Research on Child and Adolescent Psychopathology (2021) 49:197–210
https://doi.org/10.1007/s10802-020-00728-2

Preschool Neuropsychological Predictors of School-aged Sluggish Cognitive Tempo and Inattentive Behaviors

Stephen P. Becker[1,2] · **Melissa R. Dvorsky**[3] · **Leanne Tamm**[1,2] · **Michael T. Willoughby**[4]

Accepted: 21 October 2020 / Published online: 28 December 2020

Abstract

Sluggish cognitive tempo (SCT) is characterized by excessive daydreaming, slowed thinking, and mental confusion and 'fogginess'. A growing body of research supports the empirical differentiation of sluggish cognitive tempo (SCT) from the inattentive (IN) behaviors that characterize attention-deficit/hyperactivity disorder (ADHD). Further SCT and IN are uniquely associated with clinical correlates across academic, social, and emotional domains; however, there is limited understanding of how neuropsychological functioning contributes to SCT and/or IN behaviors. The two broad domains of neuropsychological functioning that have been most frequently examined in relation to SCT behaviors are processing speed and executive functions (EF). The present study tested whether EF and processing speed measured when children were on average age five years were predictive of teacher-rated IN and SCT behaviors in 1st – 3rd grades. Participants included 1,022 children from the Family Life Project, an ongoing prospective longitudinal study of child development in low-income, non-metropolitan communities. EF and processing speed uniquely made independent contributions to the prediction of IN and SCT. In secondary analyses that focused on specific facets of EF and processing speed, inhibitory control and working memory abilities predicted lower IN but not SCT behaviors, whereas slower processing speed significantly predicted both greater SCT and IN behaviors. These results are discussed as they inform developmental models of SCT and IN.

Keywords ADHD · Executive function · Inattention · Neurocognition · Processing speed · Sluggish cognitive tempo

Introduction

Sluggish cognitive tempo (SCT) is characterized by excessive daydreaming, slowed thinking, and mental confusion and 'fogginess'. A growing body of research supports the empirical differentiation of SCT from the inattentive (IN) behaviors (e.g., easily distracted, makes careless mistakes, difficulty sustaining attention, failing to follow through on instructions) that characterize attention-deficit/hyperactivity disorder (ADHD) (Becker et al., 2016). Increasingly, researchers have turned to examining whether SCT and IN have unique clinical correlates across academic, social, and emotional domains (Barkley, 2014; Becker & Barkley, 2018). One domain that remains relatively understudied is neuropsychological task performance. Existing studies have reported mixed findings and been limited in a number of ways, including small sample sizes, reliance on samples of youth diagnosed with ADHD which may mask SCT-specific findings (Barkley, 2013, 2014), and/or using cross-sectional designs that cannot test developmental questions. The two broad domains of neuropsychological functioning that have been most frequently examined in relation to SCT behaviors are processing speed and executive functions (EF).

Historically, a key priority for SCT-related research has been to examine whether SCT behaviors are uniquely related to processing speed and EF above and beyond IN behaviors. This work has informed questions related to the external validity of the SCT construct as differentiated from

✉ Stephen P. Becker
stephen.becker@cchmc.org

✉ Michael T. Willoughby
mwilloughby@rti.org

[1] Division of Behavioral Medicine and Clinical Psychology, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, USA

[2] Department of Pediatrics, University of Cincinnati College of Medicine, Cincinnati, OH, USA

[3] Division of Psychology and Behavioral Health, Children's National Hospital, Washington, DC, USA

[4] Education and Workforce Development, RTI International, Research Triangle Park, NC, USA

IN. However, the primary focus on examining SCT and IN as differentially or uniquely related to neuropsychological functioning has left the reverse association almost entirely unexamined. That is, it is unknown whether neuropsychological functioning uniquely or differentially predicts SCT and IN behaviors. This is important to consider as the failure of children to develop effective EF has been proposed as a putative cause of ADHD symptoms (Brocki, Nyberg, Thorell, & Bohlin, 2007; Halperin, 2011; Nigg, Willcutt, Doyle, & Sonuga-Barke, 2005; Sonuga-Barke, 2005). Specifically, disruptions in the executive circuit (i.e., thalamo-cortico-striatal) of the brain are thought to lead to cognitive dysfunction (i.e., inhibitory and EF deficits) which then manifest at the symptom level (Sonuga-Barke, 2005). Further, overall efficiency of information processing (indexed by processing speed) is implicated in the processes involved in the distribution of effort (i.e., cognitive–energetic resources) to activation and arousal systems that are required to meet the changing demands of different situations and settings and that appear to be disrupted in ADHD (Sergeant, 2005). Although this model has not been investigated in SCT, we argue that SCT, which is believed to be characterized by low arousal and under-activation and frequently co-occurs with ADHD (Becker & Willcutt, 2019), may itself be associated with processing speed and EF deficits. Examining these constructs as longitudinal predictors of behavior may further elucidate unique associations between EF and processing speed and SCT and IN. Here, we test the unique contributions of processing speed and EF, measured in early childhood, as predictors of SCT and IN behaviors in early elementary school. Given the absence of research examining neuropsychological functioning as a predictor of both SCT and IN behaviors, we built our hypotheses based on studies that examined unique associations between SCT and IN behaviors with processing speed and EF.

Associations between SCT and IN Behaviors with Processing Speed

Given the term ‘sluggish cognitive tempo,’ it is often assumed that SCT reflects, at least in part, slowed processing speed. However, it is not clear that this is indeed the case, with extant studies reporting mixed findings. When examining SCT and IN as independent variables, two studies failed to find SCT behaviors to be uniquely cross-sectionally (Bauermeister, Barkley, Bauermeister, Martinez, & McBurnett, 2012) or longitudinally (Becker, Burns, Leopold, Olson, & Willcutt, 2018) associated with slower processing speed.

Other studies have found greater SCT behaviors to be uniquely associated with slower processing speed, above and beyond ADHD behaviors (Becker, Marsh, Holdaway, & Tamm, 2020; Willcutt et al., 2014). There is also some indication that the association between SCT behaviors and slowed processing speed may be especially strong in younger children. In a sample of 61 four-year-old children at-risk for ADHD, Tamm and colleagues found teacher-reported SCT behaviors, but not IN behaviors, to be uniquely associated with slower processing speed (Tamm, Brenner, Bamberger, & Becker, 2018). As more direct evidence of possible developmental differences, Jacobson, Geist, and Mahone (2018) found the association between SCT and processing speed to be moderated by age. Specifically, in a sample of 566 clinically referred children, SCT daydreamy behaviors were significantly associated with slower processing speed in younger children (ages 6–9 years) but not in older children (ages 10–16 years). This finding was unchanged when IN behaviors were included in the model, though IN behaviors were also significantly associated with slower processing speed (Jacobson, Geist, & Mahone, 2018). Consistent with these studies, we hypothesized that slower processing speed would be associated with both IN and SCT behaviors in early childhood.

Associations between SCT and IN Behaviors with Executive Functions (EF)

EF refer to high-level cognitive processes that regulate one’s thoughts and behaviors (Miyake & Friedman, 2012). There has been longstanding interest in how EFs relate to, or underpin, ADHD symptoms (Barkley, 1997; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Although there is substantial heterogeneity in the EF of individuals with ADHD (Kofler, Irwin, Sarver, et al., 2019; Kofler, Irwin, Soto, et al., 2019; Willcutt et al., 2005), and associations may not be as strong as initially believed (Willoughby, Wylie, & Blair, 2019), there is clear evidence that IN behaviors are associated with poorer performance across EF measures of response inhibition, working memory, and set shifting (Willcutt et al., 2012).

It is far less clear if SCT behaviors are uniquely associated with EF skills. We are not aware of any study that has used a composite measure of EF to examine associations with SCT behaviors, and those studies examining SCT and IN behaviors in relation to individual EF components have generally not found unique associations for SCT in relation to either set shifting (Tamm et al., 2018) or working memory (Bauermeister et al., 2012; Skirbekk, Hansen, Oerbeck, & Kristensen, 2011; Tamm et al., 2018; Wåhlstedt & Bohlin, 2010; Willcutt et al., 2014).

In considering inhibition, findings are mixed. Two studies failed to find a unique association between SCT behaviors and inhibition (Wåhlstedt & Bohlin, 2010; Willcutt et al., 2014). In contrast, a study of preschool children found teacher-rated SCT behaviors to be positively associated with errors of commission (an index of disinhibition or impulsivity), whereas no association was found when parent-rated SCT behaviors were examined (Tamm et al., 2018). Given the generally nonsignificant findings among studies examining SCT and inhibition, we did not expect inhibition skills to be uniquely associated with SCT behaviors. In contrast, we expected poorer broad EF skills, as well as the specific shifting, working memory, and inhibition skills, to be uniquely associated with greater IN behaviors.

