Explaining Heterogeneity: Identifying Subgroups of Adult Attention-Deficit/Hyperactivity Disorder

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EXPLAINING HETEROGENEITY: IDENTIFYING SUBGROUPS OF ADULT ATTENTION-DEFICIT/HYPERACTIVITY DISORDER

by

Laura M. McGuigan, B.A.

A Thesis submitted to the Faculty of the Graduate School, Marquette University, in Partial Fulfillment of the Requirements for the Degree of Master of Science

Milwaukee, Wisconsin

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ABSTRACT

EXPLAINING HETEROGENEITY: IDENTIFYING SUBGROUPS OF ADULT ATTENTION-DEFICIT/HYPERACTIVITY DISORDER

Laura M. McGuigan, B.A.

Marquette University, 2024

Attention-deficit/hyperactivity disorder (ADHD) is a highly prevalent neurodevelopmental disorder that often persists into adulthood. Individuals with ADHD present with varied patterns of neurocognitive impairment, psychological comorbidities, and functional challenges. The current characterization of ADHD into three subgroups (primarily inattentive, primarily hyperactive/impulsive, combined inattentive-hyperactive/impulsive presentation) does not fully explain the heterogeneity of challenges experienced by this population. In this study, 259 adult patients [Mage= 25.94; SD=7.83; 78% Caucasian; 54% male] referred for an ADHD evaluation were investigated, and latent profile analysis was conducted. Self-reported ADHD symptoms, psychological functioning, and neuropsychological functioning were considered to identify subgroups. Results revealed four distinct classes: a class with low neuropsychological performance and elevated mood and behavioral self-report (Neuropsychiatrically Distressed), a class with relative inefficiencies across neuropsychological performance with a particular deficit in sustained attention/vigilance and a high report of inattention symptoms (Relative Cognitive Inefficiencies only), a class with relative inefficiencies across neuropsychological performance with unimpaired sustained attention/vigilance (Relative Cognitive Inefficiencies with Preserved Vigilance), and a class with high neuropsychological performance and low self-reported mood and behavioral symptoms (Neuropsychiatrically Resilient). There were differences in likelihood of ADHD diagnosis, insufficient effort, and years of education across classes. Age and gender did not significantly differ across classes. Identification of distinct subgroups of adult patients referred for an ADHD evaluation provides additional evidence to support the cognitive, emotional, and behavioral heterogeneity observed in adult ADHD, which in turn, may allow clinicians to better tailor relevant treatment recommendations.
ACKNOWLEDGEMENTS

Laura M. McGuigan, B.A.

In no particular order, I would like to thank my parents, Mark and Teresa, and my siblings, Ryan and Rachel, for instilling a love for learning while being my biggest cheerleaders. I would also like to thank my partner, Jon, for his endless support and encouragement in my graduate school endeavors. Additionally, I would like to thank members of the Hoelzle lab for their advice and support while completing this project. Finally, I would like to thank my thesis committee, particularly my advisor, Dr. James Hoelzle, for his mentorship, expertise, and guidance throughout this project.
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Introduction

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by age-inappropriate symptoms of inattention, impulsiveness, and/or hyperactivity (American Psychiatric Association [APA], 2022). It is estimated that 5-10% of children and 4% of adults meet diagnostic criteria for ADHD (Faraone et al., 2003). Inattention is often manifested as daydreaming, distractibility, and difficulty focusing on a single task for a prolonged period, whereas hyperactivity is often expressed as fidgeting, excessive talking, and restlessness (Biederman, 2005). The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition, Text Revision (DSM-5-TR; APA, 2022) describes three primary ADHD subtypes associated with distinct presentations: predominantly inattentive, predominantly hyperactive/impulsive, and combined presentation. ADHD symptoms in children significantly impact daily functioning, often resulting in interpersonal challenges, poor academic performance, and decreased quality of life (Matza et al., 2005). This can lead to long-term negative outcomes for children with ADHD including financial stress to families, poor academic and vocational performance, and occupational instability (Biederman, 2005). These deleterious outcomes emphasize the importance of well-defined assessment, diagnosis, and management of ADHD symptoms.

ADHD is three times more likely to be diagnosed in males. It is believed that females are consistently under identified because of differences in overt expression of ADHD symptomatology. That is, females are more likely to report symptoms of inattention than hyperactive/impulsive symptoms when compared to males, which results in females displaying less disruptive behavior (Skogli et al., 2013). Another contributing factor that increases the likelihood of females not receiving an ADHD diagnosis is the high prevalence of comorbid
psychiatric disorders. Notably, as many as 75% of children with ADHD meet diagnostic criteria for at least one additional psychiatric disorder (Barkley, 1994). Females tend to have comorbid internalizing disorders, while males tend to exhibit more externalizing disorders. The tendency to attribute inattention and distractibility solely to an internalizing disorder further propagates the under identification of ADHD in females (Skogli et al., 2013).

Currently, DSM-5-TR diagnostic criteria is believed to primarily reflect challenges experienced by school-aged white American children (primarily boys), which overlooks how ADHD may be expressed in minorities and adults (e.g., see Conners, 1970). For example, diagnostic criteria such as “often fidgets with or taps hands or feet or squirms in seat,” (APA, 2022) is most applicable to school-aged children, whereas a criterion such as “has a challenging time sitting still through regular work meetings” may be more appropriate for adults (Bell, 2011; Ramsay & Rostain, 2006). Additionally, thresholds for deeming disruptive behavior as normal or abnormal can vary across cultures leading to under identification, and at times over identification of ADHD by parents, teachers, and physicians (Slobodin & Masalha, 2020). This highlights a need for additional research on the presentation and expression of ADHD to improve management of symptoms throughout the lifespan in diverse populations.

The etiology of ADHD is not fully understood; however, prior research has identified both genetic and neurobiological origins (e.g., see Cortese, 2012). Current diagnostic criteria are not defined by an etiological source or biological markers. The relationship between these aforementioned factors and clinical definitions of ADHD is not clearly defined (e.g. blood biomarkers to determine ADHD subtype) (Luo et al., 2019). Currently, a diagnosis of ADHD is typically determined through a comprehensive clinical interview and completion of ADHD behavioral symptom self-report forms to ensure DSM-5-TR criteria are met (Wolraich et al.,
The clinical interview gathers information surrounding the quantity, severity, and duration of behavioral symptoms, including functional impairment. Standardized self-report forms are completed by the patient and, ideally, informants (parents/teachers) to confirm symptomatology and presence of symptoms in two or more settings (Shah et al., 2019). Despite high comorbidity rates in ADHD, the clinician must also rule out that the symptoms are not better explained by another mental disorder.

Neurocognitive impairment is a core feature of ADHD symptomatology, however a documented deficit determined by administering objective measurement of cognitive functioning is not required as part of diagnostic criteria. Most commonly, individuals with ADHD exhibit difficulties in the domains of sustained attention, executive functioning, working memory, and self-regulation (Barkley, 1997). Numerous studies have identified performance differences on neurocognitive tasks between children with ADHD and normal controls. Children with ADHD show relatively weaker performance on tasks of vigilance, verbal learning (particularly encoding), working memory, and executive functioning tasks such as set-shifting, planning and organization, complex problem solving, and response inhibition (Barkley, Grodzinsky & DuPaul, 1992; Seidman, 2006). It is estimated that 33-50% of children with ADHD present with some degree of executive dysfunction (Kofler et al., 2019). Roberts and colleagues (2017) explored the heterogeneity of executive functioning within a child ADHD sample. Through cluster analysis, they were able to reliability identify individual differences, or “subtypes” of performances on tasks of executive functioning. Thus, neuropsychological assessment can be an important tool to identify and quantify the cognitive challenges a patient may be experiencing (Schoechlin & Engel, 2005). However, its use in diagnostic decision-making continues to be debated, with some arguing neuropsychological assessment is unable to reliably capture “real-world” executive
dysfunction such as difficulties with planning, time-management, organization, and self-motivation (Barkley, 2019).

Although medication and evidence-based therapies are utilized for the treatment of ADHD symptoms, there is currently no curative treatment for ADHD (Luo et al., 2019). Current treatment guidelines for ADHD include behavioral management, parent training, and behavioral classroom interventions for young children (ages 4-6 years) with ADHD (DuPaul et al., 2011; Wolraich et al., 2019). For children and adolescents six years and above, the first line treatment recommendation is FDA-approved medications (both stimulant and non-stimulant) (e.g., see Wolraich et al., 2019). Nevertheless, studies consistently find that behavioral and pharmacological treatments have improved efficacy when combined (Pelham & Gnagy, 1999; So et al., 2008).

**Adult ADHD**

While ADHD is often thought of as a childhood disorder, many individuals diagnosed during childhood continue to experience ADHD-related challenges into adulthood (Hechtman et al., 2016). The impact of adult ADHD is significant. For example, adults with ADHD had, on average, a 17% lower annual income than adults with no ADHD (Jangmo et al., 2021). Additionally, marriage satisfaction and overall adjustment are relatively lower in adults with ADHD compared to their non-ADHD counterparts (Barkley et al., 2008; Wymbs et al., 2021).

Although it is estimated that ADHD persists into adulthood for up to 65% of children, individuals may seek an ADHD diagnosis for the first time as an adult for numerous reasons (Luo et al., 2019). First, if the adult experienced a mild form of ADHD as a child, symptoms may have been masked by an undemanding (or highly structured) environment. As demanding (and less structured) tasks increase in prevalence in adulthood, mild symptoms may be
exacerbated and expressed as functional impairment for the first time. Second, an adult may seek a delayed ADHD diagnosis due to their parents/caregivers having a dismissive attitude toward ADHD when they were a child. Alternatively, or simultaneously, the adult may have possessed cognitive strengths or was raised in a supportive environment that mitigated childhood ADHD symptoms (Sibley, 2021).

Assessing for adult ADHD can present unique challenges for clinicians. Due to ADHD being a neurodevelopmental disorder, the diagnostic criterion consists of language centered around school-aged child behavior (e.g., difficulty sustaining attention in task or play activities) which leaves clinicians working with adults guidelines that are sub-optimal for diagnosis (Sibley, 2021). In partial recognition of this, DSM-5 criterion was revised for adults, with only five criteria required for adults while six are needed for children (APA, 2022; Planton et al., 2021). To further the complexity in diagnosis, the expression of ADHD symptoms often changes from childhood into adulthood. Studies have also shown that overt symptoms (e.g. hyperactive symptoms) tend to wane over time as more covert symptoms (e.g. inattentive symptoms) persist (Biederman et al., 1993). Subsequently, researchers have proposed the creation of alternative diagnostic criteria for ADHD in adults, which includes symptoms such as emotional over-reactivity, affective lability, and explosive short-lived outbursts (Wender et al., 2001).

Additionally, the presence of current and childhood symptoms is required for an ADHD diagnosis in adulthood, which requires the adult to retroactively endorse childhood symptoms. This can result in inaccurate retroactive symptom endorsement due to the length of time passed, as current criteria require several symptoms present prior to age 12 years (APA, 2022). Additionally, it can be easy for a patient to report experiencing childhood ADHD symptoms even if they were not genuinely experienced, or if they were related to another psychosocial
challenge, such as experiencing a traumatic event. With respect to current symptom report, it is increasingly recognized that individuals perceive benefits to receiving an ADHD diagnosis (e.g., academic accommodations, access to psychostimulant medications) and therefore may exaggerate report of ADHD symptoms (e.g., see Sansone & Sansone, 2011). In fact, it has been speculated that over 50% of college students with an ADHD stimulant medication prescription may have feigned their symptoms (Ramachandran et al., 2020; Sibley, 2021). This highlights the importance of clinicians administering performance and symptom validity measures, particularly when evaluating ADHD, due to the possibility of amplification of symptoms for secondary gain.

