Published in final edited form as:

J Atten Disord. 2017 June ; 21(8): 642–654. doi:10.1177/1087054714539995.

Does Sluggish Cognitive Tempo Fit within a Bi-factor Model of Attention-Deficit/Hyperactivity Disorder?

Annie A. Garner, Ph.D.^a, James Peugh, Ph.D.^b, Stephen P. Becker, M.A.^{b,c}, Kathleen M. Kingery, M.A.^{b,d}, Leanne Tamm, Ph.D.^b, Aaron J. Vaughn, Ph.D.^{b,a}, Heather Ciesielski, Ph.D.^b, John O. Simon, M.A.^b, Richard E. A. Loren, Ph.D.^b, and Jeffery N. Epstein, Ph.D.^{b,d}

^aDivision of General and Community Pediatrics, Cincinnati Children's Hospital Medical Center, Cincinnati, OH

^bDivision of Behavioral Medicine and Clinical Psychology, Cincinnati Children's Hospital Medical Center, Cincinnati, OH

^cDepartment of Psychology, Miami University, Oxford, OH, USA

^dDepartment of Psychology, University of Cincinnati, Cincinnati, OH

Abstract

Objective—Studies demonstrate sluggish cognitive tempo (SCT) symptoms to be distinct from inattentive and hyperactive-impulsive dimensions of Attention-Deficit/Hyperactivity Disorder (ADHD). No study has examined SCT within a bi-factor model of ADHD whereby SCT may form a specific factor distinct from inattention and hyperactivity/impulsivity while still fitting within a general ADHD factor, which was the purpose of the current study.

Method—168 children were recruited from an ADHD clinic. Most (92%) met diagnostic criteria for ADHD. Parents and teachers completed measures of ADHD and SCT.

Results—Although SCT symptoms were strongly associated with inattention they loaded onto a factor independent of ADHD 'g'. Results were consistent across parent and teacher ratings.

Conclusions—SCT is structurally distinct from inattention as well as from the general ADHD latent symptom structure. Findings support a growing body of research suggesting SCT to be distinct and separate from ADHD.

Keywords

ADHD; Attention Deficit Disorder; Factor Structure; SCT; Sluggish Cognitive Tempo

Attention-Deficit/Hyperactivity Disorder (ADHD), as described in the *Diagnostic and Statistical Manual of Mental Disorders-Fifth Edition* (DSM-5; American Psychiatric Association [APA], 2013), is characterized by developmentally inappropriate and functionally impairing symptoms of inattention and/or hyperactivity/impulsivity. The two-

factor (i.e., inattention and hyperactivity/impulsivity) structure of ADHD symptoms has gained extensive empirical support (Bauermeister, Alegria, Bird, Rubio-Stipec, & Canino, 1992; Burns et al., 1997; Friedman-Weieneth, Doctoroff, Harvey, & Goldstein, 2009; Molina, Smith, & Pelham, 2001; Willcutt et al., 2012). Despite the fact that the two ADHD symptom domains are distinct, the inattentive and hyperactive/impulsive dimensions are highly correlated and share approximately 44% of their variance with one another (Willcutt et al., 2012). Thus, symptoms of inattention and hyperactivity/impulsivity have a common link which the simple two-factor model of ADHD does not fully capture.

A bi-factor model may provide a better model of ADHD symptom structure. A bi-factor model of ADHD symptoms specifies an underlying ADHD 'g' factor that relates to all 18 symptoms of ADHD, as well as independent latent factors of Inattention and Hyperactivity/Impulsivity which account for additional variance in ADHD symptom structure beyond the overall 'g' factor. This type of model would help explain the significant heterogeneity in symptom presentation among patients meeting diagnostic criteria for ADHD (Martel, von Eye, & Nigg, 2010; Smith, Tamm, Hughes, & Bernstein, 2013). Specifically, within such a model individuals could present with different constellations of symptoms across the two symptom domains yet still be considered to have the same underlying condition. Even within individuals, there is often variability in terms of symptom presentation over time such as the well-documented developmental pattern of decreasing hyperactivity symptoms with age (Hart, Lahey, Loeber, Applegate, & Frick, 1995) and a frequently-observed transition from ADHD, Combined Type to ADHD, Predominantly Inattentive Type from childhood to adolescence (Hurtig et al., 2007). These developmental phenomena can also be accounted for within a bi-factor model of ADHD since it would allow for variation in ADHD subtyping as long as the underlying ADHD 'g' factor was still exhibited via expression of individual ADHD symptoms. This is because a bi-factor model suggests that there is general risk for ADHD as well as specific risk for domains of inattention and hyperactivity/impulsivity.

Indeed, a quickly growing literature provides support for the bi-factor model of ADHD symptoms over two-factor models with correlated factors (Dumenci, McConaughy, & Achenbach, 2004; Gibbins, Toplak, Flora, Weiss, & Tannock, 2012; Gomez et al., 2013; Martel, von Eye, & Nigg, 2012; Smith et al., 2013; Ullebo, Breivik, Gillber, Lundervold, & Posserud, 2012; Willoughby & Blanton, in press) and second-order models where individual ADHD symptoms load directly onto two specific factors which then in turn load onto a "second-order" factor (Martel et al., 2012; Ullebø, et al., 2012; Willoughby & Blanton, in press). Most studies support a bi-factor model consisting of a 'g' factor and specific factors for Inattention and Hyperactivity/Impulsivity (Burns, Moura, Beauchaine, & McBurnett, 2013; Dumenci, McConaughy, & Achenbach, 2004; Gomez et al., 2013; Martel, von Eye, & Nigg, 2012; Willoughby & Blanton, in press), with a few exceptions whereby a third specific factor of impulsivity also emerged (Gibbins et al., 2012; Ullebø et al., 2012). Of note, evidence for a bi-factor model of ADHD has been found in school-based samples (Gomez, 2013; Willoughby & Blanton, in press), community samples (Burns et al., 2014; Martel, von Eye & Nigg, 2010; Ullebo, et al., 2012), and clinical samples (Dumenci et al., 2004; Martel et al., 2012; Gibbins et al., 2012; Smith et al., 2013; Toplak et al., 2009, 2012). Further, the bi-factor model is invariant across sex (Gibbins et al., 2012; Martel, von Eye, & Nigg, 2010; Ullebo et al., 2012), age groups (Martel et al., 2010; Martel, von Eye, & Nigg,

2012; Toplak, Sorge, Flora, Chen, Banaschewski, Buitelaar, ... & Faraone, 2012), and ADHD diagnostic status (Martel et al., 2010; Martel et al., 2012). Finally, the bi-factor model of ADHD replicates across methods of assessment (e.g., Burns et al., 2014; Dumenci et al., 2004; Gibbins et al., 2012; Martel 2010) and across raters (Burns et al., 2014; Ullebø et al., 2012; Martel et al., 2012).

