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Sluggish Cognitive Tempo Symptoms Contribute to Heterogeneity in Adult Attention-Deficit Hyperactivity Disorder

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Abstract Attention-deficit hyperactivity disorder (ADHD) persists into adulthood in over 50% of cases, although its associated symptom profiles, comorbid problems, and neuropsychological deficits change substantially across development. Sluggish cognitive tempo (SCT) symptoms may contribute to associations between ADHD and comorbid problems and may partially explain the substantial heterogeneity observed in its correlates. 349 adults aged 18–38 years (M = 23.2, SD = 4.5, 54.7% male, 61.03% with ADHD) completed a multi-informant diagnostic procedure and a comprehensive neuropsychological battery. Adults with ADHD (n = 213) were retained for analyses. Latent class analyses (LCA) revealed three profiles of SCT symptoms among those with ADHD, which we classified as minimal, moderate, or severe SCT. Multiple analysis of covariance (MANCOVA) revealed significant differences among these profiles, which remained when controlling for persistence of ADHD symptoms and sex. In general, adults with ADHD combined with SCT symptoms (moderate and severe) had significantly more symptoms of anxiety, depression, and persistent inattention, and had more severe professional and relational impairment compared to ADHD adults without SCT. Compared to those with moderate or minimal SCT symptoms, the severe SCT group had the most symptoms of depression and internalizing disorders, and the most impairment in the domain of daily responsibility. No significant differences based on externalizing symptoms emerged when controlling for sex and persistence of inattention symptoms, suggesting the moderate and severe SCT groups do not simply reflect more symptoms. Moreover, follow-up mediation analyses revealed that SCT might at least partially explain the heterogeneity in ADHD. Findings have implications for refinement of etiological conceptualization, assessment methods, and intervention strategies.

Keywords Attention-deficit/hyperactivity disorder · Sluggish cognitive tempo · Latent class analysis · Multiple analysis of covariance · Mediation analysis

Attention-deficit hyperactivity disorder (ADHD) is a common neurodevelopmental disorder characterized by age-inappropriate overactivity, impulsivity, inattention, and disorganization (American Psychiatric Association 2013). Although once considered a disorder of childhood, research has now demonstrated that ADHD persists into adulthood in well over 50% of cases (Barkley et al. 1990b; Barkley et al. 2002; Faraone et al. 2006). Importantly, ADHD that persists into adulthood is associated with increased comorbidity and functional impairments (Faraone and Antshel 2008). Notably, adult ADHD also accounts for over 50% of the costs associated with the disorder and over $105 billion in national annual incremental costs (Doshi et al. 2012). Challenges to identification of causal contributors to ADHD include substantial heterogeneity in the disorder's symptom presentation (i.e., correlated but distinct symptom dimensions of inattention-disorganization and hyperactivity-impulsivity; Willcutt et al. 2012), neurocognitive correlates (Nigg et al. 2005), and comorbid problems (Wåhlstedt et al. 2008) – all which pose difficulties in regard to methods of assessment and optimal treatment. Therefore, identifying factors that contribute to ADHD heterogeneity is a clear research priority that has the potential to improve etiological conceptualization, assessment methods, and intervention strategies.

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Decades of work have described and evaluated a cluster of symptoms termed sluggish cognitive tempo (SCT), which often accompany ADHD in youth and adults (Becker et al. 2016). SCT symptoms involve daydreaming, feeling spacey, moving slowly, and processing information slowly, and have been posited to signal a potentially separate disorder (Barkley 2014; Bauermeister et al. 2012; Lee et al. 2014). Multiple factor analytic studies have supported an association between SCT and ADHD (Dumenci et al. 2004; Quay 1983; Quay and Quay 1965; Willcutt et al. 2012), but have indicated SCT symptoms do not represent another constituent symptom dimension of ADHD (Langberg et al. 2014; McBurnett et al. 2013). These findings have prompted researchers to call for SCT to be studied in its own right, apart from ADHD and other disorders (Becker et al. 2016), even though the vast majority of work continues to examine SCT within the context of ADHD (Frick et al. 1994). Further, given that adults with persistent ADHD often have increased comorbidity, compared to individuals whose ADHD has remitted, examining SCT in the context of adults with ADHD may highlight how ADHD is linked to other comorbid problems. Importantly, recent work has demonstrated that while hyperactivity/impulsivity symptoms decrease normatively with age, inattention symptoms remain stable, and SCT symptoms tend to increase slightly across development (Leopold et al. 2016), suggesting SCT symptoms may become especially relevant as ADHD persists into adulthood.

While more work is needed to determine if SCT symptoms in fact signal a qualitatively distinct category or taxon of psychopathology (Barkley 2013b), another largely unexplored possibility is that SCT symptoms contribute to associations between ADHD and comorbid problems, and may be involved in an indirect pathway that explains the substantial heterogeneity observed in its correlates, particularly during adulthood. Past work has already suggested that inattention and hyperactivity may show differential patterns of association with disruptive behavior symptoms versus internalizing symptoms (Zenglein et al. 2016), such that hyperactivity-impulsivity may be more strongly linked to other externalizing problems (Lahey et al. 2008), whereas inattention may show stronger links with internalizing symptoms (although findings have been mixed; see Gaub and Carlson 1997; Power et al. 2004). In regard to SCT, prior work has indicated that SCT symptoms may fully account for associations between inattention symptoms and internalizing problems in particular, while SCT symptoms were only weakly correlated with hyperactivity-impulsivity and negatively correlated with ODD behaviors once inattention symptoms were controlled for (Penny et al. 2009). Similarly, other work has also reported negative associations between SCT and externalizing problems after controlling for ADHD (Lee et al. 2014). Recently, SCT has also been found to be associated with internalizing symptoms in young adults with and without ADHD (Becker et al. 2014b). Moreover, longitudinal research has demonstrated that compared to inattention symptoms, SCT was more strongly associated with internalizing symptoms (based on parent-report) (Bernad Mdel et al. 2016). Additionally, based on emerging evidence of this association, recent work has theorized that SCT and internalizing symptoms may be significantly associated because of shared core aspects, such as apathy, decreased effort, and lack of interest in activity (Smith and Langberg 2017). Thus, SCT symptoms may be relevant for understanding links between ADHD and internalizing problems in particular, which may be especially relevant given the substantial overlap between ADHD in adulthood and internalizing problems (McGough et al. 2005).

In addition, prior work has suggested that SCT, like many psychopathology constructs, is multi-dimensional, rather than uni-dimensional. As reviewed by Becker et al. (2016), there appear to be two dimensions to SCT: (1) a "Slow/Sluggish or Sleepy" factor that includes items such as underactive/slow moving, sluggish, sleepy/drowsy, tired/lethargic, and slow processing/thinking, and (2) a, "Daydreamy or Inconsistent Alertness" factor, that includes items such as confused, in a fog, stares blankly, daydreams, and lost in thoughts. Moreover, work relying on parental ratings of SCT among children with ADHD has suggested there may be additional factors of SCT that capture problems with motivation (Penny et al. 2009) or working memory (McBurnett et al. 2013). Thus, in addition to exploring different dimensions of SCT, work in this area may benefit from also considering the role of neurocognitive functioning in these associations. For example, a person-centered approach (e.g., Latent Class Analysis) may be useful in demonstrating how individuals with varying levels of SCT differ in their neurocognitive functioning. This parallels prior work that has used a similar approach to identify subgroups of individuals with ADHD with particular patterns of neuropsychological dysfunction (Fair et al. 2012). In line with this, the present study strategically utilized a person-centered approach, as it is useful in clarifying the heterogeneity that exists in complex psychiatric disorders, such as ADHD.