Neuropsychological Domains as Unique Predictors of SCT and IN

As noted above, most studies to date have used SCT and IN behaviors as independent variables to examine unique relations of these constructs in relation to neuropsychological performance. Thus, these studies cannot speak to whether broad or specific neuropsychological functioning domains uniquely or differentially relate to SCT and IN behaviors. Remarkably few studies have directly tested processing speed and EF as correlated predictors of SCT and IN behaviors.

We are aware of only one study that has examined whether specific neuropsychological performance domains are uniquely associated with SCT behaviors. In a sample of 132 children (ages 8–13) with and without ADHD, Kofler and colleagues (Kofler, Irwin, Soto, et al., 2019) examined processing speed indicators, in addition to speeded performance in inhibitory control, working memory manipulation, and set shifting, as unique predictors of parent- and teacher-reported SCT behaviors. The investigators found that global information processing speed was not related to SCT behaviors. In contrast, slower working memory manipulation speed was uniquely associated with both parent- and teacher-rated SCT behaviors. Finally, faster inhibition speed (or overinhibition) was also uniquely associated with higher parent-reported SCT behaviors, though no association was found when teacher-rated SCT behaviors were examined. Importantly, the pattern of findings was unchanged when controlling for IN behaviors and intelligence (Kofler, Irwin, Sarver, et al., 2019; Kofler, Irwin, Soto, et al., 2019).

Although Kofler, Irwin, Soto et al. (2019) examined whether neuropsychological domains were *uniquely* associated with SCT behaviors, they included IN behaviors as a covariate and therefore could not examine whether neuropsychological domains were *differentially* associated with SCT or IN behaviors. We examine both unique and differential associations in the present study to examine not only whether broad or specific neuropsychological functioning domains predicted SCT behaviors but also whether neuropsychological functioning domains were differentially related to SCT or IN.

The Need for Longitudinal Research Spanning Early Childhood to School-age

Almost all studies examining neuropsychological correlates of SCT behaviors have used a cross-sectional design. One study has examined SCT and IN behaviors as predictors of later processing speed (Becker et al., 2018). We are not aware of any study that has considered the reverse association whereby neuropsychological function predicts subsequent SCT *and* IN behaviors. This is especially important given interest in the extent to which neuropsychological brain function underlies or contributes to SCT and/or IN behaviors (Barkley, 2014), and research showing neuropsychological performance in early childhood is associated with future ADHD severity (Rajendran, Rindskopf, O'Neill, et al., 2013; Rajendran, Trampush, Rindskopf, et al., 2013). Examining neuropsychological performance as predictors of SCT and IN in early childhood is a particular research priority, as findings may inform developmental models of these behaviors (Becker & Barkley, 2018) and point to possible directions for prevention and intervention (Diamond, 2016).

Current Study

The goal of this study was to examine the associations between broad and specific neurocognitive processes with subsequent IN and SCT behaviors in using a longitudinal sample of U.S. children from non-urban settings. Teacher ratings of SCT were used in the present study since there is some indication that teachers may be especially able to distinguish IN and SCT behaviors (Burns, Becker, Servera, Bernad, & Garcia-Banda, 2017; Garner, Marceaux, Mrug, Patterson, & Hodgens, 2010; McBurnett, Pfiffner, & Frick, 2001).

Our primary analyses examined overall processing speed and EF skills assessed at preschool age as predictors of IN and SCT behaviors as rated by teachers in first, second, and third grades. In addition, given some evidence that working memory and processing speed tasks with greater motor demands may be more clearly associated with SCT behaviors (Becker et al., 2020; Hinshaw, Carte, Sami, Treuting, & Zupan, 2002; Kofler, Irwin, Sarver, et al., 2019; Kofler, Irwin, Soto, et al., 2019), we conducted secondary analyses examining the specific processing speed subtests (i.e., coding, symbol search) and EF components (i.e., inhibitory control, working memory, and attention shifting) predicting later IN and SCT behaviors. In both cases, we were interested in (1) whether neurocognitive function domains assessed in early childhood *uniquely* predicted IN and SCT behaviors in early elementary school (grades 1–3), and (2) whether neurocognitive function was *differentially* associated with later IN or SCT behaviors. We hypothesized that slower processing speed assessed in early childhood would significantly uniquely predict both increased IN and SCT behaviors in early childhood, whereas poorer EF performance assessed in early childhood would significantly predict increased IN but not SCT behaviors. Based on recent research (Becker et al., 2020), for the secondary analyses we further hypothesized that coding subscale would be uniquely associated with SCT behaviors.

Methods

Participants and Procedures

The Family Life Project was designed to study young children and their families who lived in two of the four major geographical areas of the United States, east of the Mississippi river, with high poverty rates (Dill, 2001). Specifically, three counties were in Eastern North Carolina and three counties in Central Pennsylvania were selected to be indicative of the Black South and Appalachia, respectively, with participants identifying as African American or White. The Family Life Project adopted a developmental epidemiological design in which complex sampling procedures were employed to recruit a representative sample of 1,292 children whose families resided in one of the six counties at the time of the child's birth. Low-income families in both states and, in Eastern North Carolina, African American families, were oversampled; however, using weighted analyses, all inferences generalize back to the six-county study area as if participants were selected using simple random sampling. Detailed information on the study design and sampling plan are detailed elsewhere (Vernon-Feagans et al., 2013).

This study was approved by the University of North Carolina at Chapel Hill Institutional Review Board (IRB). Following hospital screening, participants who were selected and consented to participate completed up to eight home visits when target children ranged from two months to approximately seven years of age (during a first-grade visit). At each visit, parents and children completed a variety of standardized tasks, observational procedures, interviews, and questionnaires. Information was also collected from children at up to five school visits that began with a pre-kindergarten (pre-K) visit and that continued throughout elementary school. The EF and processing speed measures that were used as focal predictors in this study were obtained at the age 5-year home visit (child ages $M = 5.0$, $SD = 0.3$, Range = 4.7 to 6.2 years) and pre-K school visit ($M = 5.0$, $SD = 0.3$, Range = 4.4 to 5.9 years), respectively. Although on average the age 5 home visit and pre-K visits occurred close in time ($M = 0.0$ years, $SD = 0.4$), there was variation that resulted from scheduling challenges with families and preschools whereby in some instances the home visit occurred first and in other instances the pre-K visit occurred first (Range = -1.6 to 0.8 years apart). SCT and IN ratings that were used as primary outcomes were obtained from teacher ratings that were completed in the spring of the 1st, 2nd, and 3rd grade years.

Analytic sample. Of the 1,292 children whose families were enrolled in the main study, 1,022 were included in the current study based on having at least one of the processing speed, EF, or receptive language predictors and teacher-rated IN or SCT behavior data at 1st, 2nd, or 3rd grade assessments. Participating children ($N = 1{,}022$) included 511 (50.0%) males, 443 (43.3%) identified as African American with remaining participants identifying as White, 421 (41.2%) were recruited from Central Pennsylvania, 821 (80.3%) of primary caregivers had a high school degree. Participating families had a family income-to-needs ratio ranging from 0.00 to 20.89 across waves, $M = 1.84$ ($SD = 1.40$), which was used to index household poverty and 794 (77.7%) were recruited into the poor strata for analyses. Participating children and families ($N = 1{,}022$) did not differ from nonparticipating children and families ($N = 270$) with respect to recruitment state (41% vs. 36% from Pennsylvania, $p = 0.14$), recruitment into the poor strata (78% vs. 77% poor, $p = 0.82$), race (43% vs. 40% African American, $p = 0.27$), sex (50% vs. 54% male, $p = 0.23$), or primary caregiver education (80% vs. 80% had high school degree, $p = 0.79$).

Measures

IN and SCT behaviors. Following precedent (Pelham, Evans, Gnagy, & Greenslade, 1992), nine DSM-IV (American Psychiatric Association, 1994) IN behaviors were rated by teachers using a four-point scale (0 = *not at all*, 1 = *just a little*, 2 = *pretty much,* 3 = *very much*). Using the same four-point scale, four additional items that represented SCT behaviors were also rated (i.e., daydreams; is sluggish, slow moving or lacks energy; is apathetic or unmotivated; seems in a "fog"). The selection of SCT items was inspired by the literature at the time data collection decisions were made (Carlson & Mann, 2002; McBurnett et al., 2001; Todd, Rasmussen, Wood, Levy, & Hay, 2004). The current study focuses on these 13 items (i.e., the nine DSM ADHD IN items plus the four SCT items) that were completed by teachers in the spring of 1st, 2nd, and 3rd grade years. Previous analyses have demonstrated that the IN and SCT behaviors used in this study are distinct constructs in this sample (Dvorsky, Becker, Tamm, & Willoughby, 2019). Alphas for the nine IN items (ranges 0.931-0.955) and four

SCT items (ranges 0.862-0.882) were adequate. Missing data was generally low; 85 (8.3%) had a teacher rating at 1 time point, 286 (28.0%) had a teacher rating at 2 time points, and 651 (63.7%) had a teacher rating at all time points.