As previously mentioned, ADHD is a highly comorbid mental health disorder. There is also a higher likelihood for an adult to present with a comorbid disorder due to their age. Up to 80% of adults with ADHD have at least one co-existing psychiatric disorder, including anxiety and mood disorders, substance use disorders (SUD), and personality disorders (Katzman et al., 2017). Major depressive disorder (MDD) is the most frequently observed comorbidity in adults with ADHD (50%; Wilens et al., 2009). To complicate the differential diagnosis, comorbid disorder symptomatology often overlaps with ADHD symptoms. As an example, concentration difficulties and lack of motivation are shared features of major depression and adult ADHD. Restlessness and distractibility are shared expressions of adult ADHD and anxiety. In order to make an ADHD diagnosis, the clinician must rule out the possibility that experienced symptoms are not better accounted for by another mental health disorder (APA, 2022). Additionally, treatment guidelines recommend that the most impairing condition should be treated first when ADHD is comorbid with other disorders in adults (Katzman et al., 2017). Currently, the clinician’s ability to identify and differentiate ADHD within a psychiatric comorbid profile is not fully defined nor understood, highlighting the complexity and heterogeneity of the disorder.
The use of neuropsychological assessment as a diagnostic tool in adult ADHD has been examined, but with contradicting results. Schoechlin and Engel (2005) found that executive functioning was generally not reduced in adult ADHD patients compared to controls, which contrasts with childhood ADHD findings (El Wafa et al., 2020). On the other hand, Theiling and Petermann (2016) identified robust working memory and processing speed deficits in adults with ADHD when compared to non-ADHD adult controls. The vast majority of studies examining neuropsychological performance compare adults with ADHD to control subjects, which confounds the possibility of identifying subtype-specific nuances in neurocognitive functioning (Planton et al, 2021). To explore this research gap, LeRoy and colleagues (2019) compared controls to the three ADHD subtypes. ADHD inattentive and ADHD combined subtypes performed worse on tasks measuring executive functioning, attention, working memory, and memory compared to controls. When examining differences across subtypes, memory performance was significantly worse in the combined subtype.

Neuropsychological profiles in individuals with ADHD are often similar to the profiles associated with other mental health conditions. Neuropsychological performances of those with anxiety often reflect challenges with complex attention, executive functioning, and social cognition (Langarita-Llorente & Gracia-Garcia, 2019). Hammar and Ardal (2009) found that individuals with Major Depressive Disorder had diminished processing speed, attentional challenges, executive dysfunction, and slowed psychomotor speed. An ADHD neuropsychological profile has similarities to these profiles, most often exhibiting impairments in working memory, reaction time variability, response inhibition, and planning/organizing (Pievesky & McGrath, 2018). These overlapping profiles can present challenges for clinicians as neuropsychological impairments are not specific to a given diagnosis.
Neuropsychological performances in individuals with comorbid ADHD have also been explored and there is not clear evidence delineating a comorbid ADHD neuropsychological profile from an ADHD only profile. One study found that ADHD patients with a comorbid psychiatric disorder showed increased neuropsychological impairment compared to ADHD patients without comorbidity (Roh et al., 2023). However, Guo and colleagues (2021) and Nikolas and colleagues (2019) did not identify any meaningful differences in neuropsychological impairment between those that presented with and without a psychiatric comorbidity. One study examining ADHD in adults found neurocognitive performance differences between individuals with comorbid ADHD (depression/anxiety) compared to those only experiencing depression/anxiety symptoms. However, after removing invalid neuropsychological profiles, these significant differences disappeared, which again highlights the importance of using validity measures when interpreting neurocognitive test data (Hoelzle et al., 2019).

It is somewhat easy for adults to amplify ADHD symptoms on self-report measures that quantify childhood or current symptoms (e.g., see Frazier et al., 2008). Young and Gross (2011) found that behavioral rating scales were unable to distinguish between a clinical ADHD group and a group instructed to feign ADHD symptoms. Similarly, research has also identified a relatively high prevalence of performance exaggeration (i.e., performing in a manner that suggests clinically significant impairment) on neuropsychological testing in ADHD patients (e.g., see Marshall et al., 2010). Booksh and colleagues (2010) found that participants who were instructed to simulate ADHD on an objective measure showed similar performance to the clinical ADHD comparison group. In a study examining an adult ADHD sample, Ovsiew and colleagues (2023) found that invalid performance validity was present in 16% of their sample. Invalid performance resulted in a significant reduction in cognitive test scores compared to those
with valid performance validity tests. In a study examining a test of sustained attention, the group that failed a measure of noncredible performance were found to have clinically impaired performance on the task compared to those with ADHD and to the controls (Suhr et al., 2011). As such, it is imperative to assess for invalidity and assess the role of invalid profiles within an adult ADHD sample. Additionally, more research is needed to assess patterns of invalid profiles within adult ADHD neuropsychological profiles. Doing so will foster a greater understanding of the neuropsychological sequela associated with adult ADHD.

In summary, individuals with ADHD present in diverse ways. ADHD is a highly heterogeneous disorder with multifactorial etiologies, diverse developmental trajectories, psychiatric comorbidities, and varied patterns of neurocognitive impairment. As described above, there are limitations to the DSM-5-TR criteria as a diagnostic tool for ADHD in adults. The current characterization of ADHD into three subgroups fails to recognize the heterogeneity present in adults with ADHD. Conceptualization and treatment of adult ADHD is likely to be improved by understanding variations in behavioral symptom report, psychological comorbidities, and neurocognitive profile patterns.

**Latent Profile Analysis**

Latent profile analysis (LPA) is a statistical method that might uniquely assist in identifying and understanding the heterogeneity observed in adults with ADHD, as it classifies individuals into subgroups (latent profiles). Emerging profiles of individuals with shared characteristics are compared to other emerging profiles (e.g., comparing how the characteristics combine to form the profiles, and how those combinations are related to outcomes) (Collins & Lanza, 2009; Spurk et al., 2020). LPA can also be beneficial for identifying subgroups of
individuals with shared characteristics who may benefit from a common intervention (Weller et al., 2020).

Previous research has explored this statistical technique to examine ADHD, but primarily with child populations. As an example, Gomez and colleagues (2014) utilized LPA to identify distinct groups of children with ADHD based on their working memory ability. The profile that emerged with the lowest level of working memory performance also had relatively lower IQ and academic achievement, and increased depression. Additionally, working memory performance differences were not observed across ADHD subtype. These results emphasize the added utility of identified latent profiles to inform ADHD outcomes, in addition to the current DSM-5-TR ADHD subtype classification. Ostrander and colleagues (2008) utilized LPA to examine patterns of psychopathology in a community sample of childhood ADHD. Nearly one-half of the children emerged in classes that could not be reliably delineated through current DSM-5-TR subtypes. Instead, ADHD classes were characterized by the degree to which children displayed disruptive behavior, internalizing symptoms (particularly anxiety), or both. Similar to Gomez and colleagues’ (2014) work, this research highlights the degree to which the current diagnostic criteria may not adequately capture the functional impairments children experience, including the severity of symptom disruption. A novel study examining ADHD in adults explored domains of working memory and processing speed through WAIS-IV subtests. After removing individuals with insufficient effort, LPA analyses revealed four distinct classes that differed significantly in demographically predicted IQ, education, and self-reported anxiety and depression (Leib et al., 2021). This study highlighted that working memory and processing speed abilities vary in adults with ADHD, and that cognitive functioning is associated with self-reported emotional
functioning within each class. This is one of the few studies that utilizes LPA to examine an adult ADHD sample and considers how mood and demographic characteristics differ by class.

Although LPA has primarily been utilized to examine ADHD presentation in children (e.g., see Arnett & Flaherty, 2022; Cohen et al., 2023), it has not been widely used to examine adult ADHD populations. Additionally, prior LPA research on ADHD subgroups has examined neurocognitive performance in specific neurocognitive domains (Gomez et al., 2014; Leib et al., 2021) or in a relatively small battery of cognitive tasks (e.g., see Hulst et al., 2015), which theoretically decreases the probability of identifying distinct subgroups. The primary objective of this study is to identify distinct groups of individuals in a referred adult ADHD population based on self-reported behavioral symptoms, emotional functioning, and performance on a comprehensive neuropsychological battery. A benefit of using a referred adult ADHD sample is the ability to capture both clinical and sub-clinical ADHD symptom profiles allowing for a better understanding of the functional impairment of ADHD symptoms.

**Current Study**

There are many challenges associated with the diagnosis of ADHD in adulthood. While current DSM-5-TR criteria describes three subtypes, this does not fully account for the heterogeneous presentation of adults with ADHD, which might include psychiatric comorbid and diverse neurocognitive profiles. If neurocognitive, mood, and behavioral symptom profiles could be reliably identified, it is likely to improve conceptualization and treatment of ADHD in adulthood. Further, it might inform changes to diagnostic criteria in future iterations of the DSM.

LPA allows one to identify subgroups of individuals who express similar characteristics. LPA has primarily been used to identify subgroups of children with ADHD, but less commonly with adults. Uniquely, this study will conduct LPA to examine a referred adult sample
experiencing inattention and/or hyperactivity/impulsivity that is plausibly associated with ADHD. Performance on a comprehensive neuropsychological battery (domains of sustained attention, executive functioning, memory, working memory, and processing speed), ADHD behavioral rating scales, and mood severity will be considered.

The primary aims of this research are to: (1) Identify distinct homogenous subgroups of adults presenting with inattention and/or hyperactivity/impulsivity, plausibly related to ADHD, based on neuropsychological test performance, report of ADHD symptoms, and self-reported symptoms of depression and anxiety. (2) Assess neuropsychological, psychological, and behavioral differences between identified subgroups. (3) Identify the likelihood/probability of subgroup identification based on demographic characteristics, ADHD diagnosis, and an invalid neuropsychological performance profile. Collectively, this research will identify distinct neurocognitive and clinical subgroups of adult patients to better inform our understanding of the heterogeneity in adulthood ADHD and, in turn, may improve clinicians’ ability to tailor treatment recommendations.
Method

Sample

Archival de-identified data was obtained from Hennepin County Medical Center, Department of Psychiatry, Neuropsychology Clinic (Minneapolis, Minnesota) between March 2008 and July 2014. 423 adult patients (M\text{age}= 26.13; SD=7.47; 79% Caucasian; 60% male) were referred for an ADHD assessment and completed a comprehensive neuropsychological evaluation. This included an extensive semi-structured clinical interview, behavioral observations, completion of self and informant ADHD behavior rating scales, the administration of numerous cognitive tests, and symptom/performance validity measures. Most of the patients were attending or completed college (85%; M\text{edu}=14.42; SD=1.68) and were referred by psychiatrists, psychologists, or nurse practitioners at a university mental health clinic for assistance with differential diagnosis. Patients were excluded if they had (1) an estimated Wechsler Adult Intelligence Scale, Fourth Edition (WAIS-IV; Wechsler, 2008a) Full Scale IQ less than 70, (2) been previously diagnosed with a learning disability, (3) a physical/neurological condition that might compromise cognitive or central nervous system functioning, (4) a major psychiatric condition (excluding depression, anxiety, or bipolar disorders), and/or (5) used alcohol, illicit substances, and/or prescription drugs to the degree that it would plausibly cause impaired cognitive functioning.