Like children with ADHD, adults with the disorder exhibit neurocognitive deficits across a variety of domains (Mostert et al. 2015). As a group, individuals with ADHD demonstrate problems with executive functioning, working memory, reaction time variability, response inhibition, and reward-processing compared to controls (Halperin et al. 2008; Kofler et al. 2011; Kofler et al. 2013; Martinussen et al. 2005; Wåhlstedt et al. 2008), but with substantial inter-individual heterogeneity regarding which domains are impaired. Notably, SCT appears to contribute to heterogeneity in neurocognitive performance as prior work has shown that children and adolescents with SCT symptoms have lower scores on tests of general intelligence and deficits in response

inhibition, working memory, processing speed, and sustained attention (Becker and Langberg 2013; Hartman et al. 2004; Mikami et al. 2007; Reeves et al. 2007; Skirbekk et al. 2011; Wåhlstedt and Bohlin 2010; Willard et al. 2013; Willcutt et al. 2014). Additionally, in children, adolescents, and adults, SCT has been found to be related to executive functioning in daily life; however, findings are mixed, such that these associations weaken or are eliminated when controlling for inattention symptoms (Barkley 2013a; Hinshaw 2002; Jarrett et al. 2014; Wåhlstedt and Bohlin 2010; Willcutt et al. 2014; Wood et al. 2014). Findings have suggested that SCT may be independently associated with poor sustained attention and processing speed, whereas deficits in response inhibition, working memory, and reaction time variability may be more related to comorbid inattention symptoms (Wåhlstedt and Bohlin 2010; Willcutt et al. 2014).

Importantly, research is only beginning to evaluate SCT as a potential behavioral and mechanistic link between ADHD and co-occurring internalizing symptoms in adults. Thus, the purpose of the present study is to determine if varying levels of SCT symptoms impact heterogeneity in neurocognitive performance, reports of functional impairment, and internalizing symptoms among adults with ADHD. Latent class analysis was used to identify different subgroups of adults with ADHD based upon the severity of their SCT symptoms. We also conducted follow-up mediation analyses to formally examine if SCT symptoms indirectly explained these associations between ADHD symptoms and various outcomes.

Based on prior work, we predicted that there would be differences in internalizing symptoms, neurocognitive performance, and impairment among individuals with ADHD based upon their level of SCT symptoms. Further, because of the known overlap among ADHD, SCT, internalizing symptoms and associated impairments, we hypothesized that one possible explanation for this may be that SCT symptoms would indirectly affect any significant associations between ADHD symptoms and outcomes, such that childhood ADHD symptoms would predict current SCT symptoms, and in turn, predict internalizing symptoms and impairment domains.

Method

Participants

Participants were 349 adults aged 18–38 years (M = 23.2, SD = 4.5, 54.7% male). In order to obtain as representative a sample as possible, participants were recruited via advertisements in local newspapers, email listservs, and at local clinics. Participants with a confirmed or suspected diagnosis of ADHD, as well as those without ADHD, were invited to participate in a study of the disorder among young adults. Informed consent was obtained from all individual participants included in this study. Participants were similar in ethnicity to the surrounding area (a Midwestern college town) and self-reported their ethnicity as primarily Caucasian (87.1%), with smaller proportions of African-American (2.6%), Latino (3.2%), Asian (2.3%), and multi-ethnic participants (3.4%).

Diagnostic Procedures

All participants completed a three-hour laboratory visit, which included administration of a diagnostic interview to assess current and lifetime symptoms of ADHD (based upon Kessler et al. 2005). The interview included all 18 *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; *DSM–5*; American Psychiatric Association 2013) ADHD symptoms (9 inattention and 9 hyperactive-impulsive items that included adult-specific wording as specified in *DSM–5*) as well as 9 additional sluggish cognitive tempo items. Further, the interview assessed 14 non-*DSM* items that have been previously examined in adults with ADHD and have been found to be relevant in predicting ADHD related impairments in this population (Kessler et al. 2010). These items were included at the time of the study initiation, given that the *DSM-5* criteria had not been finalized. Interviewers assessed the frequency and severity of current and childhood ADHD symptoms as well as the persistence of each behavior across multiple contexts (e.g., at home, at school/work, during leisure time), and they gathered exemplar behaviors in order to rate the overall presence or absence of each symptom. Participants also completed a battery of neuropsychological tests following the diagnostic interview. After the visit, participants completed questionnaires online via Qualtrics. These included rating scales of current and childhood ADHD symptoms, ratings of executive functioning, and ratings of ADHD-related impairments. Additionally, participants provided contact information for two individuals to serve as informants (e.g., parents, roommates, friends, romantic partners, employers). These individuals also completed ratings of the participant's ADHD symptoms, executive function, and impairment. The majority of participants (72.5%, n = 253) had at least one informant complete a report.

Final diagnostic status was determined by the principal investigator (Nikolas), who reviewed all self and informant report data from questionnaires and responses and examples provided on the diagnostic interview to determine final *DSM-5* diagnosis. Only the appropriate *DSM-5* items were included for diagnostic consideration and diagnoses proceeded in accordance with recommendations by Sibley et al. (2016). An overall symptom count for both current and childhood ADHD symptoms was calculated by applying an *or algorithm* to self and informant

data, meaning that symptom is counted as present if it is endorsed by the participant *or* by their informant, as in the *DSM-IV* field trials (Lahey et al. 1994). Notably, as in prior work (Martel et al. 2007; Nikolas and Nigg 2013), the algorithm was implemented such that no one rater could contribute more than three unique symptoms to the *or* algorithm total. Additionally, scores of current and childhood functional impairment from the diagnostic interview and questionnaire measures, cross-situational presence of symptoms, and onset of symptoms before age 12 was determined for each participant in line with *DSM-5* criteria. Both a childhood and current diagnostic presentation type were assigned based upon appropriate symptom thresholds specified in *DSM-5* (6 for childhood, 5 for present functioning).

The full sample included 217 adults with ADHD (met full diagnostic criteria during childhood only *or* during childhood and currently) and 114 non-ADHD adults. We chose to include individuals with a childhood only diagnosis *or* childhood and current diagnoses, given literature indicating longitudinal persistence of symptoms and impairment, despite changes among those meeting full diagnostic criteria (Lahey et al. 2005; Sibley et al. 2016). The majority of ADHD participants (n = 185, 85.3%) met criteria currently *and* during childhood, whereas n = 32 (14.7% of the ADHD group) didn't meet full symptom thresholds in adulthood. However, these individuals reported significantly more symptoms compared to the non-ADHD participants ($p < .001$, $d = .54$) and had self and informant ratings of impairment that were greater than the 85th percentile. 45.2% of the ADHD group reported current prescription stimulant use, similar to past reports of medication use within community samples (Visser et al. 2007). 18 adults presented with subthreshold or situational ADHD symptoms (did not meet diagnostic criteria during childhood or adulthood) – these individuals were excluded from analyses.

For the purposes of the current study, we elected to only focus on those participants in the ADHD group who had completed data on SCT symptoms, given our focus on understanding heterogeneity in SCT among adults with ADHD. Therefore, our final sample included n = 213 adults with ADHD (as four participants were missing data on SCT symptoms).

Exclusion Criteria Participants were excluded if they were not fluent in English or a native English speaker, and if they had a history of Tourette's disorder, schizophrenia, psychosis, or autism spectrum disorder (based on parent report). Participants were also excluded if they were taking antipsychotic or sedative medications or were taking long-acting stimulant medications and could not complete the wash-out procedures. Participants were also required to have normal or corrected-to-normal vision and hearing.

Measures

ADHD and SCT Symptomatology ADHD and SCT symptom dimension scores were derived from self- and informant-report on the Barkley Adult ADHD Rating Scale- IV (BAARS-IV Current and Childhood versions; Barkley 2011). Current and childhood inattentive and hyperactive-impulsive symptoms and current sluggish cognitive tempo symptoms were rated on a 4-point Likert scale (*never, sometimes, often,* and *very often*). Total scores for each dimension were computed by summing the relevant items. Reliability and validity of the BAARS-IV has been established (Barkley 2011). Internal consistencies for all the BAARS-IV scales in the current sample were adequate ($\alpha > .91$).

