor Society in Psychology** – Member