Despite this convergence of evidence supporting a bi-factor model of ADHD (i.e., ADHD “g” and Inattention and Hyperactivity/Impulsivity specific factors), there is considerable interest in whether sluggish cognitive tempo, or SCT, is a symptom dimension of ADHD or a separate diagnostic entity (see Barkley, 2014; Becker, Marshall, & McBurnett, 2014). SCT is a construct comprised of symptoms such as confused/seems to be in a fog, daydreams, stares blankly, underactive/slow-moving, and apathetic/unmotivated. A separate SCT factor, distinct from ADHD inattention, was first identified in the mid-1980s and this finding was replicated in the DSM-IV field trials (Lahey et al., 1994). However, SCT symptoms were ultimately not included in the DSM-IV diagnostic criteria for ADHD because most children with ADHD Predominantly Inattentive Type did not also display high levels of SCT (Frick et al., 1994). Nonetheless, multiple studies examining ADHD and SCT symptoms in youth have continued to provide support for a three-factor model that includes separate but correlated factors of ADHD-Inattention, ADHD-Hyperactivity/Impulsivity, and SCT (Willcutt et al., 2012). When controlling for ADHD inattentive symptoms, some studies found that the relationship between SCT and hyperactivity/impulsivity is non-significant (Burns, Servera, Bernad, Carrillo, & Cardo, 2013), whereas other studies found the two domains to be significantly, negatively associated (Lee et al., 2014; Penny et al., 2009). Not surprisingly, there are substantial correlations between the SCT and inattention factors across studies, $r_s = .54 - .76$ (see Willcutt et al., 2012). The high correlation between inattention symptoms and SCT would seem to suggest that SCT might be subsumed under an overall ADHD ‘g’ factor along with the two ADHD symptom domains.

To our knowledge only one study has included symptoms of SCT in their assessment of the bi-factor model of ADHD (Dumenci et al., 2004). Using the Teacher's Report Form (TRF), investigators included four items commonly used to measure SCT in a series of analyses comparing the fit of a (a) one-factor model of ADHD, (b) correlated two-factor model of Inattention and Hyperactivity/Impulsivity, and (c) bi-factor model of ADHD ‘g’ plus two specific factors of Inattention and Hyperactivity/Impulsivity. These models were tested separately in clinical and nonclinical samples. A bi-factor model of ADHD was supported in both samples. Notably, an SCT factor was not modeled in this study; instead, symptoms of SCT were modeled as loading directly onto ADHD ‘g’ and onto the Inattention domain specifically. In the clinical sample, standardized factor loadings for SCT items on ‘g’ were weak (ranging from .11 to .31; average standardized factor loading = .22). In contrast, the standardized loadings of these items on the specific Inattention factor were strong (ranging from .69-.75; average standardized factor loading = .71). These findings suggest that SCT may be distinct from ADHD, yet related to symptoms of inattention.

Indeed, Barkley (2012, 2013, 2014) has argued that SCT may reflect a unique disorder rather than a symptom dimension of ADHD. Supporting this theory, individuals with high SCT symptoms demonstrate a differential pattern of functional impairments and association

with comorbidities from the pattern exhibited by individuals with symptoms of ADHD (Barkley, 2012, 2013; Lee et al., 2014). For example, in a recent study of 52 adolescents with ADHD, symptoms of SCT, but not symptoms of inattention, were uniquely associated with lower grade point average and more teacher-rated homework problems (Langberg, Becker, & Dvorsky, 2014). Willcutt and colleagues (Willcutt et al., 2014) found a similar pattern where SCT was uniquely related to problems with written language in a sample of over 700 youth with and without ADHD. Within the social domain, SCT is associated with social isolation and impairment in the peer domain even when controlling for ADHD, depressive, and anxiety symptoms (Becker, 2014; Willcutt et al., 2014). Furthermore, SCT is associated with higher rates of anxiety and depression symptoms even when symptoms of inattention are included as predictors (Becker, Luebke, Fite, Stoppelbein & Greening, 2014; Penny et al., 2009). Given this association between SCT and anxiety/depression, it is not surprising that SCT is also strongly linked to emotion regulation difficulties (Barkley, 2012; Flannery et al., 2014). Finally, SCT and inattention show a differential association with measures of neuropsychological functioning such that inattention is uniquely associated with response inhibition, working memory, and increased response variability while SCT is associated with problems in sustained attention (Willcutt et al., 2014; Wåhlstedt & Bohlin, 2010).

Given research demonstrating SCT to be closely linked to ADHD inattention but also uniquely related to psychosocial and neuropsychological functioning, the purpose of this study is to examine the factor structure of ADHD and SCT using both parent and teacher ratings. Specifically, we sought to compare models in which symptoms of SCT fit within the bi-factor framework of ADHD to an alternative model in which SCT symptoms form a distinct factor independent of ADHD 'g'. We hypothesized that, consistent with prior research examining the DSM-IV/DSM-5 ADHD symptom structure, symptoms of ADHD would form inattentive and hyperactive/impulsive factors as well as an overall ADHD 'g' factor. Given the exploratory nature of the present study, we did not make specific predictions about whether the SCT factor would be subsumed within an ADHD 'g' factor (thus explaining the high association between inattention and SCT) or whether SCT would best fit outside the overarching ADHD 'g' factor (which would support the contention that SCT symptoms reflect the presence of a distinct disorder).

Method

Participants

The study sample was drawn from a clinical outpatient population seeking psychological evaluation for behavioral concerns at the BLINDED FOR REVIEW. Families being seen for an ADHD evaluation were approached about allowing ratings collected during the evaluation to be used for research purposes. The Institutional Review Board approved the above described procedures and the analyses presented in this study.

