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The Associations Between Sluggish Cognitive Tempo, Internalizing Symptoms, and Academic Performance in Children With Reading Disorder: A Longitudinal Cohort Study

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Abstract

Objective: To investigate whether sluggish cognitive tempo (SCT) was associated with anxiety, depression, and academic performance (AP) in children with reading disorder (RD), and whether ADHD-Inattention (ADHD-IN) moderated these relationships. **Method:** Parents and teachers of children with RD ($N = 147$, ages 6–18) completed evaluations of SCT, ADHD, anxiety, depression, and AP, every 3 months for 18 months. Baseline and longitudinal associations between SCT and outcomes, and effect moderation of ADHD-IN, were assessed. **Results:** Teacher-rated SCT was positively associated with teacher-rated anxiety ($p < .001$) and negatively associated with AP ($p < .001$) cross-sectionally and longitudinally, with significant effect modification by ADHD-IN for both outcomes. SCT was not associated with depression in adjusted cross-sectional and longitudinal analyses. There were no significant findings for any parent-reported measures. **Conclusion:** SCT has negative effects on anxiety and AP in children with RD among individuals with low ADHD-IN according to teacher report. Targeted treatment of SCT may provide substantial benefits. *(J. of Att. Dis. 2022; 26(12) 1576-1590)*

Keywords

academic performance, ADHD, anxiety, dyslexia, sluggish cognitive tempo

Introduction

Sluggish cognitive tempo (SCT) is a relatively new clinical construct that refers to a constellation of symptoms, including lethargy, daydreaming, drowsiness, mental confusion, and slowed behavior and thinking (Becker, 2021; Servera et al., 2018). Until recent times, SCT has been studied in the context of ADHD, particularly as a symptom of the ADHD-Inattentive (ADHD-IN) subtype (Barkley, 2013; Becker, 2021). However, there has been much evidence suggesting SCT to be a distinct construct of its own, with both empirical and clinical differentiation (Servera et al., 2018). A 2015 meta-analysis of 73 factor analytic studies, in particular, showed that SCT items consistently loaded on the SCT factor rather than the ADHD factor, demonstrating its position as a separate construct (Becker et al., 2015).

SCT has been shown to be positively associated with internalizing symptoms (anxiety, depression, and withdrawal), as well as academic impairment in both cross-sectional and longitudinal studies (Becker & Langberg, 2013; Bernad et al., 2014, 2016; Burns et al., 2013; Lee et al., 2017; Servera et al., 2018). These associations remained significant even after controlling for ADHD or ADHD-IN symptoms. In contrast, SCT has been observed to be either unassociated or negatively associated with externalizing symptoms, after controlling for ADHD (Lee et al., 2014; Sevincok et al., 2020). This is different from ADHD-IN's significant positive associations with externalizing behaviors, further demonstrating the external validity of SCT (Lee et al., 2017).

Studies demonstrating the associations between SCT and anxiety, depression and academic performance have been conducted in ADHD and typically developing children, adolescent, and adult populations, whereby those with higher levels of SCT were more likely to have higher levels of anxiety, depression, and academic impairment. Among typically developing children, higher rates of SCT symptoms have

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been associated with academic problems, emotional and peer relationship problems (Camprodon-Rosanas et al., 2017) and greater anxiety/depression, emotional reactivity, withdrawal, and somatic complaints (Lee et al., 2017).

In populations with ADHD, those with SCT symptoms had higher anxiety scores and autistic traits (Ekinci et al., 2021) and SCT was shown to predict both academic impairment and internalizing psychopathology (Smith & Langberg, 2017). In a study by Servera et al. (2018), 2,142 school children were divided into four groups: SCT only, ADHD only, SCT and ADHD combined, and controls. The three groups with ADHD, SCT, or both had higher scores of anxiety, depression, and academic impairment than the control group, but more importantly, the SCT only and SCT + ADHD groups had higher internalizing scores than the ADHD only group, demonstrating the unique impact of SCT on these outcomes regardless of ADHD status.

Similar associations have also been observed in longitudinal studies among typically developing children. In a large 2-year longitudinal study by Bernad et al. (2016), higher scores on SCT uniquely predicted higher levels of teacher-reported depression and academic impairment (for 1-year interval only), independent of ADHD-IN. A recent study found baseline SCT symptoms to predict future depression and teacher-rated (but not child-rated) anxiety (Becker et al., 2021). Similarly, a 7-year longitudinal study showed SCT to predict internalizing behaviors and anxious/depressive behaviors, even after controlling for the effects of ADHD (Vu et al., 2019). However, in the same study, SCT was not predictive of future academic outcomes after controlling for ADHD.

In addition to ADHD and community samples, SCT has recently been investigated in children and adolescents with autism spectrum disorder (Brewe et al., 2020; Duncan et al., 2019; Mayes et al., 2021), trauma (Musicaro et al., 2020), and sleep disorders (Becker et al., 2016), which points toward SCT being a construct of transdiagnostic significance. However, SCT has rarely been examined in the context of reading disorder (RD), which includes dyslexia.

With a reported prevalence between 5% and 17%, RD is common in the general population (Lagae, 2008). It is typically characterized by impairments in word reading accuracy, reading fluency, and comprehension that is unexpected given an individual's IQ and schooling (Peterson & Pennington, 2012). As such, children with RD have higher rates of academic failure compared to their typically developing peers (Haft et al., 2016). They also tend to have higher levels of anxiety and depression and a higher prevalence of co-morbid ADHD (Hendren et al., 2018). Given the internalizing problems and academic challenges that children with RD face, it is important to determine if SCT is a significant predictor of these outcomes in this population. In addition, given the comorbidity of RD with ADHD, it also seems imperative to know whether ADHD symptoms-particularly ADHD-Inattention, which is more closely associated with SCT than the ADHD-Hyperactivity/Impulsivity subtype-impact any potential associations that SCT may have in the RD population.