Self and informant ratings of items on the current and childhood versions of the *BAARS-IV* were used to create persistence scores as follows. For each informant, similarities or changes among each individual item score were evaluated and given a score (0–2) to reflect is consistency between the childhood and current rating. For example, items rated as occurring often or very often at both times (childhood and current) were given the highest persistence score (e.g., 2). Those items rated as often/very often in childhood but rated as occurring sometimes during the past 6 months were given the moderate persistence score (e.g., 1). Items rated as often/very often during childhood but rated as never occurring during the past 6 months (or vice versa) were given the lowest persistence score (e.g., 0). These item level persistence scores were then summed for each symptom dimension (inattention and hyperactivity-impulsivity) for each rater (self and informant). A mean score across informant was then retained for subsequent analyses.

Internalizing and Externalizing Symptoms Internalizing, anxiety, and externalizing symptoms were derived from self-report on the Achenbach System of Empirically Based Assessments, Adult Self-Report (ASEBA ASR; Achenbach and Rescorla 2003). Current psychological symptoms were rated on a 0–2 Likert scale (not true, sometimes true, and often true). The total score was computed by summing the relevant items, and a corresponding T-score was computed. For analytic purposes, we used raw scores on each dimension, based on recommendations for research (Achenbach and Rescorla 2003). Reliability and validity of the ASEBA has been established (Achenbach and Rescorla 2003). Internal consistencies ASEBA scale in the current sample was adequate (all αs > .87).

Depression Symptoms Depression symptoms were derived from self-report on the Center for Epidemiological Studies-Depression Scale (CES-D; Radloff 1977). The CES-D is a 20-item measure that asks individuals to rate how often over the past week they experienced symptoms associated with

depression, such as restless sleep, poor appetite, and feeling lonely (0–3 Likert Scale; 0 = less than 1 day, 1 = 1–2 days, 2 = 3–4 days, and 3 = 5–7 days). Scores range from 0 to 60, with higher scores indicating greater depressive symptoms. The CES-D also provides cutoff scores (e.g., 16 or greater) that aid in identifying individuals at risk for clinical depression, with good sensitivity and specificity and high internal consistency in the literature (Lewinsohn et al. 1997) and high internal consistency in this sample ($\alpha = .91$). A total sum score was computed for use in analyses.

ADHD-Related Impairments Participants and their informants also completed the Barkley Functional Impairment Scale (Barkley 2011), providing a quantifiable description of the magnitude of impairment due to ADHD symptoms across 15 different life domains, including at home with friends, at school, at work, in social relationships, in dating/marital relationships, and managing money. Participants rated problems in each domain on a Likert scale from 0 to 9 (0 = *not impaired at all*; 9 = *extremely impaired*). Internal consistency for the measure was high (self $\alpha = .88$, informant $\alpha = .81$). We conducted maximum likelihood factor analysis on the 15 items, to reduce the number of impairment domains, revealing 3 factors with eigenvalues of 1.0, accounting for 82.1% of the variance in ratings. Factor loading results revealed a relationship impairment factor (family problems, dating/marital relationship problems, friend problems, sexual problems, child-rearing problems), a professional impairment factor (educational problems, occupational problems, community activity problems), and a daily living impairment factor (money management problems, driving problems, chore completion problems, daily responsibility problems, self-care problems, health problems – see Kamradt et al. 2014). Mean scores of self and informant ratings for each of the three impairment domains were retained for all analyses.

Neurocognitive Testing Battery Additionally, after the diagnostic interview, all participants completed a testing battery. This included measures covering a range of component processes of executive functions (i.e., inhibition, working memory, interference control) as well as non-executive neuropsychological processes relevant to ADHD (e.g., response variability, arousal; see Nikolas and Nigg 2013). All tasks were administered in the following fixed order across participants (further described below): WASI: two-subtest version, WAIS-IV: Digit Span, Stop Task, DKEFS: Color-Word Interference, Conners' Continuous Performance Task (CPT), and DKEFS Trailmaking Task. All participants taking stimulant medication completed a 24- to 48-h washout prior to neurocognitive testing (*M* washout time = 46.2 h, *SD* = 18.3 h). 46.7% of the ADHD group was currently taking ADHD medication, consistent with prior work documenting stimulant medication rates in community samples (Visser et al. 2007).

IQ In order to estimate full-scale IQ, the two-subtest version of the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler 1999) was administered.

Memory Span and Verbal Working Memory: Digit Span Verbal working memory was measured using the digit span subtest from the Wechsler Adult Intelligence Scale—Fourth Edition (WAIS-IV; Wechsler 2008), in which participants are asked to recall a series of orally presented digits. In forward span, they recalled the digits in order. In backward span, they recalled the digits in reverse order. On sequencing, they recalled the digits in numerical order. The span of digits for all trials increases, beginning at 2 and ending at a series of 9 digits. Participants completed each section until they fail to correctly complete two trials of the same span of digits. Raw scores on the forward (memory span), backward (verbal working memory), and sequencing (verbal working memory) trials were retained for analyses. Test-retest reliability for these measures have been reported at $r = .79–.90$ (Wechsler 1999).

Interference Control: Color-Word Interference In order to assess interference control, the color-word interference subtest, which is similar to the classic Stroop task, (D-KEFS; Delis et al. 2001) was administered. Participants completed four trials. On the first trial, participants were presented with a series of color patches on a page and instructed to name the colors out loud (Color Naming). The second trial involved reading the color names (Word Reading). On the third trial, participants were presented with color names printed in different-colored ink and instructed to say the color of the ink and avoid reading the word (Inhibition; similar to the interference trial in the classic Stroop paradigm). On the last trial, participants were again presented with color names printed in different-colored ink; some names were inside of boxes. In this final trial, for all colored names printed in different-colored ink, participants were to read the ink color, however, when a word was inside of a box, they were instructed to read the word and refrain from naming the color of the ink (Inhibition/Switching). On all trials, participants were instructed to perform as quickly as they could, without making mistakes or skipping any items. The total completion times for each trial (Color Naming, Word Reading, Inhibition, and Inhibition/Switching) were retained for analyses. Test-retest reliability for this measure has been reported at $r = .62–.76$ (Homack et al. 2005).

Motor Response Inhibition: Stop Task Motor response inhibition was assessed with the Stop Task (Logan 1994), which requires the suppression of a prepotent motor response. During this choice reaction time task, participants saw a circle or a square on a computer screen and responded rapidly with one of two keys to indicate which letter they had seen (called Go Response trials). On 25% of trials, a tone sounded shortly

after the shape was displayed, indicating that participants were to withhold their response. A stochastic tracking procedure was used; stop signal reaction time (SSRT) was computed as an index of how much warning each participant needed to interrupt a response. Trials were presented across 4 blocks and validity criteria were implemented, such that participants had to have at least one valid block to have their data included. In order for the block to be valid, the hit rate on Go Trials had to be greater than 90% and the probability of stopping could not be significantly different than 50% (see Nikolas and Nigg 2013). In line with prior work, SSRT was calculated by subtracting the average stop signal delay from the average Go Response time (Logan 1994). Test-retest reliability for this measure has been reported at r = .65 (Weafer et al. 2013).

Signal Detection (Arousal): Continuous Performance Task To assess vigilance and sustained attention, the Conners' Continuous Performance Task (CPT), Version II (Conners and Staff 2002), was administered. In this task, a series of letters appeared rapidly on a visual display, and participants had to press the spacebar on the keyboard for every letter presented with the exception of the letter *X*. For 20 min, stimuli were presented continuously, with a varying interstimulus interval (1 s, 2 s, or 4 s). Omission and commission errors were calculated and then used to compute *d* prime (*d'*), a sensitivity index expressed in units of standard deviation in line with manual recommendations. A higher *d* prime score traditionally indicates greater sensitivity in distinguishing the targets (all non-*X* letters) from the nontargets (*X* letters). Additionally, indices of reaction time variability and overall reaction time were retained for analyses. Test-retest reliability for this measure has been reported at r = .42–.73 (Weafer et al. 2013).

Reaction Time Variability To measure response variability, we retained the within-person variability of the reaction time on the Go Response trials from the Stop task and the variability score from the Conners' CPT.