A total of 168 children between the ages of 6 and 12 ($M = 8.43$, $SD = 1.86$) were included in this study with approximately two-thirds ($n = 110$) of the participants being male. Eighty-one percent of the sample was Caucasian, 13% were African American, and 6% were of other race/ethnicity. Of the 168 children, 144 (86%) had both parent and teacher ratings of

the variables used in this study, an additional 17 (10%) had complete data for parent ratings only, and 2 (1%) had complete data for teacher ratings only. Thus, 146 children were included in the analyses examining teacher-reported variables and 161 children were included in the analyses examining parent-reported variables.

Diagnosis of ADHD was established by clinicians at the BLIND FOR REVIEW using the Vanderbilt ADHD Diagnostic Rating Scale completed separately by parents and teachers (Wolraich et al., 1998), the Child Behavior Checklist and Teacher Report Form (Achenbach, 1991), a clinic-developed developmental questionnaire that inquires about early developmental history, and parent responses to a clinic-developed semi-structured interview assessing ADHD symptoms and additional DSM-IV criteria for ADHD (e.g., age of onset, functional impairment), as well as possible comorbid disorders including anxiety and depression. Of the 168 participants in this study, 155 (92%) were diagnosed with ADHD. Of those, 62 (40%) were diagnosed with ADHD-Combined type, 83 (53.5%) were diagnosed with ADHD-Predominantly Inattentive Type, and 10 (6.5%) were diagnosed with ADHD Not Otherwise Specified (NOS). Finally, of the 155 children diagnosed with ADHD, 103 (66.5%) were diagnosed with ADHD alone, while 28 (18.1%) were diagnosed with a comorbid behavioral disorder (Oppositional Defiant Disorder [ODD] or Conduct Disorder [CD]), and 17 (10%) with a comorbid Anxiety Disorder. No children were diagnosed with a comorbid mood disorder.

Measures

ADHD symptoms

Parents and teachers completed the Vanderbilt ADHD Diagnostic Parent Rating Scale (VADPRS) and Vanderbilt ADHD Diagnostic Teacher Rating Scale (VADTRS) respectively (Wolraich et al., 1998). The VADPRS and VADTRS include items assessing the 18 DSM-IV symptoms of ADHD, and these items were used in the present study to measure inattentive (Parent $\alpha = .87$, Teacher $\alpha = .94$) and hyperactive-impulsive symptoms (Parent $\alpha = .92$, Teacher $\alpha = .94$). Children's behavior is rated on a 4-point scale ranging from 'never' (0) to 'very often' (3). For all variables, mean scale scores range from 0-3 with higher scores indicative of greater symptomatology.

SCT symptoms

Three items from the parent-completed Child Behavior Checklist (CBCL; Achenbach, 2001) and four items from the teacher-completed Teacher Report Form (TRF; Achenbach, 2001) were used to measure SCT. These items which appear on both the CBCL and TRF have been frequently used in previous studies to measure SCT: confused or seems to be in a fog, daydreams, and stares blankly (Becker & Langberg, 2014; Carlson & Mann, 2002; Garner et al., 2010; Hartman et al., 2004; McBurnett et al., 2001). The teacher measure of SCT includes an additional item, apathetic or unmotivated, that is not present on the CBCL. Parents and teachers rated each item on a 3-point scale ranging from 'not true' (0) to 'very true or often true' (2). Reliability on these SCT items was adequate to good in the present sample (Parent $\alpha = .76$, Teacher $\alpha = .81$). Of note, Skirbekk and colleagues (2011) found the

CBCL/TRF measure of SCT to be strongly correlated ($r = .77$) with a longer measure of SCT.

Statistical Analysis—Mplus Version 7.11 (Muthén & Muthén, 1998-2012) was used for all statistical analyses. ADHD and SCT ratings were treated as continuous data in all analyses. Missing item data varied from 0.5% to 4.2% and 0.6% to 3.2% across the parent and teacher data sets, respectively. Consistent with current best-practice, maximum likelihood estimation was used for handling missing item-level data (e.g., Enders, 2010; Graham, 2012).

Statistical modeling was conducted separately for parent and teacher ratings and followed three steps. First, three orthogonal bi-factor models were estimated and compared (Figure 1, Models 1-3). In the first two models, all symptoms loaded on a single general factor called ADHD. In Model 1, symptoms of inattention and SCT loaded on a single factor (Inattention), while symptoms of hyperactivity and impulsivity loaded onto a separate factor (Hyperactivity/Impulsivity). This model would indicate that SCT symptoms are not independent from Inattention or ADHD as a psychopathology. In Model 2, all ADHD and SCT symptoms loaded on a single general factor called ADHD. However, the three symptom dimensions loaded on separate specific factors. This model would support the notion that although symptoms of SCT represent a separate construct from Inattention these symptoms still fall under the umbrella of ADHD. In Model 3, SCT symptoms formed a separate factor and do not load on the ADHD general factor, whereas symptoms of inattention and hyperactivity/impulsivity loaded directly onto the ADHD 'g' factor as well as onto separate specific factors. This final model would suggest that SCT is a construct clearly separate from ADHD. As recommended (Muthén & Muthén, 1998-2012), all factors (general and specific) were orthogonal (i.e., correlations are fixed to zero). The three models were compared sequentially. Specifically, Model 1 was compared to Model 2 and the resulting superior model served as the model against which Model 3 was compared. Models were compared using various fit indices including chi-square fit statistics, root mean square error of approximation (RMSEA), and comparative fit index (CFI). Good fit is typically indicated by non-significant chi-square model fit values, low ($< .06$) RMSEA and ($.08$) SRMR values, and high ($> .95$) CFI values (Kline, 2011).

Supplemental analyses

Theoretically driven supplemental models (Figure 1, Supplemental Models 4 and 5) were tested in the event that model fit was poor in the original three orthogonal models. Traditionally, because the shared variance between the specific factors is thought to be "conditional" upon the g-factor, bi-factor modeling specifies that latent factors are orthogonal (Reise, 2012). However, as discussed by Jennrich and Bentler (2011), it is permissible in some cases to specify correlations between specific factors. Furthermore, Reise (2012) acknowledges that forcing orthogonality between specific factors does not reflect the true nature of psychopathology since psychiatric diagnoses are not orthogonal in the real world given the high rates of comorbidity observed across various psychiatric diagnoses.