Current Sample

To be included in the study, information obtained from the patient’s clinical interview must be (1) consistent with a history of ADHD (N = 77) or (2) indeterminant (N = 182). Patients who reported a psychosocial history that was clearly inconsistent with a diagnosis of ADHD were excluded (N=184). Thus, our study sample consists of 259 adult patients (M\text{age}= 25.94;
SD=7.83; 78% Caucasian; 54% male; M_{edu}=14.24; SD=1.57) currently reporting symptoms of inattention and/or hyperactivity/impulsivity that is plausibly associated with ADHD.

**Study Variables**

Seventeen profile indicator variables were included in the latent profile model to determine the optimal number of classes and characteristics associated with each class. Indicator variables consist of neuropsychological performance, mood severity, and behavioral ratings variables. The probability and differences of output variables (gender, ethnicity, years of education, age, ADHD diagnosis, and valid neuropsychological profile) within and across the emerging classes were then examined.

**Profile Indicator Variables**

*Neuropsychological Measures*

The neuropsychological tests used in these evaluations were administered according to standardized instructions by either a board-certified neuropsychologist or a trained and supervised clinical psychology doctoral student. The tests were administered in the same order to all patients. Patients were administered the Wechsler Adult Intelligence Scale (WAIS-IV; Vocabulary, Similarities, Block Design, Symbol Search, Letter-Number Sequencing, and Digit Span; Wechsler, 2008a), the California Verbal Learning Test-II (CVLT-II; Long Delay Free Recall; Delis et al., 2000), select Delis Kaplan Executive Function System subtests (D-KEFS; Design Fluency (Switching), Color Word Interference (Inhibition); Delis et al., 2001), and the Test of Variables of Attention (TOVA; Reaction Time, Reaction Time Variability, D-Prime; Leark et al., 1996). Table 1 lists measures that will be considered and the associated cognitive domain assessed.
Table 1. Neuropsychological Measures and Cognitive Domains

<table>
<thead>
<tr>
<th>Neuropsychological Measures</th>
<th>Cognitive Domain</th>
</tr>
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<tbody>
<tr>
<td>WAIS-IV Vocabulary</td>
<td>Verbal Comprehension</td>
</tr>
<tr>
<td>WAIS-IV Similarities</td>
<td>Verbal Comprehension</td>
</tr>
<tr>
<td>WAIS-IV Block Design</td>
<td>Visuospatial Reasoning</td>
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<tr>
<td>WAIS-IV Symbol Search</td>
<td>Processing Speed</td>
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<tr>
<td>WAIS-IV Letter-Number Sequencing</td>
<td>Working Memory</td>
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<tr>
<td>WAIS-IV Digit Span</td>
<td>Working Memory</td>
</tr>
<tr>
<td>CVLT-II Long Delay Free Recall</td>
<td>Verbal Memory</td>
</tr>
<tr>
<td>D-KEFS DF Switching</td>
<td>Executive Functioning</td>
</tr>
<tr>
<td>D-KEFS CWIT Inhibition</td>
<td>Executive Functioning</td>
</tr>
<tr>
<td>TOVA Reaction Time</td>
<td>Sustained Attention/Inattention</td>
</tr>
<tr>
<td>TOVA Reaction Time Variability</td>
<td>Sustained Attention/Inattention</td>
</tr>
<tr>
<td>TOVA D-Prime</td>
<td>Sustained Attention/Impulsivity</td>
</tr>
</tbody>
</table>


Mood Measures

Patients completed the Beck Depression Inventory, Second Edition (BDI-II; Beck et al., 1996) and the Beck Anxiety Inventory (BAI; Beck & Steer, 1993) to quantify current depression and anxiety symptom severity, respectively. The BDI-II is a 21-item multiple-choice self-report questionnaire to assess symptoms of clinical depression. A value of 0 to 3 is assigned to each question. Standardized cut-offs are as follows: 0-9: indicates minimal depression, 10-18: indicates mild depression, 19-29: indicates moderate depression, and 30-63: indicates severe depression. The BAI is a 21-item self-report questionnaire to assess symptoms of clinical anxiety. Each item is scored on a scale value of 0 (not at all) to 3 (severely). Standardized cut-offs are as follows: 0-7: Minimal, 8-15: Mild, 16-25: Moderate, and 26-63: Severe.

ADHD Behavioral Rating Scale

Barkley Adult ADHD Rating Scale (BAARS) Forms for current symptoms were administered. One hundred fifty-four patients completed an earlier version of these forms, the Barkley Adult ADHD Behavior Checklist Current (Barkley AADHDSS; Barkley & Murphy,
2006). One hundred three patients completed the most recent version of this form, the Barkley Adult ADHD Rating Scale-IV (BAARS-IV; Barkley, 2011). Both versions of the Barkley Adult ADHD Self-Report forms consist of 18 behavioral symptoms that comprise the DSM-5-TR ADHD criterion. The form is divided into sections of inattention, hyperactivity, impulsivity, and sluggish cognitive tempo. Sluggish cognitive tempo is characterized as excessive “daydreaming”, “difficulty initiating”, and “slow moving” (Jacobson et al., 2018). This set of symptoms has been identified in individuals with ADHD and is semi-independent from symptoms of inattention and/or hyperactivity/impulsivity (Barkley, 2014). The patient indicates whether they exhibit each behavior “rarely or never,” “sometimes,” “often,” or “very often.” Symptoms were considered present when endorsed as “often” or “very often”. The symptom count of inattention, hyperactive/impulsive, and sluggish cognitive tempo were examined. A symptom count of 3 or higher on inattention or hyperactivity/impulsivity is considered clinically significant (93rd percentile). A symptom count of 4 or higher on sluggish cognitive tempo is considered clinically significant (93rd percentile) (Barkley, 2011).

**Output Variables**

Demographic characteristics including gender (male or female), age (in years), ethnicity (Caucasian, African American, Asian American, Hispanic, and other), and years of education were examined. ADHD diagnoses were determined through consideration of the clinical interview and completion of ADHD symptom self-report measures. ADHD diagnoses were assigned if (1) the clinical interview supported or possibly supported a diagnosis of ADHD, and (2) the Barkley Adult Current and Childhood ADHD Rating Scale, earlier and recent editions (Barkley AADHDSS; Barkley and Murphy, 2006; BAARS-IV; Barkley, 2011) were completed
in a manner that supported a diagnosis of ADHD. Based on this criteria, 186 patients were identified as meeting criteria for ADHD.

Patient task engagement was determined based on the interpretation of embedded and stand-alone performance validity tests (PVTs). These measures were distributed throughout the assessment battery as effort/engagement can fluctuate during a single testing session (Boone, 2009). An invalid neuropsychological profile was defined as two or more of the following: (1) two or more errors on the CVLT-II Forced Choice Recognition (Root et al., 2006), (2) a score of 6 or less on the Reliable Digit Span score (Babikian et al., 2006), (3) an e-score of 14 or greater for the Dot Counting Test (Marshall et al., 2010), and/or (4) 26 or more omission errors, or 31 or more commission errors for the TOVA (Marshall et al., 2010). Based on this criteria, 27 patients were identified as meeting criteria for insufficient effort.

Statistical Analyses

Basic analyses to determine patient demographic information and to compare (sub)groups were conducted in SPSS version 28.0 (SPSS Inc., USA). LPA analyses were performed in Mplus version 8.9 (Muthen & Muthen, 2017). LPA, as a person-centered latent variable approach, groups individuals into categories based on shared characteristics (neuropsychological performance, mood severity, and behavioral ratings) that distinguish members of one group from another group (Ostrander et al., 2008). In contrast, factor analytical techniques classifies variables as opposed to individuals (Hulst et al., 2015). As such, this analysis uses quantified, continuous data to assess whether qualitatively different subgroups exist.

Indicator variables (neuropsychological performance, mood severity, and behavioral symptom count) were considered class-defining variables in the LPA model. This classification was conducted without consideration of output variables. There are currently no discrete sample
size requirements for LPA, however research suggests a sample size greater than 100 is adequate for detecting medium effects (Dziak et al., 2014). Therefore, the study sample size of 259 was deemed appropriate for analysis. Prior to beginning the analysis, test variables were examined to remove variables with a high proportion of missing data and/or variables that are highly collinear and/or redundant (e.g. TOVA and Conners CPT standardized scores). The dataset used is largely complete; however, there are some variables with missing data. Full information maximum likelihood estimation was used under the assumption that the data missing is at random, which is a widely accepted method to handle missing data (e.g., see Ostrander et al., 2008; Schafer & Graham, 2002).

The goal of LPA is to identify and reduce the data to classes that are meaningful in statistical saliency and theoretical interpretability (Schmidt et al., 2021). As such, it is recommended to use both content decision criteria and multiple fit indices to determine the optimal model fit and number of classes. Common content decision criteria include theoretical plausibility, inspection of estimation outputs for errors, and out of bound parameters (Spurk et al., 2020). The most frequently used fit indices to determine the optimal model fit and number of classes in LPA are information-theoretic methods, likelihood ratio statistical test methods, and entropy-based criterion (Tein et al., 2013). Two common information-theoretic methods are Akaike’s Information Criterion (AIC; Akaike, 1973) and Bayesian Information Criterion (BIC; Schwarz, 1978). These criterions are based on the maximum likelihood estimates of the model parameters for selecting the most parsimonious and accurate model. Models with the lowest AIC/BIC values offer the best fit. Two common likelihood ratio statistical test methods are the Lo-Mendell-Rubin likelihood ratio test (LMRT; Lo et al., 2001) and the bootstrap likelihood ratio test (BLRT; McCutcheon, 1987 and McLachlan & Peel, 2000). For both likelihood ratio
tests, the significance value of $p < .05$ indicates that the $K_0$-class model provides significantly better fit to the observed data than the $K_{-1}$-class model (Tein et al., 2013). Finally, entropy-based criterion is a measure of aggregated classification uncertainty with higher values representing more similar posterior probabilities across classes, essentially representing the level of separation between classes. Normalized entropy is scaled from 0 to 1 and values greater than 0.80 indicate the latent classes have high discrimination. The higher the value of normalized entropy the better the fit (Muthen & Muthen, 2007). A cut-off of 0.80 or higher is recommended (Clark & Muthen, 2009) while some argue a cut-off between 0.60 and 0.80 is also acceptable (Jung & Wickrama, 2008; Spurk et al., 2020).

There is no common or superior standard procedure when determining the best model fit criteria and thus a combination of the above criteria is often used when selecting an “optimal” number of latent classes (Tein et al., 2013). To determine the best model fit, preliminary models were constructed to compare model fit across a range of estimated classes. For each model, an estimation of fit was calculated to convey the likelihood that the model is an accurate reflection of class differences. BIC and AIC were used, which takes parsimony of the model (i.e., the simplest possible model) into account (Hulst et al., 2015). Latent class model estimation was also based on full-information maximum likelihood methods. This allows for the use of all data from all patients, including those with some missing data. From the preliminary models, the model with the lowest BIC, AIC, and with adequate entropy and class size was selected. There are no current guidelines on class size requirements, therefore adequate class size was determined through clinical meaningfulness and a class size that was greater than 10% of the sample. Finally, the bootstrap likelihood ratio test (Mplus 4.1) and the Lo-Mendell Rubin likelihood ratio
test were used to confirm the selection of the final class solution, a data-driven method of testing whether the selected K-class model is significantly better than the solution with K-1-class model.