Data Analysis

Missing data were minimal in the current study (< 5.3% on all measures). Therefore, full maximum-likelihood estimation, a method of directly fitting models to raw data, was used without imputing values. The current study had three analytic aims: (1) to identify meaningful subgroups of ADHD individuals based on SCT symptoms using latent class analysis, (2) to compare these subgroups in regard to comorbid symptoms, neuropsychological performance, and functional impairment using multivariate analyses, and (3) to formally test SCT as a mediator of the association between ADHD and these outcomes within a dimensional framework.

Latent Class Analysis Latent class analysis (LCA) is a statistical procedure that allows for the classification of individuals into homogeneous subgroups (Goodman 1974; Lazersfeld and Henry 1968). This person-centered approach has several advantages for understanding how SCT fits in the ADHD phenotype. First, this approach identifies configurations of values across variables, which is prototypical of the actual data patterns within the sample (Bauer and Shanahan 2012). Second, this approach may be easier to interpret, particularly in the field of clinical psychology, as individuals with distinct patterns of symptoms can be assigned to latent classes that represent subtypes of disorders (Bauer and Shanahan 2012; Geiser 2012). In this case, LCA was used to identify subgroups of ADHD individuals that differ based upon their profile of SCT symptoms. Determination of the best fitting model was based upon several criteria, including statistical and information criteria. We compared model fits for one, two, or three latent classes and examined the following criteria to determine relative model fit. First, we examined information criteria (IC), including AIC (Akaike), BIC (Bayesian), and aBIC (sample-size-adjusted Bayesian), which are descriptive indices for comparing models. IC provides information regarding both goodness of fit of a model, as well as model parsimony. Therefore, based on IC, the best model is one that fits well and uses the fewest number of parameters as possible (the model with the smallest AIC, BIC, or aBIC). However, because these indices tend to get smaller as the number of classes increase, we also employed additional methods to compare relative model fit. Therefore, we also examined two additional indices of fit, including the Vuoing-Lo-Mendell-Rubin test (VLMR) and the bootstrap likelihood ratio test (LR). The VLMR compares a model with *X* latent classes to a model with *X*-1 classes; significant values indicate that the estimated model fits significantly better than the model with one less class (Geiser 2012). The bootstrap LR test, which is similar to the VLMR test, examines differences in LR values between *X* and *X*-1 classes and is calculated with a corresponding *p*-value. Again, a significant value indicates the estimated model (*X*) fits better than the model with one less class (*X*-1). While prior work suggests that the bootstrap LR test is more accurate than the VLMR test, for completeness, we examined both in determining best class, which yielded consistent results. Mean class assignment probabilities can also be useful in determining good class solution, such that a probability of 0.8 or larger indicates good class solution. Moreover, we examined entropy, an index of the quality of the classification, which indicates whether or not classification is accurate (values close to 1 suggest good accuracy and values closer to 0 suggest lack of accuracy). All LCA analyses were conducted in MPlus (Muthen and Muthen 1998–2013).

Following identification of SCT latent classes, we used multivariate analyses of covariance (MANCOVA) models to examine group differences in 1) comorbid internalizing

dimensions (anxiety and depression), 2) comorbid externalizing dimensions, 3) neurocognitive performance, 4) impairment in professional, daily responsibility, and relational domains, and 5) persistence of ADHD symptoms. Five MANCOVAS were first conducted, such that dependent variables were grouped together as follows: anxiety and depression symptoms, internalizing and externalizing symptoms, persistence of ADHD symptoms, neurocognitive performance, and functional impairment. Covariates included sex and persistence of inattention symptoms (persistence of inattention excluded as a covariate in model examining persistence of ADHD symptoms as a dependent variable). Follow-up univariate analyses and post-hoc tests were then conducted to determine group differences on individual measures. All MANCOVAS were conducted in SPSS Version 21.

Lastly, using a mediational framework, we examined the direct and indirect effects of childhood inattention and hyperactivity-impulsivity symptoms on internalizing symptoms (anxiety and depression) and impairment, via SCT symptoms. Direct and indirect effects were tested formally using MPlus (Muthen and Muthen 1998–2013). Notably, mediation was being used in this context to test specific indirect associations, rather than to make causal assumptions, given the cross-sectional nature of the data. Sluggish cognitive tempo symptom scores, which were the mean of self- and informant- ratings, were examined as the mediator in all models. Predictor variables included symptoms of childhood inattention and hyperactivity-impulsivity, and outcome variables were depression, anxiety, daily living impairment, professional impairment, and relational impairment. We examined childhood symptoms as predictors to examine this pathway using a more specific temporal ordering of the variables. For example, if childhood symptoms predict SCT symptoms, and in turn, predict the outcome variables, this might suggest an even more important role for the evaluation SCT, as ADHD symptoms (even if diminished in adulthood) still predict SCT in adulthood. Sex and age were included as covariates in all models. Based on methodology put forth by Preacher and Hayes (2008), we examined the sum total and specific point estimates for each model.

Results

LCA Model and Class Identification

Table 1 shows fit statistics for the 1, 2, and 3 class LCA solutions, and Table 2 illustrates class counts and proportions. Overall, fit statistics supported a 3-class model. All indices of information criteria were examined as indicators of model fit, with lower (or more negative) scores indicating better fit. Fit statistics for a 1-class model indicated the poorest fit to the data, with the highest scores (AIC = 5385.78, BIC = 5446.285, and aBIC = 5389.249). However, because as class number increases, information criteria values decrease, we also examined the bootstrap LR difference test, the VLMR test, the mean latent class probabilities values, and entropy. According to both the bootstrap LR difference and VLMR test, a 3-class model fit the data significantly better than a 2-class model (bootstrap LR test: H_0 loglikelihood value = −2442.123, $p < 0.001$; VLMR test: H_0 loglikelihood value = −2442.123, $p = 0.02$). Again, because both of these tests are based on a principle of comparing estimates of model fit for both the *X* and *X-1* model, their corresponding *p*-values are interpreted similarly. Specifically, the significant *p*-values associated with the LR and the VLMR test indicated that the 3-class model fits the data better than the more parsimonious models with one less class. Additionally, as highlighted in Table 3 mean latent class probabilities for most likely latent class membership supported the 3-class model, as indicated by values greater than 0.80 (1-class = 0.94, 2-class = 0.90, 3-class = 0.97). Finally, results for the 3-class model demonstrated good classification accuracy, entropy = 0.85, with values closer to 1 indicating better accuracy. Therefore, LCA procedures revealed three classes that can be described as follows: Minimal SCT (45.5%), Moderate SCT (31.4%), and Severe SCT (23.1%).

Table 1 LCA model fit statistics for SCT symptoms in adults with ADHD

Latent Classes	AIC	BIC	aBIC	VLMR Log	VLMR p
1	5385.782	5446.285	5389.249		
2	4940.245	5034.361	4945.638	−2674.891	0
3	4792.325	4920.054	4799.643	−2442.123	0.0205

Entropy (classification quality) = 0.851

AIC, Akaike Information Criteria; *BIC*, Bayesian Information Criteria; *aBIC*, Sample-Size Adjusted Bayesian Information Criteria; *VLMR Log*, Vuong-Lo-Mendell-Rubin Loglikelihood Ratio Test; *VLMR p*, Vuong-Lo-Mendell-Rubin Likelihood Ratio Test *p*-value

LCA Group Comparisons

Figure 3 depicts how SCT symptoms were distributed across latent classes. Demographic and descriptive statistics (Table 4) indicated that the SCT groups did not differ significantly with

Table 2 LCA class counts and proportions

Latent Classes	Class Count	Proportions
1	98	0.4601
2	66	0.3099
3	49	0.2301

Classification of individuals based on their most likely latent class membership

Table 3 LCA mean latent class probabilities

Latent Classes	1	2	3
1	0.94	0.06	0.00
2	0.08	0.90	0.03
3	0.00	0.03	0.97

Average latent class probabilities for most likely latent class membership (row) by latent class (column)

regard to sex, age, stimulant medication usage, ethnicity, or full scale IQ. When examining group differences in current self-report ADHD symptoms, significant differences emerged for inattention and hyperactivity symptoms ($p < .001$), such that those in the moderate and severe SCT groups had significantly more current symptoms of inattention and hyperactivity-impulsivity than those without SCT symptoms. Additionally, the groups were significantly different based on self-reported childhood symptoms of ADHD, such that those in the moderate and severe SCT groups had significantly more childhood symptoms of inattention than those without SCT symptoms. Groups did not differ in regard to childhood hyperactivity-impulsivity.