Hence, in the first supplemental model (Model 4) we planned to test whether allowing the two ADHD symptom factors to correlate with each other would improve model fit. Allowing specific factors to correlate with one another would suggest that there is “left-over” shared variance between Inattention and Hyperactivity/Impulsivity even with ADHD ‘g’ is modeled. This shared variance could be due to a third related factor (e.g., comorbidity).

In addition, given the strong association between SCT and inattention (Wilcutt et al., 2012) we tested a final model (Model 5) in which we estimated the correlation between SCT and specific ADHD factors. We also modeled the correlation between SCT and hyperactivity/impulsivity since studies are mixed in regard to the nature of the relationship between these dimensions (Burns et al., 2013; Lee et al., 2014; Penny et al., 2009). Support for Model 5 would suggest that although SCT is a construct independent from ADHD as a diagnostic entity, it is highly comorbid among individuals with high levels of inattention and possibly hyperactivity/impulsivity (depending on the nature of the relationship between the two factors).

Results

Means and descriptive statistics for teacher- and parent-rated items are presented in Table 1. Fit indices for the orthogonal bi-factor teacher and parent models 1-3 are presented in Tables 2 and 3, respectively. These analyses suggest that Model 3 (ADHD symptoms loading onto ADHD ‘g’, specific factors Inattention and Hyperactivity and separate SCT factor) was the orthogonal model with the overall best fit to our data across teacher [$\chi^2(191) = 451.147, p < .000$; CFI=0.881; RMSEA=0.095; SRMR=1.138] and parent ratings [$\chi^2(191) = 451.147, p < .000$; CFI=0.881; RMSEA=0.095; SRMR=1.138]. Although Model 3 had better fit than other orthogonal models tested, overall fit statistics suggest questionable model fit [high ($< .06$) RMSEA and (.08) SRMR values, and low ($> .95$) CFI values (Kline, 2011)] for both teacher and parent models.

Supplemental analyses

Given the poor fit for Model 3, we next tested this model against the theoretically-driven supplemental models (Models 4 and 5). First, Model 3 was modified to allow specific factors of inattention and hyperactivity/impulsivity to correlate with one another (i.e., Model 4) for both teacher and parent reports. Across raters, likelihood ratio nested model testing suggested that modifications to the model statistically improve the fit of Model 3 for teachers (Table 2) but not parents (Table 3). CFI minimally improved across raters, RMSEA and SRMR fit indices were worse for teacher Model 4 (Table 2) and unchanged for parent Model 4 (Table 3) in comparison to Model 3.

Finally, Model 3 was compared to a model in which specific factors were allowed to correlate each other as well as with the SCT factor (Model 5). For both teacher and parent models, likelihood ratio nested testing was significant with Model 5 showing improved overall fit statistics in comparison to Model 3 (though they do not meet criteria for “good” fit across all fit indices; see Statistical Analysis section as well as Tables 2 and 3). Standardized factor loadings for Model 5 are presented in Figures 2 and 3 for teacher and parent report, respectively.

The correlations between the latent factors in Model 5 were inspected for significance (Figures 2 and 3). SCT was strongly correlated with Inattention for both teacher ($r = 0.67$, $p < .001$) and parent ($r = 0.54$, $p < .001$) ratings. SCT was negatively and significantly correlated with hyperactivity/impulsivity for teacher ($r = -0.40$, $p = .01$). While SCT and hyperactivity/impulsivity were also negatively correlated for parent ratings, this correlation was not statistically significant ($r = -0.16$, $p = .17$). Across teacher and parent ratings, Inattention and Hyperactivity/Impulsivity were not correlated with one another (teacher $r = -.05$, $p = .80$ and parent $r = .00$, $p = .42$).

Discussion

Although one study has modeled SCT items as loading onto the Inattention specific factor in a bi-factor evaluation of ADHD (Dumenci et al., 2004), this is the first study to our knowledge to test the fit of the SCT latent construct in a bi-factor model of ADHD and is therefore important for answering the critical question of whether symptoms of SCT represent a distinct symptom category from the Inattention and Hyperactivity/Impulsivity domains used to define ADHD. Results of this study indicate that symptoms of SCT are best modeled outside of a bi-factor model of ADHD and, importantly, results were consistent across both parent- and teacher-ratings of children's symptoms. Given the emerging state of the SCT literature, we tested the fit of additional non-orthogonal bi-factor models. A model in which specific factors of ADHD (Inattention and Hyperactivity/Impulsivity) were allowed to correlate with one another and with SCT was a statistical improvement over the orthogonal bi-factor models. Inspection of correlations of these latent dimensions suggests that SCT is strongly, positively correlated with inattention and weakly to moderately negatively correlated with Hyperactivity/Impulsivity. This model suggests that though symptoms of SCT are correlated with inattention symptoms, SCT is a construct that is structurally distinct not only from symptoms of inattention but also from an overall ADHD 'g' factor.

Our finding that SCT forms a latent construct independent from ADHD as a diagnostic category is a novel finding, yet consistent with recent arguments that SCT may be itself a distinct psychiatric disorder (Barkley, 2012, 2013, 2014; Bauermeister, Barkley, Bauermeister, Martínez, & McBurnett, 2012; Lee et al., 2014). This argument has been primarily based on factor analytic studies which have investigated whether SCT symptoms fall within the Inattentive dimension or are better represented by a distinct dimension. It has been consistently found that symptoms of SCT form a dimension independent from Inattention and Hyperactivity/Impulsivity (see Willcutt et al., 2012).

However, previous factor analytic research of SCT has not addressed whether SCT is independent from ADHD as a diagnostic category because studies have not taken into account the bi-factor structure of ADHD. Despite growing evidence that symptoms of ADHD are best represented by a bi-factor model (Gomez et al., in press; Martel et al., 2010; Normand et al., 2012; Smith et al., 2013; Toplak et al., 2012), SCT factor analytic studies have modeled SCT as a third factor in a single-order two-factor model of ADHD. Such models do not explicitly model inattention and hyperactivity/impulsivity symptoms loading onto an underlying ADHD factor (i.e., ADHD 'g'). Only one study has tested whether SCT

symptoms also load onto an underlying ADHD factor but in this study symptoms of SCT were only modeled as part of the specific Inattention factor (Dumenci et al., 2004). Our finding that SCT forms its own factor that best fits outside of ADHD 'g' is consistent with Dumenci and colleagues' (2004) finding that SCT symptoms had very weak loadings on ADHD 'g'. Our results demonstrating SCT to be distinct from both ADHD symptom dimensions and the broader ADHD umbrella provides further support for SCT to be conceptualized as distinct from ADHD.