To our knowledge, there have been very few studies that explored SCT in the context of RD or dyslexia. One was a poster abstract that investigated whether or not SCT is more prevalent in children with dyslexia (Tahıllıoğlu et al., 2019). They found no statistically significant difference in SCT symptoms between children with and without dyslexia. The other two studies were based on a 16-week placebo-controlled, double-blind randomized trial of atomoxetine in children with ADHD and Dyslexia combined, Dyslexia-only, or ADHD-only (McBurnett et al., 2017; Wietecha et al., 2013). The primary results of the trial found atomoxetine to improve ADHD symptoms in ADHD and Dyslexia combined and ADHD-only subjects, but not in Dyslexia-only subjects (Wietecha et al., 2013). However, SCT symptoms (as measured by parents, teachers, and self-reports) improved in all three groups (including Dyslexia-only) after atomoxetine treatment. The second study was a post hoc analysis of this atomoxetine trial, with SCT being the primary outcome. This study found atomoxetine to be associated with significant reductions in seven of the nine SCT outcomes in the dyslexia populations (ADHD and Dyslexia combined and Dyslexia-only), even after controlling for change in ADHD symptom severity, indicating that the SCT improvements seen in the original study were independent of the improvement in ADHD symptoms (McBurnett et al., 2017). However, neither of these studies explored the impact of SCT on academic performance or internalizing symptoms.

We therefore conducted a prospective cohort study in three schools specializing in the treatment of children with RD to determine whether SCT was associated with anxiety, depression, and academic performance both at baseline and over time. Furthermore, we also investigated whether ADHD-IN symptoms moderated any of these relationships.

Methods

Protocol

The study was approved by the University of California San Francisco (UCSF) Institutional Review Board (IRB), which reviews human subject research studies, on 09/28/2016. This study is part of a larger cohort study to track academic progress, socio-emotional health, mental health, and quality of life over time in school-aged children with RD to identify predictors of successful outcomes and to identify and disseminate targeted interventions.

Questionnaires measuring SCT and other outcome factors (anxiety, depression, academic performance, and ADHD) were completed by parents and teachers approximately every

3 months each academic school year. Data was collected through an online secure research platform called eBit (evidence-based intervention and treatment) on the following five dates: October 2019, February 2020, May 2020, November 2020, and March 2021.

Participants and Consent

One hundred forty-seven participants (aged between 6 and 18 years) were recruited by email from three specialized education schools for children with RD in the San Francisco Bay Area, CA. To be enrolled in the schools and study, all students were required to have a diagnosis of RD. For one of the schools (School A), RD was determined by a required neuropsychological evaluation onsite. For the other two schools (B and C), RD was determined by neuropsychological reports, educational assessments, and/or school district Individualized Education Program (IEPs) that were shared by the parents at the time of admission. The local schools were all recognized as schools that specialize in the education of children with dyslexia and other forms of RD. Details regarding the instructional approach at the schools and the types of interventions implemented are described in Supplemental Table 1. Recruitment for participants was ongoing throughout the study period, resulting in staggered entry over the 1.5 years. This led to differential follow-up times for the participants, with the earliest participants having up to five timepoints of measurement. Informed consent was obtained from parents before any research activities were started.

Measures

Sluggish Cognitive Tempo

SCT was measured by the Kiddie-Sluggish Cognitive Tempo (K-SCT) Rating Scale, which is a 15-item rating scale that measures symptoms of SCT and groups them into three distinct categories (Daydreaming, Working Memory Problems, and Sleepy/Tired). Each of these SCT factor categories shows strong convergent and discriminant validity in both Exploratory Factor Analysis (EFA) and in a confirmatory model with the ADHD factors (McBurnett et al., 2014). It has both parent and teacher versions. Examples of items include "gets lost in thought," "gets confused," and "seems drowsy," with possible answer choices of "never/rarely," "sometimes," "often," or "very often." It has a possible final score range of 0 to 45, which is calculated by taking the sum of the individual items' scores, with higher scores indicating increased SCT symptoms.

In our sample, exploratory factor analysis of the SCT and ADHD-Inattention (ADHD-IN) items (from the ADHD-RS 5 Attention and Behavior Rating Form) identified four distinct factors: the 15 SCT items grouped into the three categories of Daydreaming (parent-rated factor loadings from 0.72 to 0.90; $M=0.79$ to $SD=0.07$; and teacher-rated factor loadings from 0.71–0.89; $M=0.84$ to $SD=0.07$), Working Memory Problems (parent-rated factor loadings from 0.72 to 0.83; $M=0.79$ to $SD=0.04$; and teacher-rated factor loadings from 0.63–0.93; $M=0.80$ to $SD=0.13$) and Sleepy/Tired (parent-rated factor loadings from 0.64 to 0.86; $M=0.78$ to $SD=0.1$; and teacher-rated factor loadings from 0.70–0.85; $M=0.82$ to $SD=0.08$), whereas all the ADHD-IN items grouped into the ADHD-IN factor (parent-rated factor loadings from 0.41 to 0.88; $M=0.76$ to $SD=0.14$; and teacher-rated factor loadings from 0.68 to 0.89; $M=0.79$ to $SD=0.07$), thus demonstrating the convergent validity and divergent validity of K-SCT. The K-SCT also showed good and excellent internal consistency at baseline for the parent and teacher-reported versions respectively (Cronbach's alpha: .86 and .93). It also showed moderate test-retest reliability, with the parent version having an intraclass correlation coefficient (ICC) of .74 (95% CI [0.65–0.80]) and the teacher version having an ICC of .68 (95% CI [0.61–0.75]).

Anxiety

Anxiety was evaluated by the 8-item Spence Children's Anxiety Scale (SCAS). It has both parent and teacher versions and is designed to assess symptoms of DSM-IV anxiety disorders in children. Examples of items include "worries about things" and "worries what people think of him/her," with possible answer choices being between "never," "sometimes," "often," or "always." It has a possible final score range of 0 to 24, which is calculated by taking the sum of the individual items' scores. Higher scores indicate higher anxiety. The measure is known to have good internal consistency, agreement among reporters, and convergent and divergent validity (Reardon et al., 2018). In our sample, the 8-item SCAS had good and fair internal consistency at baseline for parent and teacher versions respectively (Cronbach's alpha: .83 and .71). It also showed moderate test-retest reliability for both parent (ICC = 0.74; 95% CI [0.66–0.81]) and teacher versions (ICC = 0.6; 95% CI [0.51–0.68]). It achieved convergent validity with the Emotional subscale of the Strengths and Difficulties Questionnaire (SDQ) (Goodman, 1997) at baseline, with parent-reported scores having a correlation coefficient (r) of .69 ($p < .0001$) and teacher-reported scores having an r of .75 ($p < .0001$). It achieved divergent validity with ADHD-RS 5 total score by having weak correlations at baseline for both parent ($r = .24$ to $p = .02$) and teacher ($r = .32$ to $p = .0004$) versions of SCAS.