Multivariate Analyses of Covariance (MANCOVA)

All MANCOVAs included persistence of inattention symptoms and sex as covariates. All follow-up ANOVAs remained significant when controlling for these variables, unless otherwise noted. See Figs. 1, 2 and 3 for class differences in anxiety symptoms, depression symptoms, internalizing symptoms, externalizing symptoms, impairment, and neuropsychological performance, and for distribution of SCT symptoms across latent classes.

Anxiety and Depression Results revealed that the SCT groups significantly differed with respect to anxiety and depression (F (2187) = 29.90, $p < .001$). Follow-up univariate analysis of variance (ANOVA) indicated that individuals with ADHD and SCT symptoms (moderate and severe) had significantly more anxiety than those without SCT. Also, those with moderate SCT had significantly more depression than those without SCT symptoms; however the severe SCT group had significantly more depression than both the moderate SCT and minimal SCT groups.

Internalizing and Externalizing Symptoms MANCOVA also indicated that the SCT groups significantly differed in overall internalizing and externalizing symptoms based on self-report on the ASR (F (2208) = 30.31, $p < .001$). Specifically, follow-up ANOVA revealed that the severe SCT group had significantly more internalizing problems than both the moderate and minimal SCT groups. The moderate and severe SCT groups also had significantly more externalizing problems than those without SCT, but this relationship was no longer significant when controlling for sex and persistence of inattention symptoms.

Neurocognitive Performance Significant group differences also emerged in neurocognitive performance (F (12, 390) = 2.79, $p = .001$). Follow-up ANOVAs revealed that on a task of working memory (digit span), the moderate SCT group performed significantly worse than the minimal SCT group and severe SCT group. Additionally, individuals with moderate SCT symptoms had a slower speeded sequencing than those with severe SCT and without SCT. Thus, while the severe SCT group exhibited increased internalizing problems relative to other individuals with ADHD, the moderate SCT group exhibited greater deficits in working memory compared to their ADHD counterparts.

Impairment MANCOVAs also revealed significant group differences in impairment (F (6, 376) = 8.21 $p = .000$).

Table 4 Descriptive statistics for the ADHD groups with minimal SCT, moderate SCT, and severe SCT for demographics

	Minimal SCT	Moderate SCT	Severe SCT	*p*-value
N	98	66	49	
% Male	62.2	50.0	49.9	.18
Age (SD)	23.6 (4.9)	23.1 (4.3)	24.3 (5.1)	.44
% Stimulant Medication	48.0	36.4	51.0	.22
% Caucasian	90.8	80.3	83.7	.15
Full-Scale IQ (SD)	114.4 (12.2)	112.7 (11.7)	114.5 (11.2)	.644
Self-Report BAARS Current				
Inattention sx (SD)	3.1 (2.5)	6.2 (2.0)	6.9 (1.9)	<.001
Hyperactivity sx (SD)	3.2 (2.1)	4.8 (2.3)	4.4 (2.3)	<.001
Self-Report BAARS Childhood				
Inattention sx (SD)	4.9 (2.8)	6.3 (2.7)	6.1 (2.5)	<.05
Hyperactivity sx (SD)	4.8 (3.0)	5.3 (2.8)	5.3 (3.0)	.513

SD, standard deviation. Symptom scores are based on symptom counts

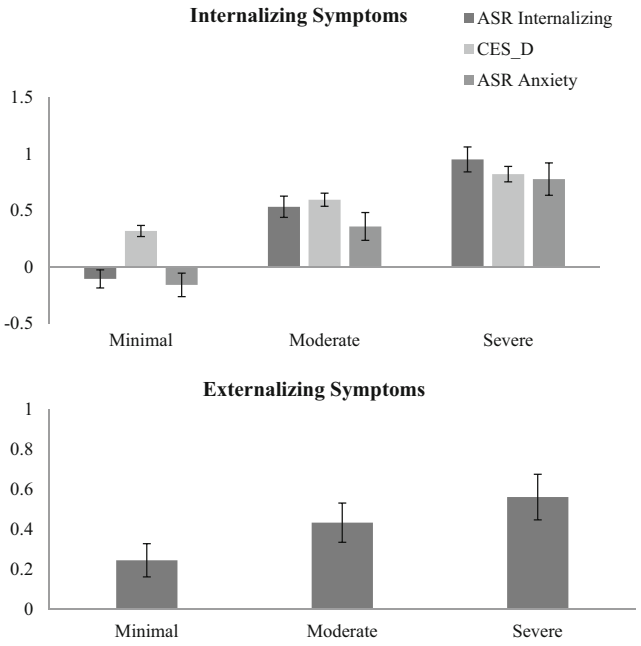

Fig. 1 Internalizing and externalizing symptoms. *Note.* All scores were transformed into standardized z-scores. Higher scores refer to more internalizing and externalizing symptoms. Severe and Moderate SCT groups had significantly ($p < .05$) more ASR anxiety than the Minimal SCT group. Severe SCT group had significantly more depression as measured by CES_D (total number of depression symptoms) than the Moderate SCT group, and the Moderate SCT group had significantly more depression than the Minimal SCT group. The Severe SCT group had significantly more ASR internalizing problems than the Moderate SCT group, and the Moderate SCT group had significantly more ASR internalizing problems than the Minimal SCT group. There were no significant group differences based on externalizing symptoms after controlling for sex and inattention persistence

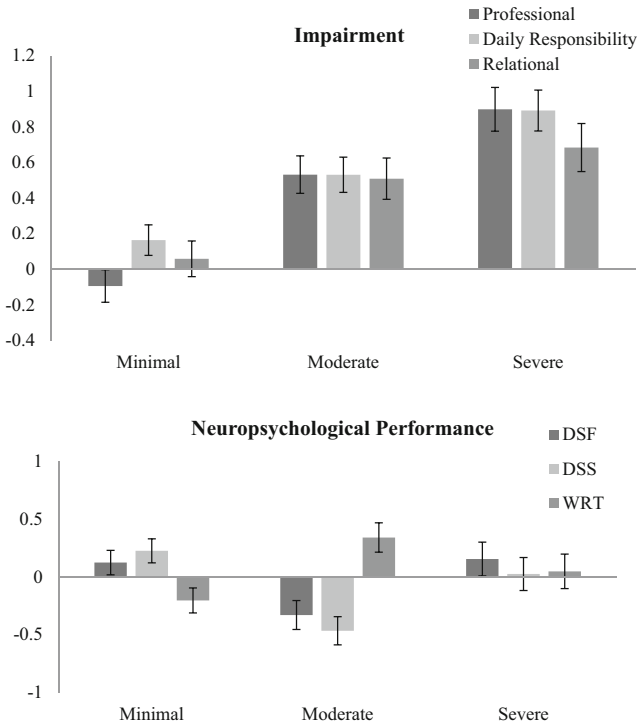

Fig. 2 Impairment and Neuropsychological Performance. *Note.* All scores were transformed into standardized z-scores. DSF = Digit Span Forward. DSS = Digit Span Sequencing. WRT = Word Reading Time. Higher scores refer to worse performance on WRT and more impairment. For DSF and DSS, lower scores refer to worse performance. The Severe and Moderate SCT groups had significantly ($p < .05$) more professional impairment than the Minimal SCT group. The Severe SCT group had significantly more daily responsibility impairment than the Moderate SCT group, and the Moderate SCT group had significantly more impairment than the Minimal SCT group. The Severe and Moderate SCT groups had significantly more relational impairment than the Minimal SCT group. The Moderate SCT group performed significantly worse than the Severe and Minimal SCT groups on DSF and DSS. The Minimal SCT group performed significantly worse than the Moderate SCT group on WRT

Follow-up analyses indicated that both groups with SCT had significantly more professional impairment and relational impairment, compared to those without SCT symptoms. Further, the severe SCT group had significantly more daily responsibility impairment than both the minimal SCT and moderate SCT groups.