Executive functions. Child neurocognitive skills were measured at the age 5 home visit using an EF battery that consisted of six tasks. Full details including task administration protocols and psychometric properties of each task are provided elsewhere (Willoughby, Blair, Wirth, & Greenberg, 2010; Willoughby, Blair, Wirth, Greenberg, & The Family Life Project Investigators, 2012). Consistent with recent work in this sample (Ribner, Willoughby, Blair, & Family Life Project Key Investigators, 2017; Willoughby et al., 2019), we created composite scores that reflected the average performance across item response theory generated scores for each task. The overall EF composite reflected average performance across all six tasks, while the inhibitory control and working memory composites reflected average performance across three and two tasks, respectively. Because the battery only included a single attention shifting task, this score was used alone. Abbreviated task descriptions appear below.

Inhibitory control. Three tasks measured inhibitory control: (a) *the silly sounds Stroop, (b) spatial conflict arrows,* and *(c) animal go/no-go.* The *silly sounds Stroop* task was modeled after the Day–Night Stroop task. Children were asked to make the sound opposite of that associated with pictures of dogs and cats (e.g., meow when shown a picture of a dog). For the *spatial conflict arrows* task children were given two response cards ("buttons") and were instructed to touch the card consistent with the direction in which an arrow presented on the flipbook page was pointing. Training trials presented compatible images on the same side, and test trials presented arrows contralateral to the correct response (e.g., an arrow pointing right was presented on the left side). The *animal go/no-go* task is a standard go no-go task in which children were instructed to push a button (which emitted a sound) whenever they saw an animal appear, except when the animal was a pig. The number of go-trials before a no-go trial varied, in a standard order of 1-go, 3-go, 3-go, 5-go, 1-go, 1-go, and 3-go trials.

Working memory. A *working memory span* task and *pick the picture game* task were used to measure working memory. For the *working memory span* task children were shown a line drawing of an animal and a color inside an image of a house and asked to keep both the animal and the color in mind, and to recall one of them (e.g., animal name) when prompted. Task difficulty increased by adding items to successive trials: Children received one 1-house trial, two 2-house trials, two 3-house trials, and two 4-house trials. Responses were summarized as the number of items answered correctly within each item set. The pick the picture game task is a self-ordered pointing task in which children were presented with a series of 2, 3, 4, and 6 pictures and instructed to continue picking pictures until each picture had "received a turn." Children are presented with successive pages in which the set of pictures within an item set is re-ordered. The ordering of pictures within each item set is randomly changed (including some trials not changing) so that spatial location is not informative. This task requires working memory because children have to remember which pictures in each item set they have already touched.

Attention shifting. The *something's the same* game task was used to assess attention shifting. Children were shown two pictures that were similar on a single criterion (e.g., the same color; the same size), and were then shown a third picture, similar to one of the first two pictures along a second dimension of similarity (e.g., shape). Participants were asked to identify which of the first two pictures was the same as the new picture.

Processing speed. Children's processing speed ability was measured at the pre-K school visit using two subscales of the *Wechsler Preschool and Primary Scales of Intelligence – Third Edition* (WPPSI-III; Wechsler, 2002): (1) *coding,* and (2) *symbol search*. The *symbol search* subtest asks participants to scan a group as quickly as possible and indicate whether a target symbol matches any symbols in the group. The *coding* subtest asks participants to match symbols with geometric shapes, and to reproduce the geometric shapes corresponding to the appropriate symbols. In the normative sample, these two subtests loaded strongly on a processing speed factor (*coding* and *symbol search* loaded 0.61 and 0.78 among children ages 4.0–4.11 years), are strongly correlated with each other ($r = 0.67$ among children ages 4.0–4.5 years), and demonstrate acceptable test–retest reliability [0.88 for *coding* and 0.86 for *symbol search* over a 14 to 50 day ($M = 26$ days) period in children ages 4.0–5.5 years] (Wechsler, 2002). In the present study, a composite measure of processing speed was calculated by averaging the scale scores across the two tasks.

Receptive vocabulary. The *Peabody Picture Vocabulary Test, Fourth Edition* (Dunn & Dunn, 2007), a norm-referenced instrument, was used to measure receptive vocabulary at the pre-K school visit. Receptive vocabulary has been established as a broad indicator of cognitive function that is also an important indicator of children's cognitive and behavioral development (Chow & Wehby, 2018; Petersen, Bates, & Staples, 2015) and served as a covariate in the present study.

Demographic covariates. Our analyses also included a range of early childhood individual and environmental characteristics and experiences as predictors of associations between neurocognitive processes and IN and SCT behaviors. Child background factors included sex (male = 1) and race (African American = 1 vs. non-Hispanic White). Parent/family background factors including family's income-to-needs ratio and state of residence (Pennsylvania = 1 vs. North Carolina). Family's income-to-needs ratio was averaged across 6, 15, 24, 36, and 48-month assessments (i.e., prior to the measurement of our focal predictors) and used to index household poverty.

Analysis Plan

We estimated a series of structural equation models to test whether performance-based measures of children's EF and processing speed skills at age 5 were uniquely and/or differentially related to teacher-rated IN and SCT behaviors. Consistent with our earlier work in this sample (Dvorsky, Becker, Tamm, & Willoughby, 2019), IN and SCT were represented as two correlated latent variables that were comprised of teacher ratings at the 1st-, 2nd-, and/or 3rd-grade assessments (1st grade ratings were used as scaling indicators for both latent variables).

In our primary analyses, we investigated whether aggregate measures of EF and processing speed were differentially and/or uniquely related to IN and SCT behaviors. In secondary analyses, we investigated whether specific facets of EF and processing speed were differentially and/or uniquely related to IN and SCT behaviors. Sex, race, family income-to-needs ratio, and state of residence were included as covariates in all models. In addition, similar to Kofler et al. (Kofler, Irwin, Sarver, et al., 2019; Kofler, Irwin, Soto, et al., 2019), receptive language was also included as a covariate as an index of broad cognitive ability that is itself also associated with children's self-regulation and behavior problems (Chow & Wehby, 2018; Petersen et al., 2015).

Primary and secondary analyses followed the same approach. Specifically, we fit a sequence of models that either freely estimated or imposed equality constraints on the coefficients that related each cognitive predictor (e.g., EF, processing speed) to IN and SCT outcomes. Satorra-Bentler chi-square difference tests were used to determine the best fitting model and directly informed our questions about whether each cognitive predictor was differentially related to IN and SCT (i.e., if parameter constraints resulted in a worse fitting model, it indicated that a given predictor was differentially related to IN and SCT). We also examined information criteria (Akaike information criteria [AIC], Bayesian information criteria [BIC]) when determining which model specification provided the best fit to the observed data. For AIC and BIC, the smallest value overall represents the best fit of the hypothesized model (Byrne, 2012). Global model fit was examined using the comparative fit index (CFI) and root mean squared error of approximation (RMSEA). CFI values of 0.95 and higher and RMSEA values of 0.06 and lower are indicative of good fit (Hu & Bentler, 1999). Likelihood ratio tests, expressed as a χ^2 statistic, were used for model comparisons, with nonsignificant change in χ^2 representing equivalence (i.e., invariance) supporting retaining the model constraint (Byrne, 2012). Once the best fitting overall model was identified (i.e., the model that took into account parameter constraints for the full set of cognitive predictors), we evaluated the statistical significance of individual predictors to inform questions about the unique contributions of EF and processing speed to IN and SCT. All models were fit using a robust full-information maximum-likelihood estimator that took into account the complex sampling design and accommodated missing data, which is consistent with best practice (Schafer & Graham, 2002). All models were estimated using Mplus version 8.3 (Muthén & Muthén, 1998–2019).