Depression

Depression was evaluated using the Short Mood and Feelings Questionnaire (SMFQ), which is a parent-rated

scale. This validated scale assesses how a child has been "feeling lately" and is a screening tool for depression in children and young people aged 6 to 19. It is a 13-item questionnaire, with items such as "s/he felt s/he was no good anymore" and "s/he hated him/herself," that are answered on a 3-point Likert scale: "not true," "sometimes," or "true." The final score range is between 0 and 26 (calculated by taking the sum of the score for each individual item), with a higher score indicating increased levels of depressive symptoms. The SMFQ has been shown to have good internal reliability and content (Angold et al., 1995), convergent, and concurrent validity (Thabrew et al., 2018). In our sample, the SMFQ showed good internal consistency at baseline (Cronbach's alpha: .88) and moderate re-retest reliability (ICC = 0.68; 95% CI [0.58–0.76]). It also achieved convergent validity with the SDQ-Emotional subscale ($r = .63$ to $p < .0001$) and divergent validity with the SDQ-Prosocial subscale ($r = -.28$ to $p = .06$) at baseline.

Academic Performance

Academic performance was measured by teacher ratings of academic progress. The academic progress scale consisted of questions in different domains, including reading, writing, math, and other skills. Each item pertained to the student's competence on a particular academic topic (e.g., reading comprehension, word recognition, algebraic thinking, or achieving goals), with the option to indicate the student's level for that academic criterion on a Likert scale (e.g., low skill level, skill development, increasing independence, consistent independence with some support, consistent independence without support). Each academic progress scale was scored in a similar manner, where the final score was the sum of each individual items' score in the scale. All schools' academic progress scales had good to excellent internal consistency at baseline, with Cronbach alpha's of .93, .88, .93 for Schools A, B, and C respectively. They all showed moderate test re-test reliability, with ICCs of 0.63 (95% CI [0.53–0.72]), 0.52 (95% CI [0.29–0.74]), and 0.76 (95% CI [0.61–0.87]) for Schools A, B, and C respectively. At baseline, the academic progress score for School A (from where the majority of the study sample was derived), showed convergent validity with the reading/literacy component of Track My Progress ($r = .72$ to $p < .0001$), which is an online assessment of the Common Cores State Standards (an education initiative that adopted the same standards for English and math across a number of different states in the USA) for each student's grade level that is taken four times a year. All schools' academic progress scores achieved divergent validity with the SMFQ ($r = -.26$ to $p = .02$) at baseline.

ADHD

ADHD symptoms were measured using the ADHD-RS 5-Attention and Behavior Rating Form. This is a well-validated and reliable scale that measures the frequency and severity of ADHD symptoms and impairments in children and adolescents (DuPaul et al., 2016). It is an 18-item questionnaire, with both parent and teacher versions. Examples of items include "easily distracted" and "interrupts or intrudes on others," with an option to choose between "never/rarely," "sometimes," "often," or "very often." It has both an inattention (IN) subscale score (nine items) and a hyperactivity-impulsivity (HI) subscale score (nine items). The total scale score is the sum of the IN and HI sub score, with higher scores indicating increased levels of ADHD symptoms. We used the ADHD-IN subscale score to measure ADHD-IN in this study. In our sample, the ADHD-IN subscale score had excellent internal consistency (Cronbach's alpha: .92 for parent and .93 for teacher versions) at baseline and good test-retest reliability for parent (ICC = 0.81; 95% CI [0.75–0.86]) and moderate test-retest reliability for teacher (ICC = 0.67; 95% CI [0.59–0.74]) versions. The ADHD-IN subscale score achieved convergent and divergent validity in factor analyses with K-SCT as detailed above. It also achieved convergent validity with the Total Difficulties score of the SDQ for both parent ($r = .64$ to $p < .0001$) and teacher-reported ($r = .71$ to $p < .0001$) measures, and divergent validity with the 8-item SCAS (parent: $r = .24$ to $p = .02$; teacher: $r = .29$ to $p = .002$) at baseline.

Statistical Analysis

Baseline characteristics were summarized using descriptive statistics. Because the academic performance measures at each school had minor differences in scoring, we standardized all the total academic progress scores to obtain their z scores so that the scores from all students could be combined and analyzed together. We did this by first calculating the mean and standard deviation for each scale (i.e., academic progress scores for Schools A, B, and C). Then, for each datapoint for each measure, we calculated the z score by subtracting the mean from the raw score and dividing it by the standard deviation. As such, for each observation per participant, a normalized academic progress score was obtained at every timepoint. These z scores were thereafter used in all subsequent analyses involving academic progress. This method of combining academic progress scores across schools has been used in previous analyses and publications in this cohort (Hossain, Bent, et al. 2021; Hossain, Chen et al., 2021, 2021). In order to report the presence or absence of ADHD at baseline, we converted the ADHD-RS total score to a categorical variable (ADHD vs. no ADHD) using a cut-off score of 18 (Brown et al., 2011).

Both cross-sectional and longitudinal analyses were performed. First, we investigated the association between SCT (predictor variable) and all the outcomes (anxiety, depression, and academic performance) cross-sectionally at baseline, with parent-reported and teacher-reported SCT being analyzed separately. We also tested whether ADHD-IN

symptoms moderated these associations. As such, we used linear regression models, with each model being subsequently adjusted for the age and sex of the child, the time since they were enrolled at the school at baseline, as well as an interaction term of SCT and ADHD-IN. Therefore, a total of eight univariate (unadjusted) regression models and eight multivariate (adjusted) regression models were conducted.