We also tested two models that were not orthogonal. A model in which Inattention and Hyperactivity/Impulsivity were allowed to correlate with one as well as with the SCT factor was statistically improved the model fit of the orthogonal model. This model is in line with the argument that SCT is a distinct disorder but also recognizes that SCT symptoms often co-occur with symptoms of inattention. Indeed, correlations of latent factors confirmed this; SCT is highly and positively correlated with the Inattention specific factor. It is interesting to note that we found that SCT and hyperactivity/impulsivity to be negatively correlated but this correlation only reached significance in the teacher model. Although some of the literature indicates that SCT and hyperactivity/impulsivity do not correlate after controlling for inattention (Burns et al., 2013), other studies found a significant negative relationship between the two factors (Lee et al., 2014; Penny et al., 2009). The differential relationship that SCT has with the ADHD domains highlights the distinctiveness of the SCT factor from the underlying ADHD 'g' construct. The strong, positive relationship between SCT and inattention despite SCT symptoms not loading onto ADHD 'g' supports Barkley's (2012) likening of the overlapping nature of SCT and inattention to that of anxiety and depression (i.e., the two are often comorbid with one another but are not subtypes of the same disorder). We note, however, that although Model 5 was statistically the best fitting model of the models tested, it did not have excellent fit. In addition, the literature is mixed in terms of whether it is permissible to allow specific factors to correlate with one another in bi-factor analyses (Jennrich & Bentler, 2011). However, recent work suggests that this approach is permissible and may better capture the comorbidity that is often encountered across psychiatric disorders (Reise, 2012). For these reasons, we believed it appropriate to model correlations between factors.

The present findings should be considered in light of several methodological limitations. Most notably, separate measures of SCT and ADHD symptoms were used which could potentially explain why SCT symptoms formed a factor independent of ADHD 'g'. The use of different measures to assess symptoms could introduce measure bias and inflate associations within measures such that items from the same scale are more likely to fall within the same factor. However, this explanation is unlikely given that a recent simple factor analytic study using the same measure to assess SCT and ADHD symptoms, the Child and Adolescent Disruptive Behavior Inventory (CADBI; Burns and Lee 2010), found evidence of SCT as independent from inattention and hyperactivity/impulsivity (Lee et al., 2014). Nonetheless, future studies should include a single measure that assesses both symptoms of ADHD and SCT in order to rule out the possibility of measurement bias on the factor structure of these domains.

A second limitation is that the sample may have had limited variability in its presentation of ADHD and SCT symptoms. It has been argued that studies of SCT and ADHD should not focus on ADHD clinic referred samples as these samples may inflate the relationship between SCT and ADHD (Barkley, 2012; Becker, 2013). However, since we did not find that SCT symptoms load onto the ADHD 'g' it seems unlikely that the relationship between SCT and ADHD was inflated. Still, this limitation could have overestimated the strength of the relationship between SCT and Inattention. Future investigations should assess whether the reported factor structure holds true in community samples or general psychiatric samples.

Relatedly, our sample size is relatively small and is comprised of children presenting for an evaluation of ADHD. This limited our ability to include other symptoms that may overlap or account for symptoms of SCT in our analyses. In particular, the possibility that SCT may represent ADHD with comorbid internalizing (Garner et al., 2013) or excessive daytime sleepiness (Langberg et al., 2014) has been raised given the overlap in symptoms across these constructs. However, recent research suggests that SCT and daytime sleepiness are distinct (Langberg, Becker, Dvorsky, & Luebke, 2014). SCT also appears to be a distinct construct from internalizing symptoms (Garner et al., 2013), with recent factor analytic work demonstrating SCT to be distinct from not only ADHD inattention and hyperactivity/impulsivity but also anxiety, depression, and oppositionality (Becker et al., 2014; Lee et al., 2014). Despite the clear association of SCT with internalizing symptoms (Becker & Langberg, 2013; Becker et al., 2014; Garner et al., 2010, 2013; Penny et al., 2009), it would be interesting if future investigations determined whether SCT symptoms fall within an internalizing or externalizing general factor. There is preliminary evidence suggesting SCT to align more closely with the internalizing spectrum of psychopathology (i.e., sensitivity to punishment; Becker, Fite, Garner, Stoppelbein, Greening, & Luebke, 2013), and additional research in this area would provide further information regarding the validity of the SCT construct. Finally our use of 3 to 4 items to measure SCT is a significant limitation given that more comprehensive measures of SCT that account for the multidimensional nature of the construct have recently been developed (Lee et al., 2014; McBurnett et al., 2014; Penny et al., 2009).

Despite these limitations, the findings of the present investigation offer a significant contribution to the extant SCT research and potentially have significant implications for the nosology of ADHD. In particular, the results do not support the inclusion of SCT symptoms in the DSM-IV/DSM-5 criteria for ADHD, Predominantly Inattentive Presentation as has been previously suggested (McBurnett, Pfiffner, & Frick, 2001). Rather, our results align with recent studies that suggest SCT is a distinct psychopathology that is frequently comorbid with ADHD (Barkley, 2012, 2013; Lee et al., 2014). Still, as discussed in a recent commentary by Barkley (2014), more research is needed before conclusions about the etiology and nature of SCT can be drawn.

References

- American Psychiatric Association. Diagnostic and statistical manual of mental disorders. 4th, text rev. Washington, DC: Author; 2000.