Once the number of classes was determined, one-way analysis of variance (one-way ANOVA) was conducted to compare neuropsychological, psychological, and behavioral differences across classes. Chi-square analyses were then conducted to determine the probability of output variables (demographic characteristics, ADHD diagnosis, and invalid neuropsychological profile) appearing in each class.
Results

Demographic information, sample characteristics, neuropsychological scores, and patient reported emotional and ADHD symptoms are described in Table 2. In brief, patients were relatively young adults ($M_{age}=25.94$), highly educated ($M_{edu}=14.24$), majority male (54.4%), and primarily Caucasian (78%). Additionally, patients were intelligent, with mean values of neuropsychological performance all within the average/high average range (Scaled Scores between 10 to 14), except for the continuous performance task scores with mean values in the mildly impaired to average range (Standard Scores between 70 and 98). Self-reported behavioral symptom counts on the BAARS-IV fell in the clinically meaningful range for current symptoms of inattention, hyperactive/impulsive, and sluggish cognitive tempo. Mean values for the Beck Depression Inventory-II and Beck Anxiety Inventory fell in the “mild” and the “minimal” ranges, respectively (Beck et al., 1996; Beck & Steer, 1993). Approximately 72% of the sample was determined to have or likely to have ADHD. 86.5% of the sample was determined to have a valid neuropsychological performance based on PVT performances.
Table 2. Study Variable Characteristics

<table>
<thead>
<tr>
<th>Sample Demographics</th>
<th>M (SD)/Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td>25.94 (7.83)</td>
</tr>
<tr>
<td><strong>Years of Education</strong></td>
<td>14.24 (1.57)</td>
</tr>
<tr>
<td><strong>ADHD Diagnosis</strong></td>
<td>---</td>
</tr>
<tr>
<td>Yes/Likely</td>
<td>186 (71.8%)</td>
</tr>
<tr>
<td>No</td>
<td>61 (23.6%)</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td>---</td>
</tr>
<tr>
<td>Male</td>
<td>141 (54.4%)</td>
</tr>
<tr>
<td>Female</td>
<td>110 (42.5%)</td>
</tr>
<tr>
<td><strong>Performance Validity</strong></td>
<td>---</td>
</tr>
<tr>
<td>Valid</td>
<td>224 (86.5%)</td>
</tr>
<tr>
<td>Invalid</td>
<td>27 (10.4%)</td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
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</tr>
<tr>
<td>Caucasian</td>
<td>202 (78.0%)</td>
</tr>
<tr>
<td>African American</td>
<td>20 (7.7%)</td>
</tr>
<tr>
<td>Asian American</td>
<td>10 (3.9%)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>11 (4.2%)</td>
</tr>
<tr>
<td>Other</td>
<td>13 (5.0%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test Variables</th>
<th>M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAIS-IV Vocabulary (ss)</td>
<td>14.40 (3.07)</td>
</tr>
<tr>
<td>WAIS-IV Similarities (ss)</td>
<td>12.08 (2.75)</td>
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<tr>
<td>WAIS-IV Block Design (ss)</td>
<td>11.40 (3.33)</td>
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<tr>
<td>WAIS-IV Symbol Search (ss)</td>
<td>10.74 (3.36)</td>
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<tr>
<td>WAIS-IV Letter-Number Sequencing (ss)</td>
<td>9.90 (3.30)</td>
</tr>
<tr>
<td>WAIS-IV Digit Span (ss)</td>
<td>10.44 (2.93)</td>
</tr>
<tr>
<td>CVLT-II Long Delay Free Recall (z)</td>
<td>-0.45 (1.16)</td>
</tr>
<tr>
<td>D-KEFS DF Switching (ss)</td>
<td>11.39 (2.92)</td>
</tr>
<tr>
<td>D-KEFS CWIT Inhibition (ss)</td>
<td>9.56 (3.44)</td>
</tr>
<tr>
<td>TOVA Reaction Time (SS)</td>
<td>97.52 (24.40)</td>
</tr>
<tr>
<td>TOVA Reaction Time Variability (SS)</td>
<td>69.54 (25.35)</td>
</tr>
<tr>
<td>TOVA D-Prime (SS)</td>
<td>77.26 (22.45)</td>
</tr>
<tr>
<td>BAARS-IV Current Inattention</td>
<td>5.61 (2.46)</td>
</tr>
<tr>
<td>BAARS-IV Current Hyperactivity/Impulsivity</td>
<td>3.94 (2.50)</td>
</tr>
<tr>
<td>BAARS-IV Current Sluggish Cognitive Tempo</td>
<td>5.04 (2.02)</td>
</tr>
<tr>
<td>Beck Depression Inventory-II</td>
<td>17.45 (11.71)</td>
</tr>
<tr>
<td>Beck Anxiety Inventory</td>
<td>13.00 (11.59)</td>
</tr>
</tbody>
</table>

*Note.* N = 259. ss = scaled score (mean of 10 and standard deviation of 3); z = z-score (mean of 0 and a standard deviation of 1); SS = standard score (mean of 100 and a standard deviation of 15); WAIS-IV = Wechsler Adult Intelligence Scale-4th Edition; CVLT-II = California Verbal Learning Test-2nd Edition; D-KEFS = Delis-Kaplan Executive Function System; DF = Design Fluency; CWIT = Color-Word Interference Test; TOVA = Test of Variable Attention; BAARS-IV = Barkley Adult ADHD Rating Scale-4th Edition.
**Aim 1:** Identify distinct homogenous subgroups of adults presenting with inattention and/or hyperactivity/impulsivity, plausibly related to ADHD, based on neuropsychological test performance, self-reported ADHD symptoms, and self-reported symptoms of anxiety and depression.

Up to seven separate profile solutions were modeled. See Table 3 for fit statistics (LL, AIC, BIC, ABIC, BLRT, LMRT, and Entropy) for each model. The LL, AIC, and ABIC decreased as number of classes increased for all classes. The BIC decreased from class one to five, with increases from classes five to seven. Taken together, the preponderance of evidence highlighted a five-class solution. However, examination of final class counts and proportions of the five-class model indicated that one of the classes only contained seven patients (3% of the sample). Due to the small class size, this model was deemed as unstable and provided limited clinical relevance compared to the four-class model. Additionally, the bootstrap likelihood ratio test confirmed the selection of the four-class solution with a significantly better fit compared to the three-model solution. As such, a four-class solution provided the best fit, as indicated by the following fit statistics (BIC = 22109, AIC = 21796, LL = −10810, ABIC = 21830, number of parameters = 88, and entropy = 0.848).
<table>
<thead>
<tr>
<th>Number of Classes</th>
<th>Parameters</th>
<th>LL</th>
<th>AIC</th>
<th>BIC</th>
<th>ABIC</th>
<th>BLRT p-value</th>
<th>LMRT p-value</th>
<th>Entropy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34</td>
<td>-11268.436</td>
<td>22604.871</td>
<td>22725.804</td>
<td>22618.011</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>52</td>
<td>-10973.665</td>
<td>22051.331</td>
<td>22236.286</td>
<td>22071.427</td>
<td>&lt;.0001</td>
<td>0.004</td>
<td>0.856</td>
</tr>
<tr>
<td>3</td>
<td>70</td>
<td>-10882.065</td>
<td>21904.130</td>
<td>22153.108</td>
<td>21932.182</td>
<td>&lt;.0001</td>
<td>0.0282</td>
<td>0.865</td>
</tr>
<tr>
<td>4*</td>
<td>88</td>
<td>-10810.131</td>
<td>21796.261</td>
<td>22109.262</td>
<td>21830.270</td>
<td>&lt;.0001</td>
<td>0.4335</td>
<td>0.848</td>
</tr>
<tr>
<td>5</td>
<td>106</td>
<td>-10759.481</td>
<td>21730.961</td>
<td>22107.985</td>
<td>21771.927</td>
<td>&lt;.0001</td>
<td>0.4176</td>
<td>0.869</td>
</tr>
<tr>
<td>6</td>
<td>124</td>
<td>-10710.875</td>
<td>21669.750</td>
<td>22110.797</td>
<td>21717.672</td>
<td>&lt;.0001</td>
<td>0.3733</td>
<td>0.866</td>
</tr>
<tr>
<td>7</td>
<td>142</td>
<td>-10666.042</td>
<td>21616.084</td>
<td>22121.153</td>
<td>21670.962</td>
<td>&lt;.0001</td>
<td>0.6689</td>
<td>0.873</td>
</tr>
</tbody>
</table>

Aim 2: *Assess neuropsychological, psychological, and behavioral differences between identified subgroups.*

Collectively, the four-class model was determined to be the best fitting and most accurate model. Classes 1, 2, 3, and 4 comprised 11.58% (N = 30), 30.89% (N = 80), 38.22% (N = 99), and 19.31% (N = 50) of the sample, respectively. Average neuropsychological, behavioral, and mood scores for each of the four classes are provided in Table 4, and visually depicted in Figures 1, 2, and 3. Briefly, based on the mean scores across characteristics for each profile, Class 1 (Neuropsychiatrically Distressed) mean scores were significantly lower across all neuropsychological measures. Class 1 reported significantly higher mood symptoms and behavioral symptoms (hyperactive/impulsive and SCT). Class 2 (Relative Cognitive Inefficiencies only) mean scores were the second lowest across all neuropsychological measures. Notably, performance on the TOVA was significantly lower in Class 2 than all other classes. Additionally, Class 2 reported the second highest behavioral symptoms (except for SCT) and mood symptoms. Class 3 (Relative Cognitive Inefficiencies with Preserved Vigilance) mean scores were second highest across all neuropsychological measures. Additionally, they reported the second to lowest mood symptoms and significantly lower behavioral symptoms than Class 1. Class 4 (Neuropsychiatrically Resilient) mean scores were significantly higher across all neuropsychological measures and Class 4 reported the lowest behavioral symptoms (hyperactivity/impulsivity and SCT) and mood symptoms. TOVA scores were significantly higher in Class 4 and Class 3, respectively. Analysis of variance revealed significant models across all profile indicator variables.
Table 4. Analysis of Variance (ANOVA) of Profile Indicator Variables Across Latent Classes