Second, we investigated the association between change in SCT and change in outcomes (anxiety, depression, and academic performance) over time within an individual. Repeated measures analysis using linear mixed-effects models were used to assess this relationship. We defined "subject ID" as the major source of random effects, while time was coded as an ordinal variable (at each timepoint of measurement, and therefore had a range of 1–5). We accounted for the nesting of students within the schools by entering "school" as a random effect as well. We subsequently controlled for the age and sex of the child, their time at the school at each survey timepoint, as well as the interaction term of SCT and ADHD-IN (to test for effect moderation) in all models. Parent-reported and teacher-reported SCT were analyzed separately. The parent-rater for a given participant was constant throughout the study. However, 48% of the participants (those who had enrolled earlier) had two teacher-raters since this study spanned longer than one academic year. In order to account for this change, we controlled for the number of teacher-raters as well. A total of eight unadjusted linear mixed-effects models and eight adjusted linear mixed-effects models were conducted. We focused specifically on the within-subject association; to make sure that the measured change in variables was due to within-individual change rather than between-individual change, we decomposed the predictor variable (SCT) to two components: the mean and deviation. We then entered both pieces into the model as predictors, where the mean form represented between-cluster association between SCT and the outcome of interest, and the deviation form represented the within-cluster association. All results of the mixed-effects models report the deviation form of SCT to reflect the within-subject change.

Another variable that we took into consideration was the issue of how the ratings and potential associations could vary between elementary school students, who had one homeroom teacher, and middle to high school students, who had multiple teachers across subject areas. In order to keep the number of teacher-raters low and as consistent as possible, we only allowed one individual teacher to rate the participant for the duration of the academic year. Typically, this was their homeroom teacher. We encouraged and advised the teachers to consult one another when completing the surveys to get better insight on their student when they came across questions that they felt another teacher (for a different subject) may be able to answer better. To examine whether this approach led to a difference in ratings and association among elementary (grade 4 and lower) versus middle and high school students (grade 5 and above), we ran some sensitivity analyses. We ran two-tailed *t*-tests to compare the mean ratings for each outcome among the two groups at baseline. We re-ran all our cross-sectional and longitudinal analyses and adjusted for the moderating effect of this "school level" categorical variable on the associations of interest. For those showing a significant moderating effect, we specifically ran the adjusted analyses in the two different strata to compare the beta coefficients and direction of association of SCT with the outcome of interest.

Considering that this study took place during the Coronavirus Disease 2019 (COVID-19) pandemic, a sensitivity analysis examining the mean difference in outcomes before and after COVID-19 was conducted using paired *t*-tests for all measures in two ways: comparing scores in February 2020 and May 2020, and comparing the average scores prior to and including February 2020 and average scores including and after May 2020.

p-Values of less than .05 were considered statistically significant. All analyses were performed using STATA (version 15.1).

Results

Baseline Characteristics

The mean age ($\pm$ *SD*) of the participants was 11 $\pm$ 2 years, with the range being between 6 and 18 years. Males comprised 62.3% of the sample (Table 1). The mean $\pm$ *SD* scores for all measures (SCT, anxiety, depression, academic performance, ADHD-total, and ADHD-IN) at baseline are also provided in Table 1. When compared to previously published data from community samples, our study sample of children with RD had lower levels of anxiety and depression at baseline. The mean baseline 8-item SCAS (anxiety) scores in this sample (parent: $M=5.1$ to $SD=3.4$; teacher: $M=3.2$ to $SD=3.0$) were lower than that seen in a normative typically-developing population (parent: $M=5.7$ to $SD=3.7$; teacher: $M=3.4$ to $SD=2.9$) (Reardon et al., 2018) . Similarly, the mean SMFQ (depression) scores in this sample ($M=2.7$ to $SD=3.5$) were lower than a community sample ($M=3.2$ to $SD=3.7$) (Lerthattasilp et al., 2020). In contrast, the mean ADHD-IN subscale score at baseline for this sample (parent: $M=11.2$ to $SD=7.4$; teacher: $M=9.02$ to $SD=6.9$) was higher than a non-clinical sample of comparably-aged children (parent: $M=4.9$ to $SD=4.3$; teacher: $M=5.7$ to $SD=5.4$) but lower than an ADHD clinical sample (parent: $M=15.7$ to $SD=5.8$; teacher: $M=15.3$ to $SD=6.2$) (Dobrean et al., 2021).

According to both parent and teacher reports, approximately 35% of the cohort were above the cutoff of 18 and thus displayed the presence of ADHD symptoms at

Table 1. Sociodemographic Characteristics and Baseline Measures of Participants ($N = 147$).

Measure	*N*	%	Mean	*SD*
Age (years)	147	–	11.1	2.3
Sex				
Male	91	62.3	–	–
Female	55	37.7	–	–
Sluggish cognitive tempo (SCT)				
K-SCT–Parent	104	–	8.9	6.5
K-SCT–Teacher	125	–	11.9	9.8
Anxiety				
8-item Spence Children's Anxiety Scale–Parent	110	–	5.1	3.4
8-item Spence Children's Anxiety Scale–Teacher	126	–	3.2	3.0
Depression				
Short Mood and Feelings Questionnaire (SMFQ)	103	–	2.7	3.5
Academic performance (z scores)				
School A	86	–	−0.42	1.1
School B	19	–	−0.04	0.8
School C	25	–	−0.3	1.0
ADHD				
ADHD-RS 5–Parent	98	–	17.7	12.4
ADHD (Present)	34	34.7	–	–
ADHD-RS 5–Teacher	122	–	15.7	11.7
ADHD (Present)	43	35.0	–	–
ADHD-Inattention				
ADHD-RS 5 – Inattention–Parent	98	–	11.2	7.4
ADHD-RS 5 – Inattention–Teacher	122	–	9.02	6.9

Note. *Z* scores for the academic performance range are reported, with higher (less negative) scores indicating higher academic performance.

baseline. The sensitivity analysis examining the difference in mean outcomes at baseline between the two school levels showed no statistically significant differences in ratings by the elementary versus middle and high school teachers for all outcomes, except for academic performance, where upper year students ($M = 0.02$ to $SD = 0.9$) had a higher overall score compared to lower year students ($M = -0.89$, $SD = 0.9$, $t(124) = -5.4$, $p \leq .0001$). However, that could be a result of the age of the students rather than the quality of teacher-raters.