- Barkley RA. Distinguishing sluggish cognitive tempo from attention-deficit/hyperactivity disorder in adults. *Journal of Abnormal Psychology*. 2012; 121:978–990. DOI: 10.1037/a0023961 [PubMed: 21604823]
- Barkley RA. Distinguishing sluggish cognitive tempo from ADHD in children and adolescents: executive functioning, impairment, and comorbidity. *Journal of Clinical Child & Adolescent Psychology*. 2013; 42:161–173. DOI: 10.1080/15374416.2012.734259 [PubMed: 23094604]
- Barkley RA. Sluggish cognitive tempo (concentration deficit disorder?): Current status, future directions, and a plea to change the name. *Journal of Abnormal Child Psychology*. 2014; 42:117–125. DOI: 10.1007/s10802-013-9824-y [PubMed: 24234590]
- Bauermeister JJ, Alegria M, Bird HR, Rubio-Stipec M, Canino G. Are attentional-hyperactivity deficits unidimensional or multidimensional syndromes? Empirical findings from a community survey. *Journal of the American Academy of Child and Adolescent Psychiatry*. 1992; 31:423–431. DOI: 10.1097/00004583-199205000-00007 [PubMed: 1592773]
- Bauermeister JJ, Barkley RA, Bauermeister JA, Martinez JV, McBurnett K. Validity of the sluggish cognitive tempo, inattention, and hyperactivity symptom dimensions: neuropsychological and psychosocial correlates. *Journal of Abnormal Child Psychology*. 2012; 40:683–697. DOI: 10.1007/s10802-011-9602-7 [PubMed: 22179974]
- Becker SP. Topical review: Sluggish cognitive tempo: Research findings and relevance for pediatric psychology. *Journal of Pediatric Psychology*. 2013; 38:1051–1057. DOI: 10.1093/jpepsy/jst058 [PubMed: 23933842]
- Becker SP. Sluggish cognitive tempo and peer functioning in school-aged children: A six-month longitudinal study. *Psychiatry Research*. 2014; Advance online publication. doi: 10.1016/j.psychres.2014.02.007
- Becker SP, Fite PJ, Garner AA, Stoppelbein L, Greening L, Luebbe AM. Reward and punishment sensitivity are differentially associated with ADHD and sluggish cognitive tempo symptoms in children. *Journal of Research in Personality*. 2013; 47:719–727. DOI: 10.1016/j.jrp.2013.07.001
- Becker SP, Langberg JM. Sluggish cognitive tempo among young adolescents with ADHD: Relations to mental health, academic, and social functioning. *Journal of Attention Disorders*. 2013; 17:681–689. DOI: 10.1177/1087054711435411 [PubMed: 22441891]
- Becker SP, Langberg JM. Attention-deficit/hyperactivity disorder and sluggish cognitive tempo dimensions in relation to executive functioning in adolescents with ADHD. *Child Psychiatry and Human Development*. 2014; 45:1–11. DOI: 10.1007/s10578-013-0372-z [PubMed: 23443466]
- Becker SP, Luebbe AM, Fite PJ, Stoppelbein L, Greening L. Sluggish cognitive tempo in psychiatrically hospitalized children: Factor structure and relations to internalizing symptoms, social problems, and observed behavioral dysregulation. *Journal of Abnormal Child Psychology*. 2014; 42:49–62. DOI: 10.1007/s10802-013-9719-y [PubMed: 23359144]
- Becker SP, Marshall SA, McBurnett K. Sluggish cognitive tempo in abnormal child psychology: An historical overview and introduction to the Special Section. *Journal of Abnormal Child Psychology*. 2014; 42:1–6. DOI: 10.1007/s10802-013-9825-x [PubMed: 24272365]
- Burns, GL., Lee, S. *Child and Adolescent Disruptive Behavior Inventory–Teacher Version 5.0*. Pullman, WA: Author; 2010.
- Burns GL, Servera M, Bernad MM, Carrillo JM, Cardo E. Distinctions between sluggish cognitive tempo, ADHD-IN and depression symptom dimensions in Spanish first grade children. *Journal of Clinical Child and Adolescent Psychology*. 2013; 42:796–808. [PubMed: 24116861]
- Burns GL, Walsh JA, Patterson DR, Holte CS, Sommers-Flanagan R, Parker CM. Internal validity of the disruptive behavior disorder symptoms: implications from parent ratings for a dimensional approach to symptom validity. *Journal of Abnormal Child Psychology*. 1997; 25:307–319. [PubMed: 9304447]
- Dumenci L, McConaughy SH, Achenbach TM. A hierarchical three-factor model of inattention-hyperactivity-impulsivity derived from the attention problems syndrome of the Teacher's Report Form. *School Psychology Review*. 33:287–301.
- Flannery AJ, Becker SP, Luebbe AM. Does emotion dysregulation mediate the association between sluggish cognitive tempo and college students' social adjustment? *Journal of Attention Disorders*. 2014; Advance online publication. doi: 10.1177/1087054714527794