<table>
<thead>
<tr>
<th>Profile Indicator</th>
<th>Neuro-Psychiatrically Distressed (Class 1)</th>
<th>Relative Cognitive Inefficiencies only (Class 2)</th>
<th>Relative Cognitive Inefficiencies with Preserved Vigilance (Class 3)</th>
<th>Neuro-Psychiatrically Resilient (Class 4)</th>
<th>F</th>
<th>η²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 30 (11.58%)</td>
<td>n = 80 (30.89%)</td>
<td>n = 99 (38.22%)</td>
<td>N = 50 (19.31%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAIS-IV Vocabulary (ss)</td>
<td>10.85 (3.08)c</td>
<td>14.26 (2.40)ad</td>
<td>14.40 (2.89)ad</td>
<td>16.51 (2.52)c</td>
<td>25.155**</td>
<td>.237</td>
</tr>
<tr>
<td>WAIS-IV Similarities (ss)</td>
<td>8.22 (2.64)c</td>
<td>12.01 (2.13)ad</td>
<td>12.26 (2.41)ad</td>
<td>13.96 (2.18)c</td>
<td>36.277**</td>
<td>.308</td>
</tr>
<tr>
<td>WAIS-IV Block Design (ss)</td>
<td>7.30 (2.55)c</td>
<td>10.58 (2.52)ad</td>
<td>11.13 (2.25)ad</td>
<td>15.51 (2.42)c</td>
<td>77.326**</td>
<td>.485</td>
</tr>
<tr>
<td>WAIS-IV Symbol Search (ss)</td>
<td>5.70 (2.52)c</td>
<td>9.77 (2.53)c</td>
<td>11.32 (2.26)c</td>
<td>13.88 (2.87)c</td>
<td>68.905**</td>
<td>.457</td>
</tr>
<tr>
<td>WAIS-IV Letter-Number Seq (ss)</td>
<td>7.07 (1.82)c</td>
<td>9.42 (2.65)ad</td>
<td>9.94 (3.03)ad</td>
<td>12.14 (3.87)c</td>
<td>17.901**</td>
<td>.179</td>
</tr>
<tr>
<td>WAIS-IV Digit Span (ss)</td>
<td>7.00 (2.08)c</td>
<td>9.57 (2.07)ad</td>
<td>10.39 (2.05)ad</td>
<td>13.78 (2.76)c</td>
<td>63.545**</td>
<td>.436</td>
</tr>
<tr>
<td>CVLT-II Long Delay (z)</td>
<td>-1.91 (1.02)c</td>
<td>-0.65 (1.10)ad</td>
<td>-0.21 (0.92)c</td>
<td>0.22 (1.00)ab</td>
<td>29.278**</td>
<td>.262</td>
</tr>
<tr>
<td>D-KEFS DF Switching (ss)</td>
<td>8.67 (2.30)c</td>
<td>10.66 (2.40)ad</td>
<td>11.21 (2.49)ad</td>
<td>14.34 (2.40)c</td>
<td>38.632**</td>
<td>.319</td>
</tr>
<tr>
<td>D-KEFS CWIT Inhibition (ss)</td>
<td>5.19 (3.31)c</td>
<td>8.32 (3.28)c</td>
<td>10.25 (2.35)c</td>
<td>12.62 (1.77)c</td>
<td>52.625**</td>
<td>.392</td>
</tr>
<tr>
<td>TOVA Reaction Time (SS)</td>
<td>91.68 (23.66)c</td>
<td>72.78 (21.39)c</td>
<td>112.95 (11.69)ab</td>
<td>104.98 (18.20)ab</td>
<td>68.978**</td>
<td>.480</td>
</tr>
<tr>
<td>TOVA Reaction Time Var (SS)</td>
<td>49.26 (13.78)cd</td>
<td>45.57 (9.24)cd</td>
<td>89.64 (16.68)c</td>
<td>80.16 (21.39)c</td>
<td>137.583**</td>
<td>.626</td>
</tr>
<tr>
<td>TOVA D-Prime (SS)</td>
<td>56.04 (21.45)c</td>
<td>65.49 (20.49)c</td>
<td>88.09 (17.77)ab</td>
<td>85.24 (19.84)ab</td>
<td>32.882**</td>
<td>.285</td>
</tr>
<tr>
<td>BAARS-IV Current Inattention</td>
<td>6.74 (2.10)cd</td>
<td>6.39 (2.10)cd</td>
<td>4.94 (2.55)ab</td>
<td>5.18 (2.46)ab</td>
<td>7.962**</td>
<td>.089</td>
</tr>
<tr>
<td>BAARS-IV Current Hyper/Imp</td>
<td>4.85 (2.44)d</td>
<td>4.15 (2.71)ma</td>
<td>3.91 (2.40)ma</td>
<td>3.18 (2.20)a</td>
<td>2.994*</td>
<td>.035</td>
</tr>
<tr>
<td>BAARS-IV Current SCT</td>
<td>6.50 (1.17)cd</td>
<td>4.56 (2.38)a</td>
<td>5.24 (1.98)ma</td>
<td>4.39 (1.62)a</td>
<td>3.791*</td>
<td>.101</td>
</tr>
<tr>
<td>Beck Depression Inventory-II</td>
<td>31.77 (11.41)c</td>
<td>14.35 (11.39)a</td>
<td>18.19 (10.72)a</td>
<td>12.88 (8.46)a</td>
<td>10.607**</td>
<td>.199</td>
</tr>
<tr>
<td>Beck Anxiety Inventory</td>
<td>25.14 (15.91)c</td>
<td>12.49 (12.38)a</td>
<td>12.53 (9.80)a</td>
<td>8.04 (5.88)a</td>
<td>7.738**</td>
<td>.153</td>
</tr>
</tbody>
</table>

Note. N = 259. *p<.05, **p<.001. n² = eta squared. ss = scaled score (mean of 10 and standard deviation of 3); z = z-score (mean of 0 and a standard deviation of 1); SS = standard score (mean of 100 and a standard deviation of 15); WAIS-IV = Wechsler Adult Intelligence Scale-4th Edition; Letter-Number Seq = Letter-Number Sequencing; CVLT-II = California Verbal Learning Test-2nd Edition; D-KEFS = Delis-Kaplan Executive Function System; DF = Design Fluency; CWIT = Color-Word Interference Test; TOVA. = Test of Variable Attention; Reaction Time Var = Reaction Time Variability; BAARS-IV = Barkley Adult ADHD Rating Scale-4th Edition; Hyper/Imp = Hyperactivity Impulsivity; SCT = Sluggish Cognitive Tempo. a Denotes significant difference with Neuropsychiatrically Distressed class; b Denotes significant difference with Relative Cognitive Inefficiencies only class; c Denotes significant difference with Relative Cognitive Inefficiencies with Persevered Vigilance class; d Denotes significant difference with Neuropsychiatrically Resilient class. e Denotes significant difference will all classes. ns Denotes nonsignificant difference with all classes.
**Figure 1. Neurocognitive Profiles for the Four-Class Solution**

![Figure 1](image_url)

*Note.* All subtest scores have been converted to scaled scores. Scaled scores have a mean of 10 and standard deviation of 3. WAIS-IV = Wechsler Adult Intelligence Scale-4th Edition; VC = Vocabulary; SIM = Similarities; BD = Block Design; SS = Symbol Search; LNS = Letter-Number Sequencing; CVLT-II = California Verbal Learning Test-2nd Edition; D-KEFS = Delis-Kaplan Executive Function System; DF = Design Fluency; CWIT = Color-Word Interference Test; TOVA = Test of Variable Attention; RT = Reaction Time; RTV = Reaction Time Variability.
Figure 2. Mood Profiles for the Four-Class Solution

**Figure 3.** Behavioral Profiles for the Four-Class Solution

![Graph showing behavioral profiles for four classes](image)

*Note.* BAARS-IV = Barkley Adult ADHD Rating Scale-4th Edition; Symptom counts ≥3 on inattention or hyperactivity/impulsivity is considered clinically significant (93rd percentile). Symptom counts ≥4 on sluggish cognitive tempo is considered clinically significant (93rd percentile).
**Aim 3:** Identify the likelihood/probability of subgroup identification based on demographic characteristics, ADHD diagnosis, and an invalid neuropsychological performance profile.

The mean differences of output variables across each class were assessed through ANOVA. As shown in Table 5, age did not significantly differ across classes. Years of education in the Neuropsychiatrically Distressed group (M_{edu} = 12.73) was significantly lower than the other groups (F=13.189, p < .001). Next, the likelihood of output variables within each class was assessed. Chi-square analyses revealed that gender did not significantly differ in likelihood of appearing in each class. The likelihood of a patient receiving an ADHD diagnosis significantly differed amongst groups (X^2 (3) = 14.796, p < .05), ranging from 80% (Relative Cognitive Inefficiencies only group) to 61.6% (Relative Cognitive Inefficiencies with Preserved Vigilance group). Classes also differed significantly with respect to patient task engagement ((Performance Validity) X^2 (3) = 36.611, p < .001) and ethnicity (X^2 (18) = 43.468, p < .001). Valid performance ranged from 98.0% (Neuropsychiatrically Resilient group) to 59.3% (Neuropsychiatrically Distressed group).
<table>
<thead>
<tr>
<th>Output Variables</th>
<th>Neuro-Psychiatrically Distressed (Class 1)</th>
<th>Relative Cognitive Inefficiencies only (Class 2)</th>
<th>Relative Cognitive Inefficiencies with Preserved Vigilance (Class 3)</th>
<th>Neuro-Psychiatrically Resilient (Class 4)</th>
<th>$F$</th>
<th>$\eta^2$</th>
<th>Pairwise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>28.56 (9.01)</td>
<td>26.80 (7.83)</td>
<td>24.97 (7.40)</td>
<td>25.00 (5.29)</td>
<td>2.076</td>
<td>.025</td>
<td>1 = 2 = 3 = 4</td>
</tr>
<tr>
<td>Years of Education</td>
<td>12.73 (2.00)</td>
<td>14.24 (1.47)</td>
<td>14.42 (1.32)</td>
<td>14.76 (1.36)</td>
<td>13.189**</td>
<td>.134</td>
<td>1 &lt; 4 = 2 = 3</td>
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$X^2$ for Pairwise

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<th>ADHD Diagnosis</th>
<th>--</th>
<th>--</th>
<th>--</th>
<th>--</th>
<th>14.796*</th>
<th>.134</th>
<th>3 &lt; 2 = 1 = 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes/Likely</td>
<td>22 (73.3%)</td>
<td>64 (80.0%)</td>
<td>61 (61.6%)</td>
<td>39 (78.0%)</td>
<td>--</td>
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<td></td>
</tr>
<tr>
<td>No</td>
<td>5 (16.7%)</td>
<td>9 (11.3%)</td>
<td>36 (36.4%)</td>
<td>11 (22.0%)</td>
<td>--</td>
<td>--</td>
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</tr>
<tr>
<td>Gender</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1.013</td>
<td>1 = 2 = 3 = 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>16 (59.3%)</td>
<td>45 (57.0%)</td>
<td>55 (57.9%)</td>
<td>25 (50.0%)</td>
<td>--</td>
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<td></td>
</tr>
<tr>
<td>Female</td>
<td>11 (40.7%)</td>
<td>34 (43.0%)</td>
<td>40 (42.1%)</td>
<td>25 (50.0%)</td>
<td>--</td>
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<tr>
<td>Performance Validity</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>36.611**</td>
<td>1 &lt; 2 = 3 = 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valid</td>
<td>16 (59.3%)</td>
<td>67 (84.4%)</td>
<td>92 (96.8%)</td>
<td>49 (98.0%)</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Invalid</td>
<td>11 (40.7%)</td>
<td>12 (15.2%)</td>
<td>3 (3.2%)</td>
<td>1 (2.0%)</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>43.468**</td>
<td>1 &lt; 2 = 3 = 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>14 (46.7%)</td>
<td>59 (73.8%)</td>
<td>84 (84.8%)</td>
<td>45 (90.0%)</td>
<td>--</td>
<td>1 &lt; 2 = 3 = 4</td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>9 (30.0%)</td>
<td>8 (10.0%)</td>
<td>3 (3.0%)</td>
<td>0 (0.0%)</td>
<td>--</td>
<td>3 = 4 &lt; 2 = 1</td>
<td></td>
</tr>
<tr>
<td>Asian American</td>
<td>1 (3.3%)</td>
<td>3 (3.8%)</td>
<td>4 (4.0%)</td>
<td>2 (4.0%)</td>
<td>--</td>
<td>1 = 2 = 3 = 4</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>3 (10.0%)</td>
<td>4 (5.0%)</td>
<td>3 (3.0%)</td>
<td>1 (2.0%)</td>
<td>--</td>
<td>1 = 2 = 3 = 4</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>3 (10.0%)</td>
<td>6 (7.6%)</td>
<td>3 (3.0%)</td>
<td>1 (2.0%)</td>
<td>--</td>
<td>1 = 2 = 3 = 4</td>
<td></td>
</tr>
</tbody>
</table>

Note. *p<.05, **p < .001; $\eta^2$ = eta squared; := No statistically significant difference between groups.
Supplemental Analyses

Given that performance validity differed significantly across classes, supplemental analyses were conducted after removing individuals putting forth insufficient effort based on PVT performances (N=27). After removing individuals with insufficient effort, the study sample consisted of N = 232. Analyses previously described were repeated using only data obtained from patients putting forth sufficient effort. Results are briefly described below.