Persistence of ADHD Symptoms Finally, SCT groups differed significantly in terms of persistence of ADHD symptoms (F (4, 418) = 9.25, p = .000), such that those with SCT (moderate and severe) had significantly more persistent inattention symptoms than those without SCT, and those in the moderate SCT group had significantly more persistent hyperactivity-impulsivity symptoms than those without SCT.

Tests of Indirect Effects

Internalizing Symptoms Using a mediational framework, we focused on examining specific indirect associations, with SCT symptoms as a mediator of the association between childhood ADHD symptom outcomes (mean of self- and informant- ratings of childhood inattention and hyperactivity-impulsivity) and internalizing symptoms, including depression and anxiety (see Table 5). The direct effects of childhood inattention and hyperactivity-impulsivity on anxiety and depression were non-significant ($ps < .69$). However, significant indirect effects did emerge via SCT symptoms. Specifically, childhood inattention significantly predicted depression via SCT symptoms ($\beta = .32$, [0.25, 0.39], $p < 0.001$). Similarly, childhood hyperactivity-impulsivity symptoms also predicted depression via SCT symptoms, ($\beta = 0.23$, [0.17, 0.29], $p < 0.001$). In both cases, increased childhood ADHD symptoms predicted higher SCT symptoms, which, in turn, predicted increases in depression. Significant indirect effects also emerged for the association of childhood inattention and anxiety ($\beta = 0.223$, [0.158, 0.288], $p < 0.001$), and childhood hyperactivity-impulsivity and anxiety, ($\beta = 0.161$, [.090, .232], $p < 0.001$). Again, childhood ADHD symptoms predicted higher SCT symptoms, which, in turn predicted increased anxiety.

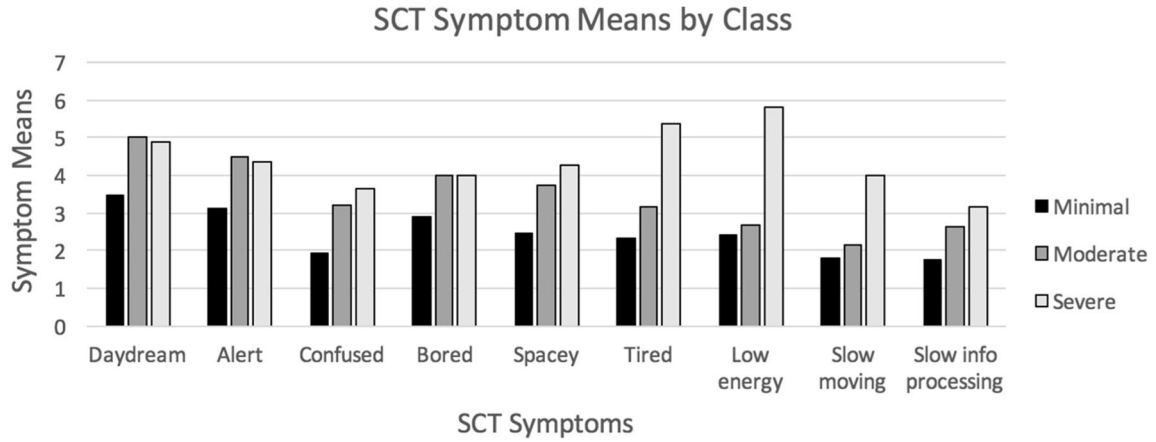

Fig. 3 SCT Symptom Elevations Across Latent SCT classes. *Note.* Latent class analyses were based on participants with ADHD

Daily Living Impairment Similarly, we examined SCT symptoms as a mediator of the association between childhood ADHD symptoms and impairment (daily living, professional, and relational; see Table 6). Direct effects of childhood inattention (β = 0.236, [0.137, 0.337], $p < 0.001$) and hyperactivity-impulsivity (β = 0.232, [0.137, 0.329], $p < 0.001$) on daily living impairment were significant. Significant indirect effects also emerged, such that childhood inattention symptoms predicted SCT symptoms, which then predicted daily living impairment (β = 0.285, [0.222, 0.347], $p < 0.001$), and childhood hyperactivity-impulsivity symptoms predicted SCT symptoms, which, in turn, predicted daily living impairment (β = 0.233, [0.169, 0.298], $p < 0.001$).

Professional Impairment Moreover, there was a significant direct effect of childhood inattention on professional impairment (β = 0.136, [0.031, 0.243], $p = 0.012$), but not for childhood hyperactivity-impulsivity. However, there were significant specific indirect effects for both inattention and hyperactivity-impulsivity via SCT symptoms. Specifically, childhood inattention symptoms predicted professional impairment via SCT symptoms (β = 0.311, [0.240, 0.384], $p < 0.001$), and childhood hyperactivity-impulsivity also predicted professional impairment via SCT symptoms (β = 0.261, [0.200, 0.323], $p < 0.001$).

Table 5 Mediation models for internalizing symptoms

Outcome	Predictor	Direct Effect (C.I.)	Indirect Effect (C.I.)
Depression	IA	−0.034(−1.505,0.794)	0.322(0.251,0.393)***
Depression	HI	0.062(−0.432,1.712)	0.229(0.170,0.287)***
Anxiety	IA	−0.018 (0.248, 0.572)	0.223 (0.158, 0.288)***
Anxiety	HI	0.041 (−0.040, 0.123)	0.161 (.090, .232)***

All predictor variables are childhood symptoms of inattention and hyperactivity-impulsivity. Sluggish cognitive tempo symptoms were examined as the mediator in all models. All direct effects were non-significant.
***$p < .001$

Relational Impairment Finally, there were significant direct effects of childhood inattention (β = 0.183, [0.071, 0.297], $p < 0.001$) and hyperactivity-impulsivity (β = 0.214, [0.114, 0.315], $p < 0.001$) on relational impairment. For both associations, significant indirect effects emerged, such that childhood inattention symptoms predicted relational impairment via SCT symptoms (β = 0.232, [0.163, 0.301], $p = <0.001$), and childhood hyperactivity-impulsivity symptoms also predicted relational impairment via SCT symptoms (β = 0.183, [0.127, 0.240], $p < .001$).

Discussion

Ongoing debate regarding the best way to conceptualize SCT has led to increased research examining how these symptoms relate to ADHD as well as other psychopathology domains. The current study examined differences among individuals with ADHD and varying levels of SCT symptoms in regard to their internalizing and externalizing symptoms, persistence of ADHD symptoms, neuropsychological performance, and functional impairment. Latent class analysis identified three subgroups of ADHD adults based on their SCT symptoms: those with minimal SCT, those with moderate SCT symptoms, and those with severe SCT symptoms. Consistent with our hypothesis, these subgroups differed in a number of important ways. In general, adults with ADHD combined with SCT symptoms (both moderate and severe groups) had significantly more symptoms of anxiety, depression, and persistent inattention, and had more severe professional and relational impairment compared to ADHD adults without SCT. Interestingly, compared to those with few or minimal SCT symptoms, the severe SCT group had the most symptoms of depression and internalizing disorders, and the most impairment in the domain of daily responsibility. Examination of specific symptom elevations in the LCA analyses indicated that the severe SCT group had high

Table 6 Mediation models for impairment

Outcome	Predictor	Direct Effect (C.I.)	Indirect Effect (C.I.)
Daily Living	IA	0.236 (0.137, 0.337)***	0.285(0.222, 0.347)***
Daily Living	HI	0.232 (0.137, 0.329)***	0.233(0.169, 0.298)***
Professional	IA	0.136 (0.031, 0.243)*	0.311 (0.240, 0.384)***
Professional	HI	0.062 (−0.038, 0.162)	0.261 (0.200, 0.323)***
Relational	IA	0.183 (0.071, 0.297)**	0.232 (0.163, 0.301)***
Relational	HI	0.214 (0.114, 0.315)***	0.183 (0.127, 0.240)***

All predictor variables are childhood symptoms of inattention (IA) and hyperactivity-impulsivity (HI). Sluggish cognitive tempo symptoms were examined as the mediator in all models. *p < .05, **p < .01, ***p < .001

rates of endorsement on several SCT items, including feeling spacey, tired, low energy, slow moving, and slow to process information. Therefore, this severe SCT group may represent a subgroup of individuals with ADHD who can be characterized as particularly slow and spacey, and who may be most prone to exhibit depression symptoms and experience problems related to daily living tasks. This builds upon prior research that has found that SCT seems to comprise a slow component, a sleepy component, and a daydreamer component (Penny et al. 2009). While research has only just begun to examine how specific components of SCT relate to psychopathology, the present study suggests that those who fall into the particularly slow domain of SCT may be at higher risk for symptoms, such as depression and anxiety, and may also have the most difficulty with activities in daily life, such as self-care and completing tasks (e.g., chores).