Results

Descriptive Statistics and Correlations

Descriptive statistics and intercorrelations for children's neurocognitive composite and specific scores and teacher-reported IN and SCT behaviors are provided in Table 1. The across-time correlations for IN ratings were large (rs = 0.53 to 0.66, ps < 0.001) and for SCT were moderate (rs = 0.34 to 0.44, ps < 0.001). The within-time associations between IN and SCT (rs = 0.70, 0.72, and 0.72 for the 1st-, 2nd-, and 3rd-grade assessments, respectively, all ps < 0.001) were consistent with previous analyses involving this sample (Dvorsky et al., 2019). Bivariate associations between neurocognitive predictors with IN were moderate (rs = -0.19 to -0.39, ps < 0.001) and low to moderate for SCT (rs = -0.12 to -0.27, ps < 0.001). The EF and processing speed composite variables were moderately correlated (r = 0.37, p < 0.001), with significant intercorrelations also present among the specific neurocognitive variables (rs = 0.19 to 0.28, ps < 0.001).

Primary Analyses: Contributions of Processing Speed and EF to IN and SCT

Are processing speed and EF differentially related to IN and SCT? A synopsis of global model fit, information criteria, and likelihood ratio tests that were used for model comparisons for the broad neurocognitive composites are displayed in Table 2. First, we estimated a baseline model (Model 1) in which all parameters were freely estimated, and this model fit the data well; see Table 2. The unconstrained model was then compared to models in which the neurocognitive composite variables were constrained to be equal across IN and SCT. Constraining all neurocognitive composites resulted in a significant decrease in fit, SB$\Delta\chi^2(4) = 79.15$, $p < 0.001$, and this constraint was

Table 1 Intercorrelations and descriptive statistics

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. IN (Grade 1)	–	0.66***	0.53***	0.70***	0.48***	0.38***	-0.35***	-0.32***	-0.27***	-0.29***	-0.36***	-0.29***	-0.28***	-0.19***	0.23***	0.18***	0.23***	-0.10**
2. IN (Grade 2)			0.63***	0.39***	0.72***	0.41***	-0.33***	-0.32***	-0.29***	-0.28***	-0.35***	-0.25***	-0.31***	-0.19***	0.25***	0.12**	0.24***	-0.07*
3. IN (Grade 3)				0.32***	0.45***	0.72***	-0.39***	-0.36***	-0.33***	-0.32***	-0.37***	-0.29***	-0.29***	-0.23***	0.25***	0.21***	0.24***	-0.19***
4. SCT (Grade 1)					0.44***	0.34***	-0.18***	-0.20***	-0.16***	-0.20***	-0.20***	-0.14***	-0.16***	-0.13***	0.16***	0.04	0.13***	0.01
5. SCT (Grade 2)						0.41***	-0.21***	-0.27***	-0.23***	-0.23***	-0.24***	-0.18***	-0.20***	-0.12***	0.18***	0.03	0.17***	-0.02
6. SCT (Grade 3)							-0.25***	-0.29***	-0.24***	-0.27***	-0.23***	-0.18***	-0.17***	-0.15***	0.16***	0.12**	0.15***	-0.14***
7. RL								0.42***	0.34***	0.42***	0.53***	0.39***	0.39***	0.39***	-0.40***	-0.44***	-0.05	0.36***
8. PS Comp									0.89***	0.87***	0.37***	0.25***	0.31***	0.23***	-0.26***	-0.17***	-0.18***	0.17***
9. Coding										0.53***	0.33***	0.22***	0.28***	0.19***	-0.18***	-0.10**	-0.22***	0.09*
10. Sym. Search											0.33***	0.22***	0.25***	0.23***	-0.28***	-0.20***	-0.09*	0.21***
11. EF Comp												0.81***	0.73***	0.58***	-0.27***	-0.28***	-0.12***	0.24***
12. Inhibition													0.34***	0.20***	-0.18***	-0.17***	-0.13***	0.14***
13. WM														0.24***	-0.20***	-0.16***	-0.09**	0.11**
14. Shifting															-0.24***	-0.32***	0.01	0.33***
15. SES																0.36**	-0.03	-0.25***
16. African Am																	0.01	-0.65***
17. Male																		0.07*
18. Pennsylvania																		–
N	895	897	818	895	897	818	948	858	849	785	995	995	992	992	1022	1022	1022	1022
M	0.77	0.80	0.80	0.50	0.54	0.55	94.02	95.98	96.24	96.43	0.30	0.35	0.29	0.17	0.78	0.43	0.50	0.41
SD	0.84	0.83	0.79	0.72	0.70	0.70	15.86	12.57	14.24	14.00	0.46	0.55	0.63	0.95	0.42	0.50	0.50	0.49

EF scores were assessed at age 5 home visit and represent Item Response Theory (IRT)-based scores that are on a common developmental scale which has a mean of 0 and a standard deviation of 1. Processing speed scores were assessed at the pre-Kindergarten school visit *IN* inattention, *SCT* sluggish cognitive tempo, *RL* receptive language, *PS* processing speed, *Sym* symbol, *WM* working memory, *SES* income-to-needs ratio, *Am* american, *EF* executive function, *Comp* composite

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Table 2 Summary of model fit statistics and model comparisons for the broad neurocognitive composites

	Model	Model fit statistics					Model Comparisons		
		AIC	BIC	χ^2 (df)	CFI	RMSEA (90% CI)	Comparing models	Satorra-Bentler $\Delta\chi^2$	Decision
1.	Unconstrained	31,059.881	31,409.877	56.863 (37)*	0.991	0.027 (0.014, 0.038)	–	–	–
2.	Constrained PS	31,060.366	31,405.432	59.136 (34)**	0.990	0.027 (0.015, 0.038)	1 vs. 3	2.414 (1)	**Retain**
3.	Constrained EF	31,087.435	31,432.501	80.531 (34)***	0.982	0.037 (0.026, 0.047)	1 vs. 4	38.465 (1)***	*Reject*
Final	**Constrained PS**	**31,060.366**	**31,405.432**	**59.136 (34)****	**0.990**	**0.027 (0.015, 0.038)**	–	–	–

AIC akaike information criteria, *BIC* bayesian information criteria, *CFI* comparative fit index, *CI* confidence interval, *RMSEA* root mean squared error of approximate, *RL* receptive language, *PS* processing speed, *EF* executive functioning. Covariates included in every model are family income-to-needs ratio, state (Pennsylvania or North Carolina), child sex, and child race (African American or White)

$*p<0.05$; $**p<0.01$; $***p<0.001$

rejected. We then imposed equality constraints for each of the neurocognitive variables separately. Imposing constraints on EF (Model 3) resulted in a significant decrease in model fit (SB$\Delta\chi^2(1)=38.47$ $p<0.001$), and the constraint was rejected. Imposing constraints on processing speed (Model 2) did not result in a decrease in model fit, SB$\Delta\chi^2(1)=2.41$, $p=0.120$, and the constraint was retained. In addition to consideration of nested likelihood ratio tests, the information criteria also identified Model 2 as providing the best fit to the observed data (see Table 2 for a synopsis of all model fit and comparisons).

Are processing speed and EF uniquely related to IN and SCT? We found that processing speed and EF skills were significantly negatively associated with both IN and SCT (see Table 3). Given the imposed equality constraint for the unstandardized coefficients for processing speed for IN and SCT, the findings represent that processing speed is similarly associated with IN and SCT (Bs = -0.01, $p<0.001$). Conversely, although EF skills were significantly associated with both IN (B = -0.36, $p<0.001$) and SCT (B = -0.16, $p=0.004$), the magnitude of the association was stronger for IN than for SCT. Receptive language was associated with IN (B = -0.01, $p<0.001$) but not SCT (B = -0.003, $p=0.077$). Family income-to-needs and child sex (male) were significantly associated with both IN and SCT.