- Friedman-Weieneth JL, Doctoroff GL, Harvey EA, Goldstein LH. The Disruptive Behavior Rating Scale-Parent Version (DBRS-PV): Factor analytic structure and validity among young preschool children. *Journal of Attention Disorders*. 2009; 13:42–55. DOI: 10.1177/1087054708322991 [PubMed: 18753403]
- Garner AA, Marceaux JC, Mrug S, Patterson C, Hodgins B. Dimensions and correlates of attention deficit/hyperactivity disorder and Sluggish Cognitive Tempo. *Journal of Abnormal Child Psychology*. 2010; 38:1097–1107. DOI: 10.1007/s10802-010-9436-8 [PubMed: 20644992]
- Garner AA, Mrug S, Hodgins B, Patterson C. Do symptoms of sluggish cognitive tempo in children with ADHD symptoms represent comorbid internalizing difficulties? *Journal of Attention Disorders*. 2013; 17:510–518. DOI: 10.1177/1087054711431456 [PubMed: 22366238]
- Gibbins C, Toplak ME, Flora DB, Weiss MD, Tannock R. Evidence for a general factor model of ADHD in adults. *Journal of Attention Disorders*. 2012; 16:635–644. DOI: 10.1177/1087054711416310 [PubMed: 22076604]
- Graham, JW. Missing data: Analysis and design. New York: Springer; 2012.
- Gomez R. ADHD bifactor model based on parent and teacher ratings of Malaysian children. *Asian Journal of Psychiatry*. 2014; 8:47–51. [PubMed: 24655626]
- Hart EL, Lahey BB, Loeber R, Applegate B, Frick PJ. Developmental change in attention-deficit hyperactivity disorder in boys: A four-year longitudinal study. *Journal of Abnormal Child Psychology*. 1995; 23:729–749. [PubMed: 8609310]
- Hurtig T, Ebeling H, Taanila A, Miettunen J, Smalley SL, McGough JJ, Moilanen IK. ADHD symptoms and subtypes: Relationship between childhood and adolescent symptoms. *Journal of the American Academy of Child and Adolescent Psychiatry*. 2007; 46:1605–1613. [PubMed: 18030082]
- Kline, RB. Principles and Practice of Structural Equation Modeling, Third Edition. New York, NY: The Guildford Press; 2011.
- Lahey BB, Applegate B, McBurnett K, Biederman J, Greenhill L, Hynd GW, et al. DSM-IV field trials for attention deficit hyperactivity disorder in children and adolescents. *American Journal of Psychiatry*. 1994; 151:1673–1685. [PubMed: 7943460]
- Langberg JM, Becker SP, Dvorsky MR. The association between sluggish cognitive tempo and academic functioning in youth with attention-deficit/hyperactivity disorder (ADHD). *Journal of Abnormal Child Psychology*. 2014; 42:91–103. DOI: 10.1007/s10802-013-9722-3 [PubMed: 23359145]
- Langberg JM, Becker SP, Dvorsky MR, Luebbe AM. Are sluggish cognitive tempo and daytime sleepiness distinct constructs? *Psychological Assessment*. 2014; Advance online publication. doi: 10.1037/a0036276
- Lee S, Burns GL, Snell J, McBurnett K. Validity of the sluggish cognitive tempo symptom dimension in children: Sluggish cognitive tempo and ADHD-Inattention as distinct symptom dimensions. *Journal of Abnormal Child Psychology*. 2014; 42:7–19. DOI: 10.1007/s10802-013-9714-3 [PubMed: 23325455]
- Martel MM, von Eye A, Nigg JT. Revisiting the latent structure of ADHD: is there a ‘g’ factor? *Journal of Child Psychology and Psychiatry*. 2010; 51:905–914. DOI: 10.1111/j.1469-7610.2010.02232.x [PubMed: 20331490]
- Martel MM, Roberts B, Gremillion M, von Eye A, Nigg JT. External validation of bifactor model of ADHD: Explaining heterogeneity in psychiatric comorbidity, cognitive control, and personality trait profiles within DSM-IV ADHD. *Journal of abnormal Child Psychology*. 2011; 39:1111–1123. DOI: 10.1007/s10902-011-9538-y [PubMed: 21735050]
- McBurnett K, Villodas M, Burns LG, Hinshaw SP, Beaulieu A, Pfiffner LJ. Structure and validity of sluggish cognitive tempo using an expanded item pool in children with attention-deficit/hyperactivity disorder. *Journal of Abnormal Child Psychology*. 2014; 42:37–48. DOI: 10.1007/s10802-013-9801-5 [PubMed: 24258302]
- Molina BS, Smith BH, Pelham WE. Factor structure and criterion validity of secondary school teacher ratings of ADHD and ODD. *Journal of Abnormal Child Psychology*. 2001; 29:71–82. [PubMed: 11316336]

- Moruzzi S, Rijdsdijk F, Battaglia M. A twin study of the relationships among inattention, hyperactivity/impulsivity and sluggish cognitive tempo problems. *Journal of Abnormal Child Psychology*. 2014; 42:63–75. DOI: 10.1007/s10802-013-9725-0 [PubMed: 23435481]
- Muthén, LK., Muthén, BO. *Mplus user's guide*. 7th. Los Angeles, CA: Muthén & Muthén; 1998-2012.
- Normand S, Flora DB, Toplak ME, Tannock R. Evidence for a general ADHD factor from a longitudinal general school population study. *Journal of Abnormal Child Psychology*. 2012; 40:555–567. DOI: 10.1007/s10802-011-9584-5 [PubMed: 22033884]
- Penny AM, Waschbusch DA, Klein RM, Corkum P, Eskes G. Developing a measure of sluggish cognitive tempo for children: Content validity, factor structure, and reliability. *Psychological Assessment*. 2009; 21:380–389. [PubMed: 19719349]
- Skirbekk B, Hansen BH, Oerbeck B, Kristensen H. The relationship between sluggish cognitive tempo, subtypes of attention-deficit/hyperactivity disorder, and anxiety disorders. *Journal of Abnormal Child Psychology*. 2011; 39:513–525. [PubMed: 21331639]
- Smith LC, Tamm L, Hughes CW, Bernstein IH. Separate and overlapping relationships of inattention and hyperactivity/impulsivity in children and adolescents with attention-deficit/hyperactivity disorder. *Attention Deficit Hyperactivity Disorder*. 2013; 5:9–20. DOI: 10.1007/s12402-012-0091-5
- Toplak ME, Pitch A, Flora DB, Iwenofu L, Ghelani K, Jain U, Tannock R. The unity and diversity of inattention and hyperactivity/impulsivity in ADHD: evidence for a general factor with separable dimensions. *Journal of Abnormal Child Psychology*. 2009; 37:1137–1150. DOI: 10.1007/s10802-009-0336-y [PubMed: 19562477]
- Toplak ME, Sorge GB, Flora DB, Chen W, Banaschewski T, Buitelaar J, Faraone SV. The hierarchical factor model of ADHD: invariant across age and national groupings? *Journal of Child Psychology and Psychiatry*. 2012; 53:292–303. DOI: 10.1111/j.1469-7610.2011.02500.x [PubMed: 22084976]
- Ullebø AK, Breivik K, Gillberg C, Lundervold AJ, Posserud M. The factor structure of ADHD in a general population of primary school children. *The Journal of Child Psychology and Psychiatry*. 2012; 53:927–936. [PubMed: 22512532]
- Wahlstedt C, Bohlin G. DSM-IV-defined inattention and sluggish cognitive tempo: Independent and interactive relations to neuropsychological factors and comorbidity. *Child Neuropsychology*. 2010; 16:350–365. [PubMed: 20574866]
- Willcutt EG, Chhabildas N, Kinnear M, DeFries JC, Olson RK, Leopold DR, Keenan JM, Pennington BF. The internal and external validity of sluggish cognitive tempo and its relation with DSM-IV ADHD. *Journal of Abnormal Child Psychology*. 2014; 42:21–35. DOI: 10.1007/s10802-013-9800-6 [PubMed: 24122408]
- Willcutt EG, Nigg JT, Pennington BF, Solanto MV, Rohde LA, Tannock R, Lahey BB. Validity of DSM-IV attention deficit/hyperactivity disorder symptom dimensions and subtypes. *Journal of Abnormal Psychology*. 2012; 121:991–1010. DOI: 10.1037/a0027347 [PubMed: 22612200]
- Willoughby MT, Blanton ZE. Family Life Project Investigators. Replication and external validation of a bi-factor parameterization of attention deficit/hyperactivity symptomology. *Journal of Clinical Child & Adolescent Psychology*. 2014 0.1080/15374416.2013.850702.