**Aim 1:** Identify distinct homogenous subgroups of adults presenting with inattention and/or hyperactivity/impulsivity, plausibly related to ADHD, based on neuropsychological test performance, self-reported ADHD symptoms, and self-reported symptoms of anxiety and depression.

Up to seven separate profile solutions were modeled. The LL, AIC, and ABIC decreased as number of classes increased for all classes. The BIC decreased from class one to class four but increased from class four to class seven. Evidence highlighted again that a four-class solution is preferrable to a five-class solution, due to the increase in BIC from four to five classes. In addition, the four-class solution allows for the examination of more subtle differences that exist within the sample compared to the three-class solution. The bootstrap likelihood ratio test also confirmed selection of the four-class solution with a significantly better fit compared to the three-model solution. As such, a four-class solution again provided the best fit, as indicated by the following fit statistics (BIC = 19568, AIC= 19265, LL= −9544, ABIC = 19289, number of parameters = 88, and entropy = 0.850).
Aim 2: Assess neuropsychological, psychological, and behavioral differences between identified subgroups.

Classes 1, 2, 3, and 4 comprised 18.5% (N = 43), 21.6% (N = 50), 40.9% (N = 95), and 19.0% (N = 44) of the sample, respectively. Like the primary analyses, a four-class model was determined to be the best fit. After removing individuals with insufficient effort, Class 3 and Class 4 remained similar sized (N=99 to N=95 and N=50 to N=44, respectively). However, Class 2 decreased from N=80 to N=50 and Class 1 increased from N=30 to N=43. Average neuropsychological, behavioral, and mood scores for each of the four classes are provided in Table 6, and visually depicted in Figures 4, 5, and 6. Briefly, based on the mean scores across characteristics for each profile, Class 1 (Neuropsychiatrically Distressed) mean scores were significantly lower across all neuropsychological measures. Class 1 reported significantly higher behavioral symptoms (hyperactive/impulsive and SCT) and mood symptoms. Class 2 (Relative Cognitive Inefficiencies only) mean scores were in the middle across all neuropsychological measures. Class 2 reported the highest inattentive symptoms and the lowest hyperactive/impulsive and SCT symptoms, and the lowest mood symptoms. Notably, performance on the TOVA was significantly lower in Class 2 than all other classes. Class 3 (Relative Cognitive Inefficiencies with Preserved Vigilance) mean scores were in the middle across all neuropsychological measures. Class 3 reported the second highest mood symptoms, the lowest inattention symptoms, but the second highest hyperactive/impulsive symptoms. Class 4 (Neuropsychiatrically Resilient) mean scores were significantly higher across all neuropsychological measures. Class 4 reported the second lowest behavioral symptoms and mood symptoms. TOVA scores were significantly higher in Class 4 and Class 3, respectively. Analysis of variance revealed significant models across all profile indicator variables. In
comparison to the primary analyses, the mean values across Class 1 and Class 2 slightly increased. Mean values across Class 3 and Class 4 remained relatively unchanged.
Table 6. Analysis of Variance (ANOVA) of Profile Indicator Variables Across Latent Classes with Insufficient Effort Removed

<table>
<thead>
<tr>
<th>Profile Indicator</th>
<th>Neuro-Psychiatically Distressed* (Class 1)</th>
<th>Relative Cognitive Inefficiencies only (Class 2)</th>
<th>Relative Cognitive Inefficiencies with Preserved Vigilance (Class 3)</th>
<th>Neuro-Psychiatically Resilient Class 4</th>
<th>F</th>
<th>η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAIS-IV Vocabulary (ss)</td>
<td>12.18 (2.75)c</td>
<td>15.08 (2.41)ad</td>
<td>14.46 (2.87)nd</td>
<td>16.72 (2.42)c</td>
<td>19.988**</td>
<td>.217</td>
</tr>
<tr>
<td>WAIS-IV Similarities (ss)</td>
<td>9.72 (2.72)c</td>
<td>12.62 (2.24)ad</td>
<td>12.23 (2.24)nd</td>
<td>13.91 (2.21)c</td>
<td>23.100**</td>
<td>.241</td>
</tr>
<tr>
<td>WAIS-IV Block Design (ss)</td>
<td>8.69 (2.74)c</td>
<td>10.94 (2.71)ad</td>
<td>11.09 (2.32)nd</td>
<td>15.70 (2.48)c</td>
<td>57.753**</td>
<td>.442</td>
</tr>
<tr>
<td>WAIS-IV Symbol Search (ss)</td>
<td>8.38 (2.74)c</td>
<td>10.00 (2.46)c</td>
<td>11.37 (2.30)c</td>
<td>14.00 (2.86)c</td>
<td>37.602**</td>
<td>.340</td>
</tr>
<tr>
<td>WAIS-IV Letter-Number Seq (ss)*</td>
<td>7.36 (2.18)c</td>
<td>10.63 (3.11)c</td>
<td>10.00 (3.12)nd</td>
<td>11.75 (3.71)ac</td>
<td>14.741**</td>
<td>.167</td>
</tr>
<tr>
<td>WAIS-IV Digit Span (ss)</td>
<td>8.38 (2.25)c</td>
<td>10.08 (2.33)ad</td>
<td>10.43 (1.96)nd</td>
<td>13.98 (2.83)c</td>
<td>45.056**</td>
<td>.381</td>
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<tr>
<td>CVLT-II Long Delay (z)</td>
<td>-1.18 (1.14)c</td>
<td>-0.40 (1.12)ad</td>
<td>-0.23 (0.98)a</td>
<td>0.18 (1.03)ab</td>
<td>12.179**</td>
<td>.142</td>
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<tr>
<td>D-KEFS DF Switching (ss)</td>
<td>9.03 (2.53)c</td>
<td>10.96 (2.50)ad</td>
<td>11.39 (2.29)nd</td>
<td>14.61 (2.25)c</td>
<td>40.281**</td>
<td>.355</td>
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<tr>
<td>D-KEFS CWIT Inhibition (ss)*</td>
<td>5.59 (2.89)c</td>
<td>9.45 (2.94)ad</td>
<td>10.19 (2.47)nd</td>
<td>12.86 (1.62)c</td>
<td>58.873**</td>
<td>.448</td>
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<tr>
<td>TOVA Reaction Time (SS)</td>
<td>85.97 (22.29)c</td>
<td>72.93 (22.53)c</td>
<td>113.14 (11.71)ab</td>
<td>106.71 (16.99)ab</td>
<td>58.870**</td>
<td>.470</td>
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<td>TOVA Reaction Time Var (SS)</td>
<td>49.36 (13.37)cd</td>
<td>46.63 (9.99)cd</td>
<td>90.33 (16.60)c</td>
<td>81.66 (21.70)c</td>
<td>111.491**</td>
<td>.603</td>
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<tr>
<td>TOVA D-Prime (SS)*</td>
<td>66.68 (20.99)c</td>
<td>67.88 (22.26)cd</td>
<td>88.47 (17.80)ab</td>
<td>85.64 (20.51)cd</td>
<td>18.386**</td>
<td>.201</td>
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<tr>
<td>BAARS-IV Current Inattention*</td>
<td>6.15 (2.19)cd</td>
<td>6.59 (2.19)cd</td>
<td>5.03 (2.57)b</td>
<td>5.18 (2.30)b</td>
<td>5.602*</td>
<td>.071</td>
</tr>
<tr>
<td>BAARS-IV Current Hyper/Imp*</td>
<td>4.68 (2.65)cd</td>
<td>3.21 (2.43)a</td>
<td>3.79 (3.39)ac</td>
<td>3.72 (2.18)a</td>
<td>3.456*</td>
<td>.046</td>
</tr>
<tr>
<td>BAARS-IV Current SCT*</td>
<td>6.55 (1.37)cd</td>
<td>3.00 (2.16)ac</td>
<td>5.14 (1.93)b</td>
<td>4.63 (1.42)a</td>
<td>38.203**</td>
<td>.231</td>
</tr>
<tr>
<td>Beck Depression Inventory*</td>
<td>31.53 (8.87)c</td>
<td>6.24 (4.37)ac</td>
<td>17.05 (9.78)ab</td>
<td>13.05 (8.85)a</td>
<td>25.689**</td>
<td>.416</td>
</tr>
<tr>
<td>Beck Anxiety Inventory*</td>
<td>23.75 (11.55)c</td>
<td>4.71 (3.96)ac</td>
<td>11.47 (7.64)ab</td>
<td>7.76 (5.94)a</td>
<td>21.515**</td>
<td>.372</td>
</tr>
</tbody>
</table>

Note. N = 232. *p<.05, **p<.001. n² = eta squared. ss = scaled score (mean of 10 and standard deviation of 3); z = z-score (mean of 0 and a standard deviation of 1); SS = standard score (mean of 100 and a standard deviation of 15); WAIS-IV = Wechsler Adult Intelligence Scale-4th Edition; Letter-Number Seq = Letter-Number Sequencing; CVLT-II = California Verbal Learning Test-2nd Edition; D-KEFS = Delis-Kaplan Executive Function System; DF = Design Fluency; CWIT = Color-Word Interference Test; T.O.V.A. = Test of Variable Attention; Reaction Time Var = Reaction Time Variability; BAARS-IV = Barkley Adult ADHD Rating Scale-4th Edition; Hyper/Imp = Hyperactivity Impulsivity; SCT = Sluggish Cognitive Tempo. a Denotes significant difference with Neuropsychiatically Distressed class; b Denotes significant difference with Relative Cognitive Inefficiencies only class; c Denotes significant difference with Relative Cognitive Inefficiencies with Persevered Vigilance class; d Denotes significant difference with Neuropsychiatically Resilient class. e Denotes significant difference will all classes. ns Denotes nonsignificant differences with all classes. * Denotes a difference from primary analyses.
**Figure 4.** Neurocognitive Profiles for the Four-Class Solution with Insufficient Effort Removed

Note. All subtest scores have been converted to scaled scores. Scaled scores have a mean of 10 and standard deviation of 3. WAIS-IV = Wechsler Adult Intelligence Scale-4th Edition; VC = Vocabulary; SIM = Similarities; BD = Block Design; SS = Symbol Search; LNS = Letter-Number Sequencing; CVLT-II = California Verbal Learning Test-2nd Edition; D-KEFS = Delis-Kaplan Executive Function System; DF = Design Fluency; CWIT = Color-Word Interference Test; TOVA = Test of Variable Attention; RT = Reaction Time; RTV = Reaction Time Variability.
Figure 5. Mood Profiles for the Four-Class Solution with Insufficient Effort Removed

Note. BDI-II = Beck Depression Inventory-Second Edition; 0-9: indicates minimal depression, 10-18: indicates mild depression, 19-29: indicates moderate depression, and 30-63: indicates severe depression; BAI = Beck Anxiety Inventory; 0-7: indicates minimal anxiety, 8-15: indicates mild anxiety, 16-25: indicates moderate anxiety, and 26-63: indicates severe anxiety.
Figure 6. Behavioral Profiles for the Four-Class Solution with Insufficient Effort Removed

Note. BAARS-IV = Barkley Adult ADHD Rating Scale-4th Edition; Symptom counts ≥ 3 on inattention or hyperactivity/impulsivity is considered clinically significant (93rd percentile). Symptom counts ≥ 4 on sluggish cognitive tempo is considered clinically significant (93rd percentile).
**Aim 3:** Identify the likelihood/probability of subgroup identification based on demographic characteristics and ADHD diagnosis.