Secondary Analyses: Contributions of Specific Processing Speed and EF Domains to IN and SCT

To explore the association for specific domains of neurocognitive functioning, we re-estimated all models substituting global with specific measures of processing speed (i.e., *coding, symbol search*) and EF skills (i.e., *inhibitory control, working memory, attention shifting*). First, we estimated a baseline model in which all parameters were freely estimated, and this model fit the data well (see Table 4; Model 1). The unconstrained model was then compared to models in which the neurocognitive variables (individually) were constrained to be equal across IN

Table 3 Standardized Path Estimates in Final Model of Broad Neurocognitive Composites Predicting Inattention (IN) and Sluggish Cognitive Tempo (SCT) Behaviors

	Teacher-Rated IN					Teacher-Rated SCT				
Predictor	B	SE	β	SE	*p*-value	B	SE	β	SE	*p*-value
PS Composite	**-0.010**	**0.002**	**-0.202**	**0.036**	**< 0.001**	**-0.010**	**0.002**	**-0.270**	**0.045**	**< 0.001**
EF Composite	**-364**	**0.060**	**-0.263**[a]	**0.041**	**< 0.001**	**-0.163**	**0.057**	**-0.157***	**0.055**	**0.004**
Receptive Language	**-0.008**	**0.002**	**-0.193**	**0.041**	**< 0.001**	**-0.003**	**0.002**	**-0.092**	**0.052**	**0.077**
Income-to-Needs Ratio	**-0.033**	**0.013**	**-0.084**	**0.032**	**0.011**	**-0.038**	**0.013**	**-0.131**	**0.040**	**0.002**
African American	0.003	0.057	0.002	0.039	0.960	-0.067	0.052	-0.061	0.047	0.200
Male	**0.205**	**0.042**	**0.166**	**0.033**	**< 0.001**	**0.117**	**0.037**	**0.126**	**0.039**	**0.001**
Pennsylvania	0.043	0.052	0.034	0.040	0.402	0.032	0.047	0.033	0.049	0.503

Final model with equality constraints imposed on the unstandardized coefficients for processing speed: $\chi^2(34)=59.136$, $p=0.005$, CFI = 0.990, RMSEA = 0.027 (CI: 0.015, 0.038) Unstandardized (B) and standardized (β) path estimates are reported here and unstandardized path estimates are reported in text *PS* processing speed, *EF* executive function. [a]Represent significantly different path coefficients for a given construct in predicting inattention relative to sluggish cognitive tempo behaviors

Table 4 Summary of model fit statistics and model comparisons for the specific neurocognitive domains

		Model fit statistics					Model Comparisons		
	Model	AIC	BIC	χ2 (df)	CFI	RMSEA (90% CI)	Comparing models	Satorra-Bentler $\Delta\chi^2$	Decision
1.	Unconstrained	42,292.227	42,819.686	71.921 (45)**	0.990	0.024 (0.013, 0.034)	–	–	–
2.	Constrained Coding	42,293.895	42,816.424	74.824 (46)**	0.989	0.025 (0.014, 0.035)	6 vs. 7	2.917 (1)	**Retain**
3.	Constrained Symbol Search	42,290.295	42,812.824	71.817 (46)**	0.990	0.023 (0.012, 0.034)	6 vs. 8	0.049 (1)	**Retain**
4.	Constrained Inhibition	42,298.385	42,820.913	78.527 (46)**	0.988	0.026 (0.016, 0.036)	6 vs. 9	7.202 (1)***	*Reject*
5.	Constrained Working Memory	42,305.827	42,828.355	84.351 (46)***	0.986	0.029 (0.019, 0.038)	6 vs. 10	13.347(1)***	*Reject*
6.	Constrained Attention Shifting	42,291.286	42,813.815	73.246 (46)**	0.990	0.024 (0.013, 0.034)	6 vs. 11	1.206 (1)	**Retain**
7.	**Final Constrained Coding, Symbol Search, and Attention Shifting**	**42,291.727**	**42,804.397**	**76.847 (48)****	**0.989**	**0.024 (0.013, 0.034)**	–	–	–

AIC akaike information criteria, *BIC* bayesian information criteria, *CFI* comparative fit index, *CI* confidence interval, *RMSEA* root mean squared error of approximate. Covariates included in every model are family income-to-needs ratio, state (Pennsylvania or North Carolina), child sex, and child race (African American or White)

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

and SCT. None of the constraints on coding (Model 2; SB$\Delta\chi^2$(1) = 2.917, $p = 0.088$), symbol search (Model 3; SB$\Delta\chi^2$(1) = 0.05, $p = 0.825$), or attention shifting (Model 6; SB$\Delta\chi^2$(1) = 1.21, $p = 0.272$) resulted in a degradation of model fit and all constraints were retained. However, the constraints on inhibitory control (Model 4) and working memory (Model 5) did result in significant decreases in model fit (SB$\Delta\chi^2$ (1) = 7.20 $p < 0.001$, and SB$\Delta\chi^2$ (1) = 13.35, $p < 0.001$, respectively) and were not retained. In addition to consideration of nested likelihood ratio tests, information criteria also identified Model 7 (with constraints held for coding, symbol search, and attention shifting) as providing the best fit to the observed data (see Table 4 for a synopsis of model fit and comparisons).

Are specific components of processing speed and EF uniquely related to IN and SCT? When examining specific neurocognitive processes separately, all neurocognitive variables were negatively associated with both IN and SCT (see Table 5). Given the imposed equality constraint for the unstandardized coefficients for *coding* (Bs = -0.003, $p = 0.047$), *symbol search* (Bs = -0.007, $p = 0.001$), and *attention shifting* (Bs = -0.030, $p = 0.192$) to IN and SCT, these findings demonstrate that these processes are similarly associated with IN and SCT. Inhibitory control and working memory were more strongly associated with IN (Bs = -0.15 to -0.17, *p*s < 0.001) than with SCT (B = -0.06 to -0.06, *p*s > 0.070). In terms of covariates, receptive language was again negatively associated with IN (B = -0.01, $p < 0.001$) but not SCT (B = -0.003, $p = 0.108$). Similar to the composite model, family income-to-needs and child sex (male) were significantly associated with both IN and SCT.

Discussion

This is the first longitudinal study examining neuropsychological predictors of SCT *and* IN behaviors. Specifically, we examined processing speed and EF assessed prior to 1st grade as predictors of teacher-reported SCT and IN behaviors across 1st-3rd grades. Our findings provide the first evidence that processing speed and EF predict later SCT and IN behaviors, and an examination of specific facets of processing speed and EF showed differential associations with these behaviors.

Slower processing speed in early childhood significantly predicted greater teacher reported SCT and IN behaviors in early elementary school. Further, the magnitude of the prospective associations was similar for SCT and IN. These findings indicate that processing speed does not more strongly predict SCT or IN but rather is a nonspecific predictor of these behaviors. The literature examining processing speed and SCT behaviors has yielded mixed findings to date.

Table 5 Unstandardized and standardized path estimates in final model of specific neurocognitive domains predicting inattention (IN) and sluggish cognitive tempo (SCT) behaviors

	Teacher-Rated IN					Teacher-Rated SCT				
Predictor	B	SE	*β*	SE	*p*-value	B	SE	*β*	SE	*p*-value
Coding	**-0.003**	**0.002**	**-0.081**	**0.041**	**0.050**	**-0.003**	**0.002**	**-0.107**	**0.054**	**0.046**
Symbol Search	**-0.007**	**0.002**	**-0.155**	**0.044**	**< 0.001**	**-0.007**	**0.002**	**-0.207**	**0.059**	**< 0.001**
Inhibition	**-0.150**	**0.044**	**-0.129**[a]	**0.036**	**< 0.001**	-0.071	0.039	-0.081[a]	0.045	0.069
Working Memory	**-0.168**	**0.044**	**-0.162**[a]	**0.043**	**< 0.001**	-0.063	0.041	-0.081[a]	0.053	0.131
Attention Shifting	-0.030	0.023	-0.045	0.034	0.189	-0.030	0.023	-0.060	0.045	0.182
Receptive language	**-0.007**	**0.002**	**-0.192**	**0.042**	**< 0.001**	-0.002	0.002	-0.084	0.052	0.106
Income-to-Needs Ratio	**-0.033**	**0.013**	**-0.085**	**0.033**	**0.009**	**-0.037**	**0.013**	**-0.128**	**0.040**	**0.002**
African American	0.008	0.057	0.005	0.039	0.891	-0.068	0.052	-0.062	0.046	0.183
Male	**0.211**	**0.043**	**0.171**	**0.033**	**< 0.001**	**0.123**	**0.038**	**0.133**	**0.041**	**0.001**
Pennsylvania	0.040	0.053	0.032	0.041	0.439	0.040	0.049	0.042	0.050	0.402

Final model with equality constraints imposed on the unstandardized coefficients for coding, symbol search, and attention shifting: χ^2 (48) = 76.847, $p = 0.005$, CFI = 0.989, RMSEA = 0.024 (CI: 0.013, 0.034) Unstandardized (B) and standardized (β) path estimates are reported here and unstandardized path estimates are reported in text [a]Represent significantly different path coefficients for a given construct in predicting inattention relative to sluggish cognitive tempo behaviors

Our findings are consistent with studies that found SCT behaviors to be uniquely associated with slower processing speed (Willcutt et al., 2014), particularly in younger children (Jacobson et al., 2018; Tamm et al., 2018), yet conflict with other studies that did not find a significant association between SCT behaviors and slower processing speed (Bauermeister et al., 2012; Kofler et al., 2019a, b). However, it is difficult to directly compare our findings to previous studies given differences in studies' designs, measures of SCT and processing speed, sample ages and characteristics, and analytic approach. For instance, most previous studies have examined whether SCT and IN behaviors are uniquely associated with processing speed, conceptualizing SCT and IN behaviors as independent variables and processing speed as a dependent variable within the constraints of a cross-sectional study. Conversely, our study took a different approach by examining whether processing speed uniquely predicts future SCT and IN behaviors, above and beyond EF and child/family characteristics. Using this approach, slower processing speed assessed in pre-Kindergarten predicted both SCT and IN behaviors in early elementary school.