Notably, the SCT groups did not exhibit many differences in neurocognitive performance. However, working memory performance and speeded sequencing was significantly worse in the moderate SCT group compared to the other groups. It may be that compared to adults with ADHD and minimal or severe SCT, those moderate SCT symptoms are at particular risk for difficulty in some neurocognitive tasks because their struggles borderline those of individuals with ADHD only and those with more specific SCT-related deficits. It may even be possible these individuals (moderate SCT) represent a neurocognitively impaired subgroup of adults with ADHD, although this is only speculation given the understudied nature of this association. In fact, to date, only one study has examined SCT in relation to neuropsychological performance in adults (Becker and Barkley 2017), and found that neither SCT nor ADHD symptoms predicted neurocognitive performance in adults, although this could be the result of their use of a non-clinical, college student sample that did not have clinically significant problems nor did it vary substantially in neurocognitive functioning (Jarrett et al. 2014). Given that research in this area is only starting to emerge, it's unclear if SCT is specifically associated with any particular neurocognitive domains (apart from ADHD). Although a comprehensive battery of neurocognitive tasks was used in this study, there may be additional, relevant neuropsychological domains that would be important to assess (e.g., reward discounting and temporal processing) to determine if there are specific neurocognitive correlates of SCT. Further, ratings of executive function deficits may provide a more ecologically-valid way to assess these impairments among adults with ADHD and SCT (Barkley et al. 1990a; Bauermeister et al. 2012; Carlson and Mann 2002; Lahey et al. 1987). However, the current findings suggest that some individuals with ADHD may exhibit more neurocognitive deficits and that this group may not overlap with a second subgroup of individuals with ADHD characterized by high levels of SCT. It's possible then, that there is a neurocognitively-impaired presentation of ADHD that is at least somewhat distinct from a subgroup of those with ADHD and SCT symptoms, and this could have implications for ADHD assessment. For example, clinicians assessing individuals with suspected ADHD without neurocognitive impairments should consider further assessment of SCT symptoms.

The current findings are also remarkably consistent with past work demonstrating that SCT may be more strongly related to internalizing comorbid symptoms as opposed to externalizing symptoms. While SCT is distinct from anxiety and depression (Bauermeister et al. 2012; Penny et al. 2009), previous work has also found that SCT is significantly associated with these internalizing, but not externalizing symptoms (Becker and Langberg 2013; Becker et al. 2014b; Lee et al. 2014; Willcutt et al. 2014). Additionally, prior research has pointed to the possibility that SCT is more strongly associated with depression than anxiety (Barkley 2013a; Becker et al. 2014c; Fenollar Cortes et al. 2014; Jacobson et al. 2012), which is consistent with our findings. We found that individuals with ADHD and SCT symptoms (in the moderate and severe group) had more anxiety and depression than those without SCT, but those with severe SCT had the most depression symptoms.

We also utilized mediation analyses to formally test specific indirect associations of ADHD, SCT, and internalizing symptoms and impairments. Again, given the cross-sectional nature of the data, mediation was not used in this context to

make causal assumptions about the variables. However, examining indirect associations in this way allows for a better understanding of if SCT may serve as one potential mechanistic link between ADHD symptoms during childhood and internalizing problems and impairment in adulthood. Overall findings suggested that childhood ADHD symptoms predicted SCT symptoms, which in turn predicted internalizing problems and impairment. The finding that childhood ADHD symptoms emerged as significant predictors accentuates the importance of evaluating SCT because this suggests that even though ADHD symptoms may be diminished in adulthood, SCT symptoms still appear to be relevant in potentially leading to negative outcomes. While there were no significant direct effects of childhood inattention and hyperactivity-impulsivity symptoms on anxiety and depression, significant indirect effects via SCT symptoms emerged, such that both inattention and hyperactivity-impulsivity significantly predicted both anxiety and depression via their effects on SCT. These findings lend initial support to the possibility that SCT symptoms may serve as a link between ADHD symptoms and internalizing problems, indicating that at least some individuals with ADHD may be at a heightened risk for developing anxiety and depression. Thus, SCT symptoms should be assessed regularly among those with suspected ADHD, and more attention should be given to SCT as a target of treatment in those who have both ADHD and SCT to prevent the onset of internalizing problems.

Few studies have examined SCT in relation to functional impairment, especially in adulthood. However, our findings are consistent with prior work, which has indicated that SCT is associated with difficulties in multiple life domains, even after controlling for ADHD symptoms (Becker et al. 2016; Combs et al. 2014; Combs et al. 2015). Mediation analyses revealed significant direct and indirect effects regarding the association between childhood ADHD symptoms and professional, relational, and daily living impairment, such that ADHD symptoms were directly predictive of more functional impairment and were indirectly related to impairment via SCT. Compared to those without SCT symptoms, both SCT groups (moderate and severe) were significantly more impaired in professional and relational domains, reflecting the possibility that individuals with SCT symptoms in combination with ADHD have a more difficult time succeeding in educational and occupational settings, as well as navigating social situations. Consistent with this, research in children has found that SCT is associated with social functioning impairment even after controlling for ADHD, which may be due to the tendency of those with SCT to be socially withdrawn and isolated (Capdevila-Brophy et al. 2014; Carlson and Mann 2002; Marshall et al. 2014; Willcutt et al. 2014). In a similar vein, group differences also revealed that those with severe SCT were also significantly more impaired in daily living, and that symptoms of being slow and spacey were what set the severe SCT group apart from the other ADHD groups. Thus, it's possible that those who are particularly slow and spacey (along with having ADHD symptoms) have the most money management problems, driving problems, chore completion problems, daily responsibility problems, self-care problems, and health problems. Taken together, these results further support the notion that SCT symptoms may be one link in the association between childhood ADHD and impairment in adulthood.

Implications

While adult ADHD has often been associated with several neurocognitive deficits, comorbid symptoms, and impairment, there exists substantial heterogeneity, making it difficult to refine etiological theories, clinical assessment, and treatment of the disorder. Therefore, a clear research priority currently is conceptualizing this heterogeneity. At the same time, a growing body of research points to the importance of examining a set of symptoms known as SCT, characterized by slowness, sleepiness, and mind-wandering, which have been found to be present in at least a proportion of those with ADHD. Examining SCT's role in explaining the heterogeneity in adult ADHD has been underexplored, and much of the prior work on SCT has focused on children.