Cross-Sectional Analysis

In unadjusted analyses, teacher-reported SCT was significantly associated with teacher-reported anxiety ($p < .001$) at baseline. This positive association remained statistically significant after controlling for age and sex of the participant, time at school, and the interaction term with ADHD-IN ($p = .001$). There was also statistically significant evidence of effect modification of ADHD-IN on this association ($p = .02$), whereby the positive association between teacher-reported SCT and teacher-reported anxiety was only seen in individuals with lower (or no) ADHD-IN symptoms but not in individuals with higher levels of ADHD-IN symptoms (Figure 1). No significant association was found between SCT and anxiety, when measured by parents (Table 2).

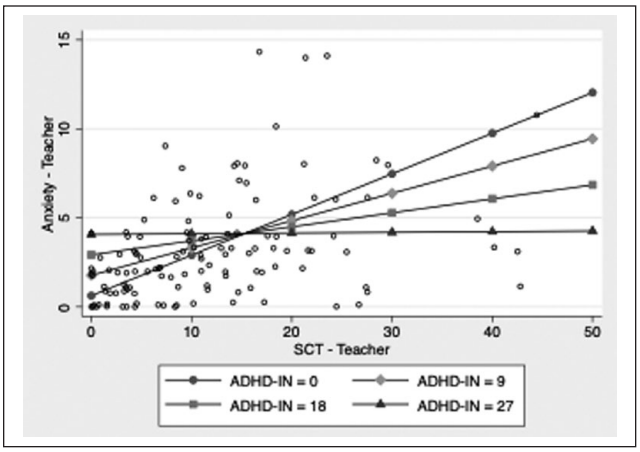

Figure 1. Cross-sectional associations at baseline between teacher-reported sluggish cognitive tempo (SCT) symptoms and teacher-reported anxiety (as measured by the 8-item Spence Children's Anxiety Scale) at different levels of Attention-Deficit/Hyperactivity Disorder-Rating Scale-Inattention (ADHD-IN) in children with reading disorder. The figure demonstrates the effect moderation of ADHD-Inattention subtype on the association.

However, the sensitivity analysis comparing elementary versus middle and high school students showed a significant adjusted association between teacher-reported SCT

Table 2. Crude and Adjusted Associations Between SCT and All Outcome at Baseline, Along With the Moderation Effects of ADHD-IN.

Measure		*N*	β	95% CI	*p*
Anxiety–Parent					
SCT–Parent	Unadjusted	104	.1	–0.001 to 0.2	.05
	Adjusted[a]	96	.15	–0.08 to 0.4	.2
	Moderation effect of ADHD-IN	96	–.01	–0.02 to 0.007	.4
SCT–Teacher	Unadjusted	90	.05	–0.03 to 0.2	.2
	Adjusted[a]	86	.09	–0.1 to 0.3	.3
	Moderation effect of ADHD-IN	86	–.01	–0.02 to 0.05	.3
Anxiety–Teacher					
SCT–Parent	Unadjusted	87	.01	–0.09 to 0.1	.9
	Adjusted[a]	82	.05	–0.18 to 0.27	.6
	Moderation effect of ADHD-IN	82	–.003	–0.02 to 0.01	.6
SCT–Teacher	Unadjusted	124	.12	0.07 to 0.17	<.001*
	Adjusted[a]	119	.23	0.1 to 0.4	.001*
	Moderation effect of ADHD-IN	119	–.01	–0.02 to –0.001	.02*
Depression					
SCT–Parent	Unadjusted	102	.17	0.07 to 0.27	.001*
	Adjusted[a]	95	.04	–0.19 to 0.3	.7
	Moderation effect of ADHD-IN	95	.005	–0.01 to 0.02	.4
SCT–Teacher	Unadjusted	87	.12	0.04 to 0.2	.002*
	Adjusted[a]	83	–0.01	–0.2 to 0.18	.9
	Moderation effect of ADHD-IN	83	.003	–0.01 to 0.01	.6
Academic performance					
SCT–Parent	Unadjusted	86	–0.03	–0.06 to 0.01	.1
	Adjusted[a]	81	–0.05	–0.13 to 0.02	.1
	Moderation effect of ADHD-IN	81	.001	–0.003 to 0.005	.5
SCT–Teacher	Unadjusted	126	–0.05	–0.07 to –0.03	<.001*
	Adjusted[a]	121	–0.05	–0.08 to –0.01	.01*
	Moderation effect of ADHD-IN	121	.002	–0.0001 to 0.004	.06

[a]Adjusted for age, sex, time at school (at baseline), and interaction with ADHD-IN.
*$p < .05$.

and parent-reported anxiety for elementary students (β = .13 to $p = .02$), but not for upper year students (β = −.02 to $p = .7$). There were no significant differences between school levels in any of the other associations of interest at baseline.

When examining the association between SCT and depression at baseline, the only significant relationship emerged in the unadjusted analyses, both when SCT was measured by parents ($p = .001$) and by teachers ($p = .002$). However, after adjusting for age, sex, time at school, and the interaction with ADHD-IN, these positive associations with depression were no longer statistically significant ($p = .7$–$.9$ for parent and teacher-reported SCT respectively).

Similar to the relationship with anxiety, teacher-reported SCT was significantly negatively associated with academic performance at baseline, which was also measured by teachers ($p < .001$ for unadjusted analysis and $p = .01$ after controlling for age, sex, time at school, and interaction with ADHD-IN). There was no significant interaction effect of ADHD-IN on the relationship, suggesting that ADHD-IN does not moderate the relationship between teacher-reported SCT and academic performance at baseline. Parent-reported SCT did not have any significant associations with academic performance.

Longitudinal Analysis

In unadjusted analyses, change in teacher-reported SCT was significantly associated with change in teacher-reported anxiety within an individual over time ($p < .001$). After adjusting for age, sex, time at school, number of teacher-raters, and the interaction term with ADHD-IN, teacher-reported SCT remained significantly and positively associated with teacher-reported anxiety, whereby every one-point increase in the SCT scale score was significantly associated with a .15-point increase in the anxiety scale score within an individual (Table 3). Like the cross-sectional analyses, there was a small but significant moderation effect of ADHD-IN on this longitudinal association ($p < .001$), whereby the positive association between

Table 3. Crude and Adjusted Associations Between SCT and All Outcomes Within Individuals Over Time, Along With the Moderation Effects of ADHD-IN.