When examining the separate processing speed subtests, both *coding* and *symbol search* significantly predicted SCT and IN behaviors. Further, it should be noted that both *coding* and *symbol search* had associations with SCT and IN behaviors of a similar magnitude. Despite some evidence that poorer performance on speeded tasks with greater graphomotor demands may be particularly associated with SCT behaviors (Becker et al., 2020; Hinshaw et al., 2002), we did not find evidence for *coding* performance being more clearly associated than *symbol search* performance with SCT. Considered together, findings from the present study indicate that slower processing speed is prospectively associated with increased SCT behaviors in early childhood, though no more so with SCT behaviors than with IN behaviors.

In contrast to processing speed, findings for EFs as predictors of SCT and IN behaviors were more nuanced. Although poorer skills in a composite measure of EF assessed at age five significantly predicted both SCT and IN behaviors in 1st-3rd grades, the association with IN behaviors was significantly stronger than the association for SCT behaviors. Further, when examining separate EFs simultaneously, both inhibition and working memory significantly predicted IN behaviors whereas none of the specific EFs uniquely predicted SCT behaviors. The current study replicates and extends findings from most cross-sectional studies (Bauermeister et al., 2012; Skirbekk et al., 2011; Tamm et al., 2018; Wåhlstedt & Bohlin, 2010; Willcutt et al., 2014) by demonstrating poorer EF skills in early childhood to be more clearly predictive of IN behaviors than SCT behaviors.

Considering the study findings together from a developmental perspective, slow processing speed in early childhood may be a nonspecific risk factor for later SCT and IN behaviors, whereas poor EF skills in early childhood may be a clearer risk factor for IN behaviors than for SCT behaviors. Still, it is important to note that the magnitude of effects were generally small-to-moderate (all standardized estimates, even when statistically significant, were $<|0.30|$). This is not surprising, as there are often modest associations between neuropsychological performance and behavior indicators (Willcutt et al., 2005). Additional studies will be needed before firm conclusions can be drawn, with a need for studies that examine whether processing speed and EFs not only predict later SCT and IN behaviors but also predict increases and trajectories of these behaviors. Nevertheless, our findings seem to be consistent with Barkley's (2014) proposition that

"*SCT is not primarily a disorder of executive functioning (EF) as manifested in daily life activities or on most EF tests*…In contrast, ADHD is a serious and pervasive EF disorder" (p. 121, italics in original). Accordingly, Barkley (2015, 2018) has suggested that EF deficits may only be weakly associated with SCT or secondary to specific daydreaming aspects of SCT. Clinically, it is possible that treatments that improve processing speed or EF also reduce SCT behaviors. However, it is important to note that studies examining neuropsychological performance and SCT, including this study, examined between-subject associations. Experimental studies are needed to provide stronger evidence for theoretical and clinical implications of our findings. That is, do experimental efforts to improve processing speed or EF in early childhood result in subsequent decreases in SCT and IN behaviors? Although neuropsychological function was not directly assessed, there is some evidence that home-school and school-based interventions that include components to improve homework and organization skills reduce parent/teacher-reported SCT symptoms in youth with ADHD (Pfiffner et al., 2007; Smith & Langberg, 2020).

Finally, although not the focus of the present study, receptive language was included as a covariate in our analyses given the relevance of language for problem behaviors in children (Chow & Wehby, 2018; Petersen et al., 2015). Although poorer receptive language was univariately associated with both SCT and IN behaviors, it predicted only IN behaviors in the multivariate models. We are unaware of any previous research that has examined language impairments in relation to SCT behaviors. The absence of a unique association between receptive language and SCT behaviors in the present study suggests that SCT behaviors such as staring and mental confusion are not likely due to poor receptive language skills. However, we did not measure expressive language in the current study, leaving it unknown if these SCT behaviors may be due to deficits in language output (expressive language) as opposed to language input (receptive language). This is an important area for future research.

Strengths, Limitations, and Future Directions

Strengths of this study include the sample recruited with a developmental epidemiological design to be representative of the six counties where participating families lived. The longitudinal design in early childhood are additional strengths, as both longitudinal studies and studies with young children are notably lacking among SCT-focused studies to date (Becker & Barkley, 2018). Our study also benefited from examining both composite and specific measures of processing speed and EF, as well as use of teacher ratings of SCT and IN behaviors during the first years of formal education.

Several limitations are also important to note. First, the measure of SCT was comprised of four items that were representative of the SCT item set at the time data collection for this project began. Previous analyses with this same sample demonstrate that these SCT behaviors are distinct from IN behaviors and invariant over time (Dvorsky et al., 2019), yet future studies would benefit from using validated SCT measures that better reflect the field's current understanding of SCT (Becker, in press; Becker et al., 2016). In particular, more recent SCT measures have included items related to mental confusion, getting lost in one's thoughts, and sleepiness/drowsiness (Burns & Becker, 2019; McBurnett et al., 2014) and these items were not captured in the current SCT item set; conversely, several studies have not found low motivation to be an optimal item for assessing SCT (Becker, Burns, Schmitt, Epstein, & Tamm, 2019; Jung, Lee, Burns, & Becker, 2020; Penny, Waschbusch, Klein, Corkum, & Eskes, 2009; Sáez, Servera, Becker, & Burns, 2019) even though the "is apathetic or unmotivated" item did show distinction from IN behaviors in previous analyses with this sample (Dvorsky et al., 2019).

In addition, processing speed was assessed using WPPSI-III *coding* and *symbol search*, which are very frequently used but both are visual tasks that include a motor component and do not capture the full scope of processing speed. It will be important for future studies to use a wider range of processing speed tasks, including both visual and auditory tasks and tasks that include both motor and non-motor processing speed. Finally, processing speed and EF were assessed at separate home or school visits, and although the assessments generally occurred close in time, there was some variability in how close these assessments were scheduled and completed. Of key importance for the current study, both domains were assessed prior to the SCT and IN behaviors, which were assessed at school entry.

Conclusions

There is a need to establish predictors of SCT behaviors in early development, and the current study makes an important step in this direction. Using a longitudinal study, the current study demonstrates that slower processing speed predicts teacher ratings of both SCT and IN behaviors in early schooling, whereas poorer EF uniquely predict IN behaviors and less clearly predict SCT behaviors. This study provides a foundation for future work aiming to build developmental models of SCT and its distinction from IN.

Acknowledgements This study made use of Phase I and Phase II data from Family Life Project. The Family Life Project was funded by NICHD(P01HD039667) with co-funding from National Institute on Drug Abuse,and more recently from the National institute of Health's Environmental Influence on Child Health Outcomes

Program (1UG3OD023332-01). The Family Life Project Phase I Key Investigators include: Lynne Vernon-Feagans, The University of North Carolina; Martha Cox, The University of North Carolina; Clancy Blair, The Pennsylvania State University; Peg Burchinal, The University of North Carolina; Linda Burton, Duke University; Keith Crnic, The Arizona State University; Ann Crouter, The Pennsylvania State University; Patricia Garrett-Peters, The University of North Carolina; Mark Greenberg, The Pennsylvania State University; Stephanie Lanza, The Pennsylvania State University; Roger Mills-Koonce, The University of North Carolina; Emily Werner, The Pennsylvania State University and Michael Willoughby, The University of North Carolina. The Family Life Project Phase II Key Investigators include: Lynne Vernon-Feagans, The University of North Carolina at Chapel Hill; Mark T. Greenberg, The Pennsylvania State University Clancy B. Blair, New York University ; Margaret R. Burchinal, The University of North Carolina at Chapel Hill; Martha Cox, The University of North Carolina at Chapel Hill; Patricia T. Garrett-Peters, The University of North Carolina at Chapel Hill; Jennifer L. Frank, The Pennsylvania State University; W. Roger Mills-Koonce, University of North Carolina-Greensboro; Michael T. Willoughby, RTI International. Stephen Becker is supported by award number K23MH108603 from the National Institute of Mental Health (NIMH). Melissa Dvorsky is supported by award number K23MH122839 from the NIMH. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Compliance with Ethical Standards

Conflict of Interest The authors declare no potential conflicts of interest with respect to the research, authorship, or publication of this article.