Importantly, findings from the present study have both theoretical and practical implications. Results highlight that SCT is a potential link between ADHD and behavioral outcomes. For example, findings included differences in internalizing symptoms and impairment based on varying levels of SCT symptoms. Specifically, it appears that those with symptoms consistent with the "slow" component of SCT are at highest risk for these problems. Moreover, follow-up analyses of specific indirect associations revealed that SCT symptoms might at least explain some of the heterogeneity in ADHD. In particular, although causal conclusions cannot be made in this context, results from examining childhood ADHD symptoms as predictors may highlight a mechanistic role for SCT in contributing to internalizing symptoms and impairment, as in these models childhood ADHD symptoms presumably onset prior to SCT symptoms. Because individuals with ADHD and varying levels of SCT symptoms differ based on the domains previously mentioned, and because of the possible contributory role of SCT symptoms in developing other problems in adulthood, assessment of ADHD may benefit from including measures of SCT symptoms. Doing so would also prevent those affected with some ADHD symptoms, but who exhibit many SCT symptoms, from "falling through the cracks". For example, Becker and colleagues 2014a) presented a case study describing a child who did not meet full criteria for ADHD, but had high levels of SCT symptoms and significant impairment. Adding in measures of SCT may address some of the challenges related to differential diagnosis of ADHD and internalizing disorders.

Given the paucity of research on SCT treatment, there are no clear treatment guidelines, although initial research in this area, including the current findings, may provide some preliminary ideas. Specifically, intervention strategies may wish to focus on targeting and improving the slowness component of SCT, such as extended time on exams if the individual is in academia, or scheduling additional time to complete activities related to self-care, an area of impairment that was highlighted in this study. While some prior work suggests individuals with SCT symptoms may benefit from the same treatment given to those with ADHD (e.g., stimulant medications, psychosocial interventions; Pfiffner et al. 2007; Wietecha et al. 2013), clinicians should also consider treatments that are well-suited for internalizing psychopathology (e.g., cognitive-behavioral therapy, anti-depressant medication), as SCT seems to align more closely with internalizing as opposed to externalizing problems (Barkley 2013b; Becker et al. 2013).

Limitations

There are some limitations of this study that are important to note. While this study used two resources (self and informant) to measure SCT symptoms, only a single method (ratings) was used. However, a smaller proportion of our ADHD group did not have a collateral informant report available, despite our best efforts to obtain them (e.g., individuals with deceased parents). It is possible that we missed individuals with ADHD because of this, as there is evidence suggesting that adults with ADHD may under-report their own symptoms and impairment (Kooij et al. 2008). While follow-up analyses revealed no significant differences in our sample between those with and without informant report in regard to symptom severity, we advocate that future research continue to collect informant reports in studies of ADHD wherever possible (Sibley et al. 2016). Similarly, our ADHD group included individuals who all met diagnostic criteria during childhood, although some did not meet full diagnostic thresholds in terms of number of symptoms in adulthood. We elected to retain these individuals in the ADHD group to capture a broader array of potential developmental trajectories and particularly given the longitudinal instability of symptom thresholds (Lahey et al. 2005). Further, those adults just below diagnostic symptom thresholds did not differ substantially in impairment, comorbidity, or treatment history from those that continued to meet full diagnostic thresholds.

We also did not recruit a "pure ADHD group", due to our desires to maintain reasonable external validity and to address questions regarding psychopathology overlap and co-occurrence in this population. Thus, we likely included individuals with ADHD as well as symptoms of anxiety and depression, which can result in similar behavioral patterns and impairments. We should note that this doesn't render our ADHD group invalid, as comorbidity is the rule and not the exception (Cadman et al. 2016). However, to boost the validity of our ADHD group, we did ensure that all of those included met full criteria during childhood, as ADHD often onsets earlier developmentally than other disorders who may share core behavioral symptoms of ADHD. Future work in psychopathology, including research into adult ADHD, will likely benefit by adopting a dimensional approach to recruitment and measurement of psychopathology in line with the goals of the NIMH Research Domain Criteria (RDoC) initiative (Insel et al. 2010).

Additionally, SCT symptoms were measured at a single time point. While most of the research in this area to date has utilized this method for assessing SCT symptoms, future studies would benefit from including additional measures of SCT, including ratings and behavioral measures at multiple time points. One way of doing so would be to utilize Ecological Momentary Assessment (EMA) of SCT symptoms, such that an individual would be prompted multiple times per day for a certain length of time to document their symptoms. Therefore, this method of assessment takes advantage of the potential lack of stability of symptoms across time and contexts, which could provide additional insight into the temporal nature and stability of SCT symptoms. This may be particularly important because SCT may not be temporally stable, but rather these behavioral symptoms may fluctuate and be even more context dependent than ADHD symptoms. If researchers determine how to properly assess SCT, it will likely become clearer how the construct is associated with, and different from, other symptom dimensions, as well as the threshold at which it causes impairment.

Furthermore, inferences about SCT in the absence of ADHD cannot be made from the current study, as the sample was comprised of individuals with ADHD. Because of the possibility of results being confounded by ADHD symptoms, persistence of inattention symptoms were used as a covariate. While future work could examine SCT apart from ADHD, it will also continue to be important to examine these symptoms within the context of ADHD, as a subgroup of individuals with ADHD exhibit these symptoms, and these symptoms seem to link the disorder to behavioral outcomes.

While our findings did not indicate differences in neurocognitive functioning across the SCT groups, more work may need to be done with additional neurocognitive measures. Some work has shown that the Digit Span tasks place relatively few demands on the "working" component of working memory, and scores on such tasks may reflect simple storage/rehearsal (Cowan 2008; Engle et al. 1999). Therefore, the finding that the moderate SCT group displayed worse working memory (as indexed by scores on digit span) should be considered preliminary in light of potential validity questions of this task. This is in line with some recent work indicating that working memory and inhibition deficits in adult with ADHD may be more strongly linked than similar deficits in children (Clark et al. 2007).

Moreover, some work has questioned whether individuals with ADHD show deficits in inhibition rather than in attention or functions of the central executive. Specifically, two previous meta-analytic reviews questioned whether particular indices of response inhibition (e.g.., stop signal reaction time, SSRT) reflect deficits in inhibition or in attention (Alderson et al. 2007; Lijffijt et al. 2005). Our findings, consistent with other studies of adults (Bekker et al. 2005), demonstrated that differences between ADHD and non-ADHD participants in SSRT reflected group differences in the stop signal delay, but not in mean reaction time, consistent with the notion that SSRT indexes inhibition deficits in this group. Response inhibition deficits (as indexed via the stop-signal paradigm) have been described in multiple studies and are frequently used in conjunction with other methods to identify relevant neural pathways associated with the disorder (Janssen et al. 2015; Lipszyc and Schachar 2010; Nigg et al. 2002). However, future work with ADHD populations across the developmental spectrum will benefit by vetting the validity of SSRT as an index of response inhibition. The validity of all indices should continue to be evaluated, given that those used in the current study are quite similar to those used across the literature focusing on neurocognitive performance among adults with ADHD (Barkley et al. 2001; Nigg et al. 2005; Stavro et al. 2007; Willcutt et al. 2005).

Finally, there may be additional correlates of SCT not examined in the present study that explain differences among those with ADHD and the previous outcomes discussed (e.g., internalizing symptoms). For example, SCT symptoms may be important in linking ADHD to emotion dysregulation, especially since 50–70% of youth and adults with ADHD exhibit emotion regulation deficits (Shaw et al. 2016). Examining broader systems of emotion regulation, and how SCT relates to this, in explaining the association between ADHD and internalizing problems and impairment, may better elucidate causal mechanisms.

Conclusions

Taken together, the current study provides support for SCT symptoms as at least one indirect pathway to explaining the association between ADHD symptoms and anxiety, depression, and impairment. Importantly, it appears that SCT symptoms are particularly associated with internalizing problems and functional impairment, which has implications for assessing and treating individuals with SCT symptoms, as well as expanding etiological theories of ADHD. Moreover, the current study extends upon past work by examining different SCT classes in a large group of adults with ADHD, and demonstrating the importance of SCT in understanding the heterogeneity of ADHD in adulthood.

Compliance with Ethical Standards

Conflict of Interest Authors Jaclyn M. Kamradt, Allison M. Momany, and Molly A. Nikolas declare that they have no conflict of interest.

Ethical Approval The current study was conducted with the informed consent of all participants. All procedures performed in this study were in accordance with the ethical standards of the University of Iowa's Institutional Review Board.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Experiment Participants All participants provided informed consent and this research study was conducted in compliance the standards of the Institutional Review Board.

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