The mean differences of output variables across each class were assessed through ANOVA. Age did not significantly differ across classes. Years of education in the Neuropsychiatrically Distressed group ($M_{\text{edu}} = 13.51$) continued to be significantly lower than the other groups ($F = 5.138, p = .002$). Next, the likelihood of output variables within each class was assessed. Chi-square analyses revealed that gender did not significantly differ in likelihood of appearing in each class ($X^2 (3) = 4.943, p > .05$). Classes did differ significantly with respect to ethnicity ($X^2 (18) = 37.185, p < .05$). The likelihood of a patient receiving an ADHD diagnosis significantly differed amongst groups ($X^2 (3) = 11.492, p = .009$), ranging from 86.7% (Relative Cognitive Inefficiencies only group) to 64.5% (Relative Cognitive Inefficiencies with Preserved Vigilance group).
Discussion

The present study explored the cognitive, behavioral, and emotional functioning of adults referred for an ADHD evaluation. ADHD is a highly heterogeneous disorder with multifactorial etiologies, diverse developmental trajectories, psychiatric comorbidities, and varied patterns of neurocognitive impairment. Diagnosis of ADHD in adults presents unique challenges due to high rates of comorbidities (with core features being non-specific in nature) and current diagnostic criteria having higher pertinence to children. Further, it requires an adult to accurately describe their current functioning and recall childhood difficulties. The current characterization of ADHD into three distinct subtypes may fail to capture the heterogeneity present within an adult ADHD population. Latent profile analysis provides nuanced, person-centered analyses to identify and explain this possible heterogeneity. This study adds to a relatively sparse literature examining the heterogeneity within an adult ADHD sample. The identification of distinct classes within adult patients referred for an ADHD evaluation makes clear that cognitive, emotional, and behavioral heterogeneity is present in adults with ADHD. This finding, in turn, may improve clinicians’ ability to tailor relevant treatment recommendations.

A primary finding of this research is the identification of four distinct latent classes that suggested significant variability, across neuropsychological performances, behavioral report, and mood symptoms. The four classes were labeled: Neuropsychiatrically Distressed (Class 1), Relative Cognitive Inefficiencies only (Class 2), Relative Cognitive Inefficiencies with Preserved Vigilance (Class 3), and Neuropsychiatrically Resilient (Class 4). Notably, patients included in this study were intelligent with broadly average to high average neuropsychological scores. Despite broad, normatively average performances, four distinct classes emerged with
significant differences amongst one another. This highlights the cognitive heterogeneity that exists even within an intelligent, educated sample.

Class 1, the most impaired and distressed group, was defined by pronounced inattention and cognitive challenges, ranging from mildly impaired to average scores across neuropsychological tests. Performances on working memory and processing speed tasks varied from mildly impaired to low average. Additionally, this was the only class to exhibit impaired performance on a task of executive functioning. Class 1 reported the greatest number of emotional symptoms. In fact, on average, patients experienced severe depression and moderate anxiety. Additionally, Class 1 reported significantly impairing (and greater) symptoms of inattention, hyperactivity/impulsivity, and sluggish cognitive tempo symptoms than the other classes. In sum, Class 1 presents with pronounced cognitive difficulties, moderate to severe mood symptoms, and clinically significant behavioral reports. Class 1’s pronounced cognitive difficulties may reflect a cumulative, negative effect of experiencing both significant psychological symptoms and ADHD symptomatology (Gallagher & Blader, 2001).

Class 2 was defined by pronounced sustained attention difficulties. Class 2 has relative cognitive inefficiencies (i.e., scores within normal limits that reflect subtly lower than anticipated performance compared to the sample) across neuropsychological measures. However, TOVA scores in Class 2 were normatively impaired with mean values exhibiting the slowest and most variable reaction times, suggesting inattention and difficulties maintaining vigilance. Class 2 reported, on average, depression and anxiety symptoms in the mild range. Class 2 also reported the second highest inattention, hyperactivity/impulsivity, and sluggish cognitive tempo symptoms. In sum, Class 2 presents with normatively average, but relatively inefficient cognitive
performances, with a normative and relative weakness in sustained attention, mild mood symptoms, and clinically significant behavioral reports.

Class 3 was defined by relative cognitive inefficiencies, with preserved sustained attention. Normatively, neuropsychological scores were largely in the average to high average range, including the TOVA. Class 3 reported the second highest mood symptoms with reported depression and anxiety symptoms in the mild range. Additionally, Class 3 reported the second highest sluggish cognitive tempo symptoms. In sum, Class 3 is presenting with normatively average, but relatively inefficient cognitive performances, mild mood symptoms, and clinically significant behavioral ratings.

Class 4 was defined by cognitive strengths and minimal mood symptoms. Normatively, all neuropsychological scores were in the high average to very superior range. Class 4 reported the lowest mood symptoms with reported depression symptoms in the minimal range and anxiety symptoms in the mild range. Class 4 also reported the lowest hyperactivity/impulsivity and sluggish cognitive tempo symptoms. In sum, Class 4 is presenting with well above average neuropsychological performances, minimal mood symptoms, and low report of behavioral symptoms. Class 4’s strengths in cognitive functioning highlight preexisting literature that not all individuals with ADHD experiencing functional impairment have significant cognitive challenges on objective testing (Baggio et al., 2020).

There were significant differences in ethnicity across classes, particularly in Caucasian and African American patients. Given the high percentage of Caucasian individuals in our sample (78%), these significant differences may fail to provide meaningful insight into why these distinctions exist. There were no significant age or gender differences across classes. Previous research has examined the gender ratio in adults with ADHD and found that while in
childhood the male to female ratio is 4:1, the ratio is closer to 1:1 in adults (Abdelnour, Jansen, & Gold., 2022). This ratio of adulthood prevalence is closely reflected in our adult sample (male: 54% vs. female: 43%). Additionally, although males with ADHD are more likely to exhibit hyperactive/impulsive symptoms, research shows that these symptoms wane over time (i.e. into adulthood) (Skogli et al., 2013). Moreover, research has found the differences on objective neurocognitive performances between genders assessed for ADHD are relatively nonexistent (e.g., Pievsky & McGrath, 2018). Therefore, while the likelihood of ADHD being diagnosed differs between males and females in childhood, there is no reason to believe that presentation differs later in life. These conclusions align with our findings of no gender differences across classes in a referred adult ADHD sample.

There were significant differences in ADHD diagnosis across classes. Diagnosis of ADHD was determined based on information obtained during the clinical interview and the consideration of current and childhood ADHD symptom reporting. Interestingly, Class 3 had the lowest rate of ADHD diagnoses (61.6%) highlighting the potential role of the TOVA, or a similar measure of sustained attention, in diagnostic decision-making. Class 3 had unimpaired TOVA scores. Conversely, Class 2 had the worst TOVA scores and the highest likelihood of ADHD diagnosis (80.0%). Taken together, and consistent with a broad literature (e.g., Hall et al., 2016; Tucha et al., 2017), measures of sustained attention appear to effectively differentiate between ADHD and non-ADHD adults. Despite intact neurocognitive performances within Class 4, the likelihood of ADHD diagnosis remained high within this class. One explanation for this could be that reporting functional impairment associated with ADHD symptoms during the clinical interview (in the absence of reporting emotional symptoms), increases the likelihood of receiving an ADHD diagnosis, despite intact neurocognitive performances.
Significant differences in performance validity were identified across classes as well. Class 1 had the highest likelihood of insufficient performance, with 41% of the group being identified as exhibiting invalid performance. Class 2 had the second highest likelihood of insufficient performance with 15% of the group exhibiting invalid performance. This confounds interpretation of findings and as such, additional analyses were warranted to explore the role of invalid performance in differentiating groups.

The likelihood of insufficient performance varied across classes in the primary analyses. As insufficient performance is likely to suppress means, it was unknown whether effort would solely account for the group differences, particularly the impaired performances in Class 1 and Class 2. As such, supplemental analyses were conducted after removing individuals with insufficient performance. Given the high occurrence of invalid cognitive performance within adults being assessed for ADHD, the main purpose of the supplemental analyses was to explore the role of invalid performance within an adult ADHD sample (Marshall et al., 2010; Ovsiew et al., 2023; Suhr et al., 2011). Additionally, the inclusion of individuals with insufficient performance within the primary analyses was intentional in order to more accurately examine a referred population in a true clinical setting. Research speculates that over 50% of college students may feign their symptoms (Ramachandran et al., 2020; Sibley, 2021). Further, many researchers exclude individuals with insufficient performance prior to analyses (Leib et al., 2021), or do not consider invalid performance at all (Theiling & Petermann, 2016). These methodological decisions result in an incomplete understanding of the referred population. By including and considering those with insufficient performance, this study allowed for examination of the role of insufficient performance within the heterogeneity of ADHD. For example, if an entire class were to be defined by individuals with insufficient performance, this
allowed for examination of other group characteristics (gender, ADHD diagnosis, etc.).

Additionally, by including those with insufficient effort in the primary analyses, we were able to conduct sensitivity analyses after excluding patients putting forth insufficient effort to glean insight into their role within the emerging classes.

Somewhat surprisingly, the removal of those with insufficient performance did not greatly impact the latent profiles. The final class solution and the significant differences between classes remained stable. This differs from prior literature that found the removal of insufficient performance resulted in significant differences (Hoelzle et al., 2019). Interestingly, Class 1 continues to emerge and be defined by significant difficulties compared to the other classes. This finding further supports the existence of a broadly distressed adult ADHD group within a referred adult ADHD sample. Notably, the removal of patients with insufficient effort impacted Classes 1 and 2 the greatest. Upon reviewing class means, values suggested that individuals who previously reported moderate symptoms of depression and anxiety were moved from Group 2 to Group 1. Class 3 and Class 4 appeared to remain relatively unchanged through the removal of insufficient performance. Of note, TOVA mean differences and the likelihood of ADHD diagnosis across classes also remained relatively stable (Class 2: lowest TOVA and highest rate of ADHD diagnosis; Class 3: highest TOVA and lowest rate of ADHD diagnosis).