Ethical Approval The study was approved by the University of North Carolina at Chapel Hill Institutional Review Board.

Informed Consent Parents provided informed consent for participation in this study.

References

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders: Fouth Edition* (4th ed.). Washington, DC: American Psychiatric Association

Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: constructing a unifying theory of ADHD. *Psychological Bulletin, 121,* 65–94.

Barkley, R. A. (2013). Distinguishing sluggish cognitive tempo from ADHD in children and adolescents: Executive functioning, impairment, and comorbidity. *Journal of Clinical Child and Adolescent Psychology, 42,* 161–173. https://doi.org/10.1080/15374416.2012.734259

Barkley, R. A. (2014). Sluggish cognitive tempo (concentration deficit disorder?): current status, future directions, and a plea to change the name. *Journal of Abnormal Child Psychology, 42,* 117–125. https://doi.org/10.1007/s10802-013-9824-y

Barkley, R. A. (2015). Concentration deficit disorder (sluggish cognitive tempo). In R. A. Barkley (Ed.), *Attention-deficit hyperactivity disorder: A handbook for diagnosis and treatment., 4th ed.* (pp. 435–452). New York, NY: Guilford Press

Barkley, R. A. (2018). *Barkley Sluggish Cognitive Tempo Scale – Children and Adolescents (BSCTS-CA)*. New York: Guilford

Bauermeister, J. J., Barkley, R. A., Bauermeister, J. A., Martinez, J. V., McBurnett, K. (2012). Validity of the sluggish cognitive tempo, inattention, and hyperactivity symptom dimensions: Neuropsychological and psychosocial correlates. *Journal of Abnormal Child Psychology, 40,* 683–697. https://doi.org/10.1007/s10802-011-9602-7

Becker, S. P. (in press). Systematic review: Assessment of sluggish cognitive tempo over the past decade. *Journal of the American Academy of Child and Adolescent Psychiatry*

Becker, S. P., & Barkley, R. A. (2018). Sluggish cognitive tempo. In T. Banaschewski, D. Coghill, & A. Zuddas (Eds.), *Oxford textbook of attention deficit hyperactivity disorder* (pp. 147-153). Oxford, England: Oxford University Press

Becker, S. P., Burns, G. L., Leopold, D. R., Olson, R. K., Willcutt, E. G. (2018). Differential impact of trait sluggish cognitive tempo and ADHD inattention in early childhood on adolescent functioning. *Journal of Child Psychology and Psychiatry, 59,* 1094–1104. https://doi.org/10.1111/jcpp.12946

Becker, S. P., Burns, G. L., Schmitt, A. P., Epstein, J. N., Tamm, L. (2019). Toward establishing a standard symptom set for assessing sluggish cognitive tempo in children: Evidence from teacher ratings in a community sample. *Assessment, 26,* 1128–1141. https://doi.org/10.1177/1073191117715732

Becker, S. P., Leopold, D. R., Burns, G. L., Jarrett, M. A., Langberg, J. M., Marshall, S. A., McBurnett, K., Waschbusch, D. A., Willcutt, E. G. (2016). The internal, external, and diagnostic validity of sluggish cognitive tempo: A meta-analysis and critical review. *Journal of the American Academy of Child and Adolescent Psychiatry, 55,* 163–178. https://doi.org/10.1016/j.jaac.2015.12.006

Becker, S. P., Marsh, N. P., Holdaway, A. S., Tamm, L. (2020). Sluggish cognitive tempo and processing speed in adolescents with ADHD: Do findings vary based on informant and task? *European Child and Adolescent Psychiatry, 29,* 1371–1384. https://doi.org/10.1007/s00787-019-01446-x

Becker, S. P., & Willcutt, E. G. (2019). Advancing the study of sluggish cognitive tempo via DSM, RDoC, and hierarchical models of psychopathology. *European Child and Adolescent Psychiatry, 28,* 603–613. https://doi.org/10.1007/s00787-018-1136-x

Brocki, K. C., Nyberg, L., Thorell, L. B., Bohlin, G. (2007). Early concurrent and longitudinal symptoms of ADHD and ODD: relations to different types of inhibitory control and working memory. *Journal of Child Psychology and Psychiatry, 48,* 1033–1041. https://doi.org/10.1111/j.1469-7610.2007.01811.x

Burns, G. L., & Becker, S. P. (2019). Sluggish cognitive tempo and ADHD symptoms in a nationally representative sample of U.S. children: Differentiation using categorical and dimensional approaches. *Journal of Clinical Child and Adolescent Psychology*. Advance online publication. https://doi.org/10.1080/15374416.2019.1678165

Burns, G. L., Becker, S. P., Servera, M., Bernad, M. D., Garcia-Banda, G. (2017). Sluggish cognitive tempo and attention-deficit/hyperactivity disorder (ADHD) inattention in the home and school contexts: Parent and teacher invariance and cross-setting validity. *Psychological Assessment, 29,* 209–220. https://doi.org/10.1037/pas0000325

Byrne, B. (2012). *Structural Equation Modeling with Mplus: Basic Concepts, Applications, and Programming*. New York: Routledge.

Carlson, C. L., & Mann, M. (2002). Sluggish cognitive tempo predicts a different pattern of impairment in the attention deficit hyperactivity disorder, predominantly inattentive type. *Journal of Clinical Child and Adolescent Psychology, 31,* 123–129. https://doi.org/10.1207/S15374424JCCP3101_14

Chow, J. C., & Wehby, J. H. (2018). Associations between language and problem behavior: A systematic review and correlational meta-analysis. *Educational Psychology Review, 30,* 61–82. https://doi.org/10.1007/s10648-016-9385-z

Diamond, A. (2016). Why improving and assessing executive functions early in life is critical. In J. A. Griffin, P. McCardle, & L. S. Freund (Eds.), *Executive function in preschool-age children: Integrating measurement, neurodevelopment, and translational research* (pp. 11-43). Washington, DC: American Psychological Association.

Dill, B. T. (2001). Rediscovering rural America. In J. R. Blau (Ed.), *The Blackwell Companion to Sociology* (pp. 196-210). Malden, MA: Blackwell Publishing.

Dunn, L. M., & Dunn, D. M. (2007). *Peabody Picture Vocabulary Test Fourth Edition (PPVT-IV)*. Bloomington, MN: Pearson.

Dvorsky, M. R., Becker, S. P., Tamm, L., Willoughby, M. T. (2019). Testing the longitudinal structure and change in sluggish cognitive tempo and inattentive behaviors from early through middle childhood. *Assessment*. Advance online publication. https://doi.org/10.1177/1073191119872247

Garner, A. A., Marceaux, J. C., Mrug, S., Patterson, C., Hodgens, B. (2010). Dimensions and correlates of attention deficit/hyperactivity disorder and sluggish cognitive tempo. *Journal of Abnormal Child Psychology, 38,* 1097–1107. https://doi.org/10.1007/s10802-010-9436-8

Halperin, J. M. (2011, September 30). *The neurodevelopment of ADHD*. Paper presented at the 22nd Eunethydis Meeting: The next 10 years, Budapest, Hungary.

Hinshaw, S. P., Carte, E. T., Sami, N., Treuting, J. J., Zupan, B. A. (2002). Preadolescent girls with attention-deficit/hyperactivity disorder: II. Neuropsychological performance in relation to subtypes and individual classification. *Journal of Consulting and Clinical Psychology, 70,* 1099–1111

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling-a Multidisciplinary Journal, 6,* 1–55. https://doi.org/10.1080/10705519909540118

Jacobson, L. A., Geist, M., Mahone, E. M. (2018). Sluggish cognitive tempo, processing speed, and internalizing symptoms: The moderating effect of age. *Journal of Abnormal Child Psychology, 46,* 127–135. https://doi.org/10.1007/s10802-017-0281-x

Jung, S. H., Lee, S. Y., Burns, G. L., Becker, S. P. (2020). Internal and external validity of self-report and parent-report measures of sluggish cognitive tempo in South Korean adolescents. *Journal of Psychopathology and Behavioral Assessment*. Advance online publication. https://doi.org/10.1007/s10862-020-09821-8

Kofler, M. J., Irwin, L. N., Sarver, D. E., Fosco, W. D., Miller, C. E., Spiegel, J. A., Becker, S. P. (2019). What cognitive processes are "sluggish" in sluggish cognitive tempo? *Journal of Consulting and Clinical Psychology, 87,* 1030–1042. https://doi.org/10.1037/ccp0000446

Kofler, M. J., Irwin, L. N., Soto, E. F., Groves, N. B., Harmon, S. L., Sarver, D. E. (2019). Executive functioning heterogeneity in pediatric ADHD. *Journal of Abnormal Child Psychology, 47,* 273–286. https://doi.org/10.1007/s10802-018-0438-2

McBurnett, K., Pfiffner, L. J., & Frick, P. J. (2001). Symptom properties as a function of ADHD type: an argument for continued study of sluggish cognitive tempo. *Journal of Abnormal Child Psychology, 29,* 207–213.