Model 1. SCT items load onto the Inattention factor and ADHD and SCT items load onto ADHD g.

Model 2. SCT items load onto the SCT dimension and ADHD and SCT items load onto ADHD g.

Model 3. SCT items load onto a SCT factor which is independent from ADHD g, while Inattention and Hyperactivity/Impulsivity items load onto independent factors and ADHD g.

Supplemental Model 4. Model 3 allowing Inattention and Hyperactivity/Impulsivity to correlate with each other but not SCT.

Supplemental Model 5. Model 3 allowing Inattention with Hyperactivity/Impulsivity and Inattention with SCT to correlate with each other.

Figure 1.

Summary of hypothesized models of SCT and ADHD symptoms. Models 1-3 are orthogonal and Models 4 and 5 allow for correlations among factors based on literature and theory.

Note. ADHD = attention-deficit/hyperactivity disorder and SCT = sluggish cognitive tempo; SCT 3/4 = Parent report of SCT includes 3 items while teacher report of SCT includes 4 items.

Figure 2.

Teacher model 5. First item of each factor is set to 1 to set the scale for the factor. Dashed lines indicate $p > .05$.

Figure 3.

Parent model 5. First item of each factor is set to 1 to set the scale for the factor. Dashed lines indicate $p > .05$.

Table 1
Means and Standard Deviations of SCT and ADHD items

	Teacher		Parent	
	Mean	SD	Mean	SD
<i>SCT</i>				
Confused	0.77	0.8	0.53	0.69
Daydreams	1.23	0.76	1.11	0.79
Apathetic *	0.57	0.72	-	-
Stares	0.61	0.7	0.40	0.63
<i>Inattention</i>				
Close attention	1.99	0.85	2.18	0.78
Sustained effort	2.32	0.77	2.41	0.71
Listens	1.64	0.91	1.94	0.84
Follow through	1.84	0.95	2.14	0.80
Organization	1.99	0.92	2.04	0.90
Mental effort	1.66	0.93	1.93	0.94
Loses things	1.53	0.91	1.87	0.99
Distracted	2.41	0.77	2.57	0.69
Forgetful	1.76	0.89	2.01	0.87
<i>Hyperactivity/Impulsivity</i>				
Fidgets	1.81	1.04	2.05	0.99
Leaves seat	1.42	1.02	1.66	1.05
Runs, climbs	0.77	0.94	1.20	1.05
Plays quietly	0.94	0.91	1.14	0.91
Driven by motor	1.08	0.94	1.50	1.09
Talks a lot	1.64	1.06	1.73	1.05
Blurts	1.21	1.07	1.47	1.02
Waiting turn	1.14	1.07	1.56	1.00
Interrupts	1.34	1.02	1.92	0.97

Note. Range 0-3 for each item.

* Apathetic item is rated by teachers only.

Table 2

Fit Indices of Bi-factor Models for Teacher Report

	χ^2	DF	RMSEA	CFI	SRMR	χ^2	DF	p
<i>Orthogonal Models</i>								
Model 1: ADHD g, Specific Factors of IA/SCT, HI	469.877 ***	185	0.104	0.882	0.126			
Model 2: ADHD g, Specific Factors of IA, SCT, HI	473.592 ***	183	0.102	0.880	0.129			
Difference between Model 1 and Model 2						15.511	2	<0.000
Model 3: ADHD g, SCT, Specific Factors of IA and HI	451.147 ***	191	0.095	0.881	0.138			
Difference between Model 2 and Model 3						22.445	8	0.004
<i>Supplemental Analysis 1: Comparing Best Fitting Orthogonal Model to a Model Specific Factors Correlate with Each Other</i>								
Model 4	481.726 ***	186	0.102	0.886	0.138			
Difference between Model 3 and Model 4						30.579	5	<0.000
<i>Supplemental Analysis 2: Comparing Orthogonal Model to a Model with Specific Factors Correlating with Each Other and SCT</i>								
Model 5	308.830 ***	186	0.071	0.918	0.059			
Difference between Model 3 and Model 5						142.317	5	<0.000

Note. RMSEA = Root Mean Square Error of Approximation; CFI = Comparative Fit Index; SRMR = Standardized Root Means Square Residual; IA = Inattention; SCT = Sluggish Cognitive Tempo; HI = Hyperactivity/Impulsivity

 $p < .001$

Table 3

Fit Indices of Bi-factor Models for Parent Report

	χ^2	DF	RMSEA	CFI	SRMR	χ^2	DF	p
<i>Orthogonal Models</i>								
Model 1: ADHD g, Specific Factors of IA/SCT, HI	467.398***	165	0.104	0.825	0.097			
Model 2: ADHD g, Specific Factors of IA, SCT, HI	371.163***	164	0.087	0.880	0.089			
Difference between Model 1 and Model 2						96.235	1	<0.000
Model 3: ADHD g, SCT, Specific Factors of IA and HI	352.986***	167	0.081	0.892	0.102			
Difference between Model 2 and Model 3						18.177	3	0.0004
<i>Supplemental Analysis 1 Comparing Best Fitting Orthogonal Model to a Model Specific Factors Correlate with Each Other</i>								
Model 4	352.152***	170	0.080	0.895	0.101			
Difference between Model 3 and Model 4						0.834	3	0.8413
<i>Supplemental Analysis 2 Comparing Orthogonal Model to a Model with Specific Factors Correlating with Each Other and SCT</i>								
Model 5	308.830***	168	0.071	0.918	0.059			
Difference between Model 3 and Model 5						44.156	1	<0.000

Note. RMSEA = Root Mean Square Error of Approximation; CFI = Comparative Fit Index; SRMR = Standardized Root Means Square Residual; IA = Inattention; SCT = Sluggish Cognitive Tempo; HI = Hyperactivity/Impulsivity

p<.001