Despite neurocognitive impairment often being a core feature of ADHD symptomatology, objective measurement of cognitive functioning is not currently required as part of diagnostic criteria. The distinct neurocognitive profiles that emerged shed light on the utility of including objective neuropsychological assessment when evaluating for adult ADHD. Results allow us to characterize an individual’s neurocognitive strengths and weaknesses in the context of mood and self-reported functioning. Although psychosocial history and self-reports
are adequate to diagnose ADHD, they do not capture an individual’s unique cognitive strengths and weaknesses. The profiles also dispel the notion that there is a singular neuropsychological profile that appears when assessing adults with ADHD. Interestingly, it was the test of sustained attention (i.e., the TOVA) within the testing battery that best differentiated groups based on neuropsychological status. Although these findings are consistent with literature, it was unexpected to not see unique differences across classes in working memory, which is often a hallmark deficit in ADHD (Kofler et al., 2020). Outside of the TOVA, all other objective measures of cognitive functioning showed a similar pattern across groups (Class 1 with the lowest scores and Class 4 with the highest scores). Prior research extensively highlights the utility of using a continuous performance test (CPT) in the diagnostic decision-making of ADHD (e.g., see Hall et al., 2016; Hollis et al., 2018). The TOVA is a 21-minute computerized CPT that examined sustained attention/vigilance in this research. The three TOVA variables considered were: Response time, Response Time Variability, and D-prime. These scores reflect the average time a subject takes to respond correctly to a target, a measure of time differences for correct responses given by a subject, and the ratio between the rate of correct responses and the rate of “false alarm” responses, respectively (Memoria et al., 2018). Results of this study confirm and emphasize the importance of CPTs, or alternative tests of sustained attention, to discriminate between classes. If difficulties on a measure of sustained attention were added to diagnostic criteria, it seems reaction time, reaction time variability, and D-prime scores would be important to consider. Alternatively, studies have argued against the utility of CPTs in diagnostic decision-making. Brunkhort-Kanaan and colleagues (2020) found that the CPT did not aid in identifying patients with ADHD in a clinic due to low sensitivity. This study counters these findings and instead highlights the potential clinical utility of objective neurocognitive measures, in particular
a CPT, in order to inform diagnostic impressions through integration with self-report measures and information obtained during the clinical interview.

Understanding neurocognitive strengths and weaknesses and comorbid emotional symptoms can also allow for the tailoring of treatment. Currently, integrated pharmacotherapy, behavioral treatment, and academic/work accommodations are recommended for individuals with ADHD (Geffen & Forster, 2018). Pharmacotherapy includes both stimulant and non-stimulant medications. Research has shown that adults with ADHD can benefit in domains of verbal memory and sustained attention by taking stimulant medication (e.g., see Biederman et al., 2008). Non-stimulant medication (e.g., atomoxetine) also appear to be beneficial, although with smaller effects (Stahl, 2013). Behavioral treatment of ADHD often consists of cognitive-behavioral therapy, compensatory strategies, and cognitive skills training (Kysow et al., 2017). Academic/work accommodations can include extra time on tests or taking a test in a low-distraction environment (Lovett & Nelson, 2021). Given the heterogeneity present in ADHD, providing identical recommendations (e.g., stimulant medication, compensatory strategies, and school/work accommodations) to all individuals with ADHD is not likely to produce uniform benefits. For example, Class 2 may be likely to benefit from prioritization of medication due to their impairment in sustained attention. Class 3, however, may have increased benefit from the prioritization of cognitive-behavioral therapy to work on compensatory strategies for broad cognitive inefficiencies. Additionally, Class 1 may benefit from the integration of medication and cognitive-behavioral therapy to address impairment in sustained attention, high mood, and compensatory strategies. Notably, stimulant medications do have the potential to exacerbate comorbid anxiety symptoms, and therefore a non-stimulant medication may be better suited for
this group (Horrigan & Barnhill, 2000). Empirical research on treatment outcomes within distinct adult ADHD profiles is warranted to examine the above hypotheses.

This research adds to a broad literature that has identified the heterogeneity that exists within ADHD. While variability in symptom reporting and neuropsychological functioning is recognized in ADHD, LPA analyses meaningfully consider and organize variance into more homogenous classes. Regarding the cognitive patterns often seen within ADHD patients, research estimates that 33-50% of children with ADHD present with some degree of executive dysfunction (Kofler et al., 2019). Interestingly, we did not observe pronounced executive difficulties across classes, however Class 1 did exhibit mildly impaired performance on one executive functioning task. Current findings are most directly comparable to Leib and colleague’s (2021) research examining the neurocognitive functioning of adults with ADHD. Utilizing LPA, they identified four distinct classes based on working memory and processing speed performance: (1) Low, (2) Average, (3) High Working Memory, and (4) High Processing Speed. Their “Low” group is similar to the “Neuropsychiatrically Distressed” group identified with mildly impaired to low average performance across tasks. Leib and colleague’s “High Working Memory” group is similar to the “Neuropsychiatrically Resilient” group with average to high average performance across tasks. Additionally, their “High Working Memory” group reported the lowest symptoms of depression and anxiety relative to other groups, which aligns with current findings. These similarities highlight that there are adults with ADHD that present with and without neurocognitive challenges and that comorbid mood is likely to negatively impact neurocognitive functioning. A significant difference between the latent classes across studies is that current findings do not suggest unique class differences across working memory and processing speed tasks (i.e., WAIS-IV Digit Span, Letter-Number Sequencing, and Symbol
Search). Additionally, it is notable that Leib and colleagues did not include a test of sustained attention, which may have resulted in identification of different classes.

**Strengths, Limitations, and Future Directions**

Strengths of this study include the use of LPA in a relatively large, referred adult ADHD sample that completed a comprehensive neuropsychological evaluation. First, this study utilized person-centered statistical methods to investigate heterogeneity, instead of alternative clustering, variable-centered statistical technique such as confirmatory factor analysis. This allows for a nuanced understanding of the sample. Second, patients’ completion of a comprehensive evaluation allowed for the simultaneous examination of multiple neurocognitive domains (executive functioning, working memory, verbal comprehension, verbal memory, and sustained attention/vigilance), while also assessing for performance validity. In addition, self-reported behavioral ratings, and self-reported mood symptoms were considered to simultaneously evaluate objective and subjective data. Prior LPA literature has primarily studied adult ADHD samples utilizing limited neurocognitive measures (e.g. see Leib et al, 2021; Ostrander et al., 2018) and without the simultaneous consideration of mood or behavioral ratings. This study is novel in that it investigates neurocognitive test scores, mood symptoms, and behavioral rating through LPA, allowing for the examination of the roles these factors play in explaining observed heterogeneity. Alternatively, many studies consider mood and behavioral ratings as outcome variables and look at the likelihood of mood/behaviors occurring within a certain class, rather than examining the role it plays within the emerging class.

The two primary measures of mood in this study, the BDI and BAI, assessing depression and anxiety symptoms respectively, are psychometrically well-established inventories with high internal consistency, high sensitivity to change, and validity in differentiating between
depressed/anxious and non-depressed/non-anxious subjects (Fydrich et al., 1992; Richter et al., 1998). However, these inventories have limitations as stand-alone measures of mood. In particular, the BAI primarily focuses on somatic symptoms of anxiety, which provides a restricted assessment of anxiety symptomatology when not supplemented with self-report of other symptoms of anxiety, such as cognitive or ruminative symptoms. Additionally, certain medical conditions have overlapping physical symptoms (e.g. racing heartbeat) with somatic symptoms listed on the BAI, emphasizing a potential limitation as a measure of trait anxiety (Julian, 2011). To overcome this potential limitation, future research should strive to include additional self-report measures of current depression and anxiety or evaluate emotional functioning through semi-structured diagnostic interview. Additionally, it would be beneficial to consider past/prior diagnoses along with current self-report of mood symptoms.

The behavioral self-reports used in this study (BAARS-IV) consisted of self-reported symptoms of inattention, hyperactivity/impulsivity, and sluggish cognitive tempo. Collateral information was not considered to confirm the patient’s report of current symptoms. Prior research has demonstrated that the possibility of symptom exaggeration or feigning is common due to secondary gain (Ramachandran et al., 2020; Sibley, 2021). While neuropsychological performance validity was assessed and supplemental analyses were conducted after excluding patients with insufficient effort, the veracity of reported ADHD symptoms was not considered. BAARS-IV self-reported symptom counts were clinically significant across classes and therefore should be interpreted in light of this as retrospective report without the confirmation of collateral report is susceptible to inaccuracies (Sibley, 2021). Future research is encouraged that incorporates measures with embedded symptom validity tests (SVTs) or free-standing SVTs. For example, the Conners’ Adult Rating Scale (CAARS; Conners et al., 1999) measures the presence
and severity of ADHD symptoms and has embedded validity indicators. The Clinical Assessment of Attention Deficit-Adult (CAT-A; Bracken & Boatwright, 2005) is a free-standing symptom validity test and includes three validity indices (Negative Impression, Infrequency, and Positive Impression). Including such measures in future research would shed light on the veracity of self-reported ADHD symptoms.

Notably, the frequency of insufficient performance within this sample was lower than expected based on prior research documenting rates of insufficient performance within referred ADHD samples, and also when comparing it to previous studies examining the broader sample used in this study (Hoelzle et al., 2019). When considering why this may be, the initial inclusion criteria is considered. In particular, only those who were deemed through clinical interview to have a psychosocial history that was consistent or indeterminant with ADHD were included. Those that were deemed to have a psychosocial history inconsistent with a diagnosis of ADHD were excluded. Therefore, it is plausible that those reporting a psychosocial history inconsistent with ADHD would be more likely to exaggerate symptoms in a compensatory manner to increase the probability of receiving a diagnosis. Nevertheless, this is an empirical question to be further considered.

Future directions for understanding adults with ADHD should consider the role of neurophysiological differences. This study solely used objective and subjective information gathered from the individual. Prior research has used quantitative electroencephalogram (qEEG) to help define the physiological underpinnings of ADHD. One study was able to identify electrical patterns (increased frontal slowing and excessive frontal theta) that were associated with sustained attention difficulties (Arns et al., 2013). As a result of these findings, the use of a qEEG as a supplementary assessment tool for the diagnosis of ADHD was approved by the Food
and Drug Administration (Konopka, 2014). The integration of current findings with neurophysiological data would further explain heterogeneity observed within adults with ADHD.

While the current sample is relatively large, it does not accurately reflect the diversity present in society. Patients in this sample were primarily White, male, and highly educated, which limits the generalizability of these findings to the general population. With an overall estimated prevalence of adult ADHD reaching 4.4% in the United States, non-Hispanic White individuals do have the highest prevalence rates (Kessler et al., 2006). However, rates of ADHD diagnosis amongst non-White individuals are increasing (Cenat et al., 2021). Future research should examine a more diverse, representative sample, one that more accurately portrays the demographics of adults being referred for ADHD evaluations. Additionally, future research is encouraged to examine the heterogeneity of ADHD across the lifespan, both in adults and in children to continue to expand our understanding of ADHD in all age groups.

**Conclusion**

The present study makes clear that cognitive, emotional, and behavioral heterogeneity exists within a primarily White and educated adult population referred for an ADHD evaluation. This study is novel as it examines the heterogeneity of a referred adult ADHD population through a comprehensive neuropsychological battery while also considering the role of invalid performance. Four distinct profiles emerged: “Neuropsychiatrically Distressed,” “Relative Cognitive Inefficiencies only,” “Relative Cognitive Inefficiencies with Preserved Vigilance,” and “Neuropsychiatrically Resilient.” While rates of invalidity varied across classes, similar classes emerged after exclusion of patients with insufficient effort suggesting the low neurocognitive and distressed mood group is not solely associated with response distortion.
This research advances our understanding of the unique cognitive, behavioral, and emotional heterogeneity of adult ADHD. In particular, the utility of administering a computerized performance test within an objective neurocognitive testing battery to delineate variability within an adult ADHD sample was confirmed. This aligns with prior studies examining the role of CPTs in ADHD diagnostic decision-making. Future efforts to replicate this research in diverse samples and explore the neurophysiological underpinnings of ADHD is encouraged. In summary, an appreciation of the heterogeneity of symptom presentation improves our conceptualization and aids in discernment in the diagnostic complexity of adult ADHD. In turn, this may inform and guide clinicians’ ability to tailor specific treatment recommendations.


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