Measure		*N*	β	95% CI	*p*
Anxiety–Parent					
SCT–Parent	Unadjusted	117	–.02	–0.1 to 0.04	.5
	Adjusted[a]	112	–.07	–0.2 to 0.07	.3
	Moderation effect of ADHD-IN	112	.003	–0.01 to 0.012	.5
SCT–Teacher	Unadjusted	115	.002	–0.04 to 0.05	.9
	Adjusted[b]	109	–.04	–0.14 to 0.05	.4
	Moderation effect of ADHD-IN	109	.001	–0.01 to 0.01	.7
Anxiety–Teacher					
SCT–Parent	Unadjusted	114	–.04	–0.12 to 0.04	.3
	Adjusted[a]	108	.07	–0.1 to 0.25	.4
	Moderation effect of ADHD-IN	108	–.01	–0.02 to 0.003	.1
SCT–Teacher	Unadjusted	143	.08	0.04 to 0.1	<.001*
	Adjusted[b]	137	.15	0.08 to 0.2	<.001*
	Moderation effect of ADHD-IN	137	–.009	–0.01 to –0.004	<.001*
Depression					
SCT–Parent	Unadjusted	117	.06	–0.03 to 0.15	.2
	Adjusted[a]	111	.05	–0.14 to 0.23	.6
	Moderation effect of ADHD-IN	111	.001	–0.01 to 0.01	.8
SCT–Teacher	Unadjusted	112	–.008	–0.06 to 0.05	.8
	Adjusted[b]	106	–.02	–0.14 to 0.11	.8
	Moderation effect of ADHD-IN	106	–.001	–0.01 to 0.01	.8
Academic performance					
SCT–Parent	Unadjusted	112	–.004	–0.03 to 0.02	.8
	Adjusted[a]	106	–.03	–0.09 to 0.03	.3
	Moderation effect of ADHD-IN	106	.002	–0.002 to 0.01	.2
SCT–Teacher	Unadjusted	144	–.03	–0.04 to –0.02	<.001*
	Adjusted[b]	138	–.03	–0.05 to –0.08	.008*
	Moderation effect of ADHD-IN	138	.002	0.0002 to 0.003	.03*

Note. This table summarizes the results of 16 mixed-effects models.
[a]Adjusted for age, sex, time at school, and interaction with ADHD-IN.
[b]Adjusted for age, sex, time at school, number of raters, and interaction with ADHD-IN
*$p < .05$.

teacher-reported SCT and teacher-reported anxiety was only seen in individuals with lower (or no) ADHD-IN symptoms, but not in individuals with higher levels of ADHD-IN symptoms (Figure 2a). No significant associations were found between changes in SCT and anxiety over time, when either (or both) measures were evaluated by parents.

Similarly, change in SCT was significantly and negatively associated with change in academic performance within an individual, only when SCT was measured by teachers but not when it was measured by parents, in both unadjusted and adjusted analyses ($p < .001$ and $p = .008$ respectively). After adjusting for age, sex, time at school, number of teacher-raters, and interaction with ADHD-IN, a one-point increase in SCT score corresponded to a 0.03 *SD* decrease in academic performance score. Contrary to what was seen in the cross-sectional analyses, however, ADHD-IN showed a small but significant effect modification on the longitudinal relationship ($p = .03$), whereby the negative association between SCT and academic performance was seen in individuals with lower levels of ADHD-IN but not in individuals with higher levels of ADHD-IN (Table 3; Figure 2b).

There were no significant longitudinal associations between SCT and depression. In the sensitivity analysis comparing the longitudinal associations among elementary versus middle and high school students, we did not observe any significant difference in the associations of interest between the two strata.

Discussion

The impact of SCT on internalizing symptoms and academic functioning has been a topic of investigation in a number of studies in the past. However, very few have examined it in the context of RD. Considering the increased challenges faced by children with RD (including being at a higher risk for anxiety disorders, depression, and academic