McBurnett, K., Villodas, M., Burns, G. L., Hinshaw, S. P., Beaulieu, A., Pfiffner, L. J. (2014). Structure and validity of sluggish cognitive tempo using an expanded item pool in children with attention-deficit/hyperactivity disorder. *Journal of Abnormal Child Psychology, 42,* 37–48. https://doi.org/10.1007/s10802-013-9801-5

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science, 21,* 8–14. https://doi.org/10.1177/0963721411429458

Muthén, L. K., & Muthén, B. O. (1998–2019). *Mplus user's guide* (Eigth ed.). Los Angeles, CA: Muthén & Muthén.

Nigg, J. T., Willcutt, E. G., Doyle, A. E., Sonuga-Barke, E. J. (2005). Causal heterogeneity in attention-deficit/hyperactivity disorder: do we need neuropsychologically impaired subtypes? *Biological Psychiatry, 57,* 1224–1230. https://doi.org/10.1016/j.biopsych.2004.08.025

Pelham, W. E., Evans, S. W., Gnagy, E. M., & Greenslade, K. E. (1992). Teacher ratings of DSM-III-R symptoms for the disruptive behavior disorders: Prevalence, factor analyses, and conditional probabilities in a special education sample. *School Psychology Review, 21,* 285–299

Penny, A. M., Waschbusch, D. A., Klein, R. M., Corkum, P., Eskes, G. (2009). Developing a measure of sluggish cognitive tempo for children: content validity, factor structure, and reliability. *Psychological Assessment, 21,* 380–389. https://doi.org/10.1037/a0016600

Petersen, I. T., Bates, J. E., Staples, A. D. (2015). The role of language ability and self-regulation in the development of inattentive-hyperactive behavior problems. *Development and Psychopathology, 27,* 221–237. https://doi.org/10.1017/S0954579414000698

Pfiffner, L. J., Yee Mikami, A., Huang-Pollock, C., Easterlin, B., Zalecki, C., McBurnett, K. (2007). A randomized, controlled trial of integrated home-school behavioral treatment for ADHD, predominantly inattentive type. *Journal of the American Academy of Child and Adolescent Psychiatry, 46,* 1041–1050. https://doi.org/10.1097/chi.0b013e318064675f

Rajendran, K., Rindskopf, D., O'Neill, S., Marks, D. J., Nomura, Y., Halperin, J. M. (2013). Neuropsychological functioning and severity of ADHD in early childhood: a four-year cross-lagged study. *Journal of Abnormal Psychology, 122,* 1179–1188. https://doi.org/10.1037/a0034237

Rajendran, K., Trampush, J. W., Rindskopf, D., Marks, D. J., O'Neill, S., Halperin, J. M. (2013). Association between variation in neuropsychological development and trajectory of ADHD severity in early childhood. *American Journal of Psychiatry, 170,* 1205–1211. https://doi.org/10.1176/appi.ajp.2012.12101360

Ribner, A. D., Willoughby, M. T., Blair, C. B., & Family Life Project Key Investigators. (2017). Executive function buffers the association between early math and later academic skills. *Frontiers in Psychology, 8,* 869. https://doi.org/10.3389/fpsyg.2017.00869

Sáez, B., Servera, M., Becker, S. P., Burns, G. L. (2019). Optimal items for assessing sluggish cognitive tempo in children across mother, father, and teacher ratings. *Journal of Clinical Child and Adolescent Psychology, 48,* 1–15. https://doi.org/10.1080/15374416.2017.1416619

Schafer, J. L., & Graham, J. W. (2002). Missing data: Our view of the state of the art. *Psychological Methods, 7*(2), 147–177.

Sergeant, J. A. (2005). Modeling attention-deficit/hyperactivity disorder: a critical appraisal of the cognitive-energetic model. *Biological Psychiatry, 57,* 1248–1255. https://doi.org/10.1016/j.biopsych.2004.09.010

Skirbekk, B., Hansen, B. H., Oerbeck, B., Kristensen, H. (2011). The relationship between sluggish cognitive tempo, subtypes of attention-deficit/hyperactivity disorder, and anxiety disorders. *Journal of Abnormal Child Psychology, 39,* 513–525. https://doi.org/10.1007/s10802-011-9488-4

Smith, Z. R., & Langberg, J. M. (2020). Do sluggish cognitive tempo symptoms improve with school-based ADHD interventions? Outcomes and predictors of change. *Journal of Child Psychology and Psychiatry, 61,* 575–583. https://doi.org/10.1111/jcpp.13149

Sonuga-Barke, E. J. (2005). Causal models of attention-deficit/hyperactivity disorder: from common simple deficits to multiple developmental pathways. *Biological Psychiatry, 57,* 1231–1238.

Tamm, L., Brenner, S. B., Bamberger, M. E., Becker, S. P. (2018). Are sluggish cognitive tempo symptoms associated with executive functioning in preschoolers? *Child Neuropsychology, 24,* 82–105. https://doi.org/10.1080/09297049.2016.1225707

Todd, R. D., Rasmussen, E. R., Wood, C., Levy, F., Hay, D. A. (2004). Should sluggish cognitive tempo symptoms be included in the diagnosis of attention-deficit/hyperactivity disorder? *Journal of the American Academy of Child and Adolescent Psychiatry, 43,* 588–597. https://doi.org/10.1097/00004583-200405000-00012

Vernon-Feagans, L., Cox, M., Willoughby, M., Burchinal, M., Garrett-Peters, P., Conger, R. D., Bauer, P. J. (2013). The Family Life Project: An epidemiological and developmental study of young children living in poor rural communities. *Monographs of the Society for Research in Child Development, 78,* 1–150. https://doi.org/10.1111/mono.12046

Wåhlstedt, C., & Bohlin, G. (2010). DSM-IV-defined inattention and sluggish cognitive tempo: Independent and interactive relations to neuropsychological factors and comorbidity. *Child Neuropsychology, 16,* 350–365. https://doi.org/10.1080/09297041003671176

Wechsler, D. (2002). *The Wechsler Preschool and Primary Scale of Intelligence, Third Edition (WPPSI-III).* San Antonio, TX: The Psychological Corporation.

Willcutt, E. G., Chhabildas, N., Kinnear, M., DeFries, J. C., Olson, R. K., Leopold, D. R., Pennington, B. F. (2014). The internal and external validity of sluggish cognitive tempo and its relation with DSM-IV ADHD. *Journal of Abnormal Child Psychology, 42,* 21–35. https://doi.org/10.1007/s10802-013-9800-6

Willcutt, E. G., Doyle, A. E., Nigg, J. T., Faraone, S. V., Pennington, B. F. (2005). Validity of the executive function theory of attention-deficit/hyperactivity disorder: a meta-analytic review. *Biological Psychiatry, 57,* 1336–1346. https://doi.org/10.1016/j.biopsych.2005.02.006

Willcutt, E. G., Nigg, J. T., Pennington, B. F., Solanto, M. V., Rohde, L. A., Tannock, R., Lahey, B. B. (2012). Validity of DSM-IV attention deficit/hyperactivity disorder symptom dimensions and subtypes. *Journal of Abnormal Psychology, 121,* 991–1010. https://doi.org/10.1037/a0027347

Willoughby, M. T., Blair, C. B., Wirth, R. J., Greenberg, M. (2010). The measurement of executive function at age 3 years: Psychometric properties and criterion validity of a new battery of tasks. *Psychological Assessment, 22,* 306–317. https://doi.org/10.1037/a0018708

Willoughby, M. T., Blair, C. B., Wirth, R. J., Greenberg, M., The Family Life Project Investigators. (2012). The measurement of executive function at age 5: Psychometric properties and relationship to academic achievement. *Psychological Assessment, 24,* 226–239. https://doi.org/10.1037/a0025361

Willoughby, M. T., Wylie, A. C., Blair, C. B. (2019). Using repeated-measures data to make stronger tests of the association between executive function skills and attention deficit/hyperactivity disorder symptomatology in early childhood. *Journal of Abnormal Child Psychology, 47,* 1759–1770. https://doi.org/10.1007/s10802-019-00559-w