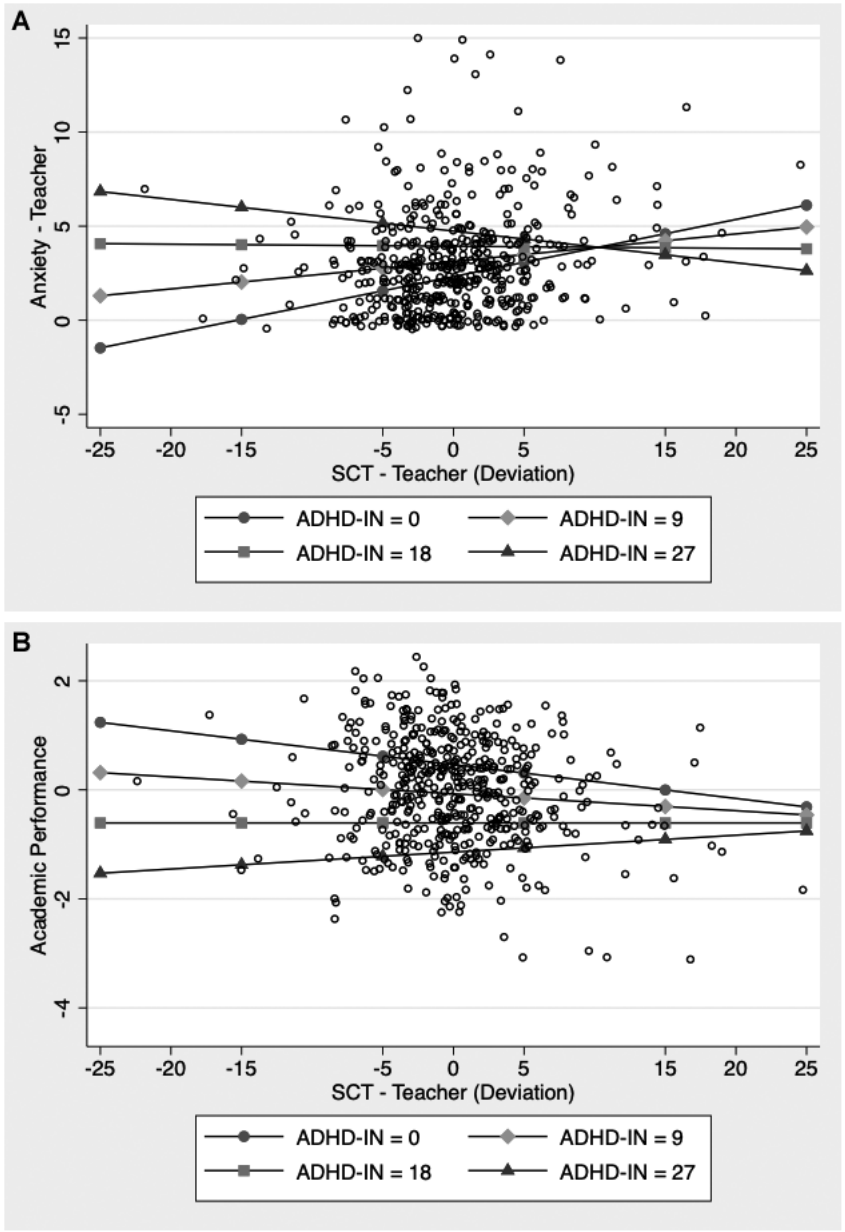

Figure 2. Longitudinal within-subject associations between teacher-reported sluggish cognitive tempo (SCT) symptoms and (a) teacher-reported anxiety (as measured by the 8-item Spence Children's Anxiety Scale); (b) academic performance among children with reading disorder. The associations are shown at different levels of Attention-Deficit/Hyperactivity Disorder-Rating Scale-Inattention (ADHD-IN), demonstrating the effect moderation of ADHD-Inattention subtype on the associations.

challenges), we sought to examine SCT's associations with these outcomes in the RD population in a longitudinal cohort study. In addition, given that RD and ADHD are frequently comorbid, we also examined whether the presence of ADHD-IN symptoms, which is the type of ADHD that is more strongly associated with SCT, moderated the strength of any potential associations. Our results showed that teacher-reported SCT was significantly associated with teacher-reported anxiety and academic performance, both cross-sectionally and over time, and that these relationships were moderated by the level of ADHD-IN symptoms, whereby significant associations between SCT and the outcomes were seen in individuals with low levels of ADHD-IN but not in individuals with high levels of ADHD-IN. Importantly, the longitudinal findings indicate that an improvement in an individual's SCT is associated with an

improvement in their anxiety and academic performance, particularly among those who do not have ADHD-IN and only have RD. SCT was not significantly associated with depression in our sample.

Our results are consistent with previous studies that demonstrate associations between SCT and anxiety, and between SCT and academic performance in both typically developing and ADHD populations including children, adolescents, and young adults (Becker et al., 2016; Bernad et al., 2016; Camprodon-Rosanas et al., 2017; Smith & Langberg, 2017; Vu et al., 2019). Furthermore, our results extend the findings of previous studies by demonstrating both cross-sectional and longitudinal associations between SCT and anxiety and/or academic performance specifically in persons with RD. Although the associations between change in SCT and change in anxiety and AP were significant, the effect sizes observed during the study period were small. It is important to note, however, that none of the students in the study were receiving interventions specifically for SCT. Future studies in the RD population should determine if specific interventions are able to lead to improvements in SCT and whether this will also result in large improvements in anxiety and AP.

Interestingly, we did not find any associations between SCT and depression in our sample, which contradicts the findings of many other studies that have shown a relationship between higher levels of SCT symptoms and increased depression (Becker et al., 2021; Bernad et al., 2014, 2016; Burns et al., 2017; Mayes et al., 2021; Ward et al., 2019). One reason for the lack of an association between SCT and depression in our sample may be that the participants had relatively low levels of depression. Indeed, at baseline, the depression scores on average in this sample (mean SMFQ = 2.7) were lower than that seen in a typically developing normative population (mean SMFQ = 3.2) (Lerthattasilp et al., 2020). One possible explanation for the lower depressive symptoms in the current study is that the children with RD had recently enrolled in specialized schools where they had a more supportive environment and therefore a more optimistic vision of the future.

While both our cross-sectional and longitudinal findings showed associations between SCT and anxiety and academic performance (in individuals with low levels of ADHD-IN), it should be noted that that the observed associations depended on the evaluator of SCT and/or anxiety. Notably, we found increased SCT to be associated with increased anxiety and reduced academic performance only when these variables were measured by teachers but not when they were measured by parents. Although the issue of measurement bias may come to mind, there is no reason to believe that the teachers would have systematic bias (e.g., reporting higher anxiety score when they observe higher SCT symptoms). Rather, these results could indicate an inherent aspect of SCT that differs depending on the context (school vs. home). Indeed, one possible reason why associations were observed only among teacher-reported measures is that schoolwork requires more sustained concentration and effort in school-based cognitive tasks (e.g., math problems, reading a paragraph, responding to a prompt, etc.) compared to the tasks performed by a child at home. As such, if a child has elevated levels of SCT, teachers may have more opportunity to observe challenges related to SCT symptoms compared to parents. In addition, teachers have the advantage of comparing the child to the many other students in the class (who may or may not display SCT) whereas parents generally have a much more limited sample of children to "calibrate" their rating of SCT. This possibility is supported by the finding that the average teacher-reported SCT score (11.9 ± 9.8) at baseline is higher than the parent-reported score (8.9 ± 6.5) in our sample.

Previous studies examining the relationships between SCT and internalizing symptoms and academic impairment have used parent (Camprodon-Rosanas et al., 2017; Ekinci et al., 2021; Jacobson et al., 2018; Lee et al., 2017), teacher (Becker et al., 2021; Bernad et al., 2014, 2016; Vu et al., 2019, and self-reports (Frederick et al., 2019, 2020) of SCT, or a combination of evaluators (Burns et al., 2017; Servera et al., 2018; Smith & Langberg, 2017). There is some evidence that teacher-reported SCT may be more consistently linked to psychopathology dimensions than parent-reported SCT (Becker, 2021), or that teachers may be more equipped to distinguish SCT from ADHD (Burns et al., 2017; Servera et al., 2018; Tamm et al., 2018). However, this is by no means proposing that parent reports of SCT are not useful. Indeed, there is a large body of work demonstrating how parent-reported SCT is associated with impairment, including global, social, and academic (Becker et al., 2015), sometimes even more than teacher ratings. Further research is required to determine differences in rater evaluations in the context of SCT. However, our results as well as those from previous studies support the value of using multiple raters (including teachers) for SCT, since it offers different perspectives and provides information on how SCT manifests in different contexts (Tamm et al., 2018). Considering that there is no nationally normative data for teacher-reported SCT (Becker, 2021), this may be an area that warrants further research.

In the current study, we not only investigated the associations between SCT and our outcomes of interest, but we also examined whether the presence of ADHD-IN symptoms moderated these relationships. We found significant evidence of effect modification of ADHD-IN for cross-sectional and longitudinal associations of SCT with anxiety and for longitudinal association of SCT with academic performance in children with RD. Specifically, we observed that in individuals with very low levels of ADHD-IN symptoms, teacher-rated SCT had significant associations with

teacher-rated anxiety and academic performance, but that these associations were not seen in individuals with high levels of ADHD-IN. While previous studies and even our own factor analysis demonstrate SCT to be a distinct construct from ADHD-IN, this finding contradicts previous studies, which increasingly point to SCT's independence from ADHD-IN in the context of internalizing symptoms and academic progress, and suggests that there is some form of overlap between the two, where ADHD-IN status influences SCT's relationships with these outcomes. However, it should be kept in mind that to our knowledge, prior studies examining these associations did not investigate the moderating effect of ADHD-IN but rather controlled or adjusted for ADHD-IN or ADHD symptoms to demonstrate that SCT *uniquely* predicted internalizing symptoms and/or academic impairment. (Becker et al., 2020; Bernad et al., 2014, 2016; Burns et al., 2017; Lee et al., 2017; Saez et al., 2019; Vu et al., 2019). One possible explanation of our results could be ADHD-IN and SCT present as symptom clusters, with the primary one being inattention, rather than two firm diagnoses based on distinct symptoms. Indeed, a study by Barkley (2013) found that 59% of participants qualifying for SCT also had ADHD, while 39% of children qualifying for ADHD also had SCT. As such, in RD individuals with high levels of ADHD-IN symptoms, the ADHD-IN might have "eclipsed" any SCT symptoms they may have exhibited, which is why we did not find any associations of SCT with anxiety and academic performance.

The relationship between SCT and ADHD-IN has important implications for treatment. Because SCT generally appears to be a distinct construct from ADHD, SCT may not always improve or respond to ADHD treatment. There have been very few studies investigating treatments and therapies for SCT, and to our knowledge they have all been examined in ADHD populations with comorbid SCT. In a study among adolescents with ADHD, two school-based ADHD interventions (organizational skills and homework completion interventions) led to significant improvements in parent-reported SCT (but not self-reported SCT) compared to the control group (Smith & Langberg, 2020). Methylphenidate (a stimulant for treating ADHD) was shown to improve SCT scores among children with ADHD both at home and at school in an open-label trial (Fırat et al., 2021). Lisdexamfetamine, approved for use in adults with ADHD, also showed improvements in SCT in a placebo-controlled trial (Adler et al., 2021). While it is promising that these ADHD treatments also led to improvements in SCT, it is important to keep in mind that these studies were exclusively conducted among individuals with ADHD. As such, we do not know whether these treatments will be beneficial in community samples or in other populations with SCT (e.g., RD, autism, trauma, etc.). Therefore, there is a pressing need to identify effective treatments for SCT in populations without ADHD. Considering that our findings indicated an impact of SCT on internalizing symptoms and academic impairment in RD individuals with low (but not in RD individuals with high) levels of ADHD-IN, this further emphasizes the need for targeted treatment for SCT in non-ADHD populations.

One important aspect of this longitudinal study to keep in mind is that the study dates included the onset and continuation of the Coronavirus Disease 2019 (COVID-19) pandemic. In addition to the devastating global impact of the disease itself (pertaining to the cases, hospitalizations, and deaths), COVID-19 has also had impact on the mental health of individuals, including children and adolescents. Indeed, multiple studies since the start of the pandemic have consistently shown that children and adolescents have faced higher rates of anxiety and depression (Deolmi & Pisani, 2020; Marques de Miranda et al., 2020; Panchal et al., 2021; Panda et al., 2021; Pfefferbaum, 2021; Śniadach et al., 2021), as well as increased levels of anger (Panchal et al., 2021), irritability, inattention (Panda et al., 2021), and post-traumatic stress (Marques de Miranda et al., 2020) as a result of the COVID-19 pandemic, with children with pre-existing problems or conditions being especially vulnerable (Panchal et al., 2021; Panda et al., 2021; Pfefferbaum, 2021). One study looking at the psychoeducational challenges of children with dyslexia found that they had increased symptoms of depression and state anxiety, more emotional difficulties, conduct problems, hyperactivity-inattention, and reduced reading activity and reading motivation (Soriano-Ferrer et al., 2021). Another study showed that reading skills among children with dyslexia improved less than expected during the pandemic (Baschenis et al., 2021).

In the context of this study population, in response to local COVID-19 lockdown measures to maintain the safety of their students and staff, the schools switched to virtual/remote learning in March 2020, then to a hybrid model (with 3 days of in-person schooling and 2 days of remote learning) in November 2020 and finally went back to fully in-person schooling shortly after the end of the study in April 2021 as the situation improved. As such, three (out of the five) survey timepoints were affected by the pandemic. To see whether COVID-19 and the various types of schooling affected our study measures, especially internalizing symptoms, we compared the pre-COVID and post-COVID means both immediately at the onset of the pandemic (February 2020 vs. May 2020) and the average scores before and after March 2020. In all but one case, there were no statistically significant differences in the pre-COVID and post COVID scores for all measures, including anxiety and depression (Supplemental Table 1). Only academic performance showed a significant difference, namely an *improvement* in the average scores post-COVID, which may reflect the natural improvement in the students' academics as they aged,

rather than a beneficial impact of COVID-19. Considering that there was no significant impact of COVID-19 on our study measures, we decided not to include that as a confounder in our analyses.

This study has several limitations. First, the academic progress scales used in the three schools had minor scoring and wording differences, although the questions covered the same content areas. We attempted to address these minor differences by normalizing the scales to their *z* scores, which allowed us to effectively combine the scores and analyze them together. Another point to keep in mind is that the types of interventions received for reading varied from school to school (Supplemental Table 1), which may have impacted the outcomes and study results. Another limitation was that our measure of SCT, the K-SCT Rating Scale has not been formally validated in an RD population. However that aspect is true for almost all scales used to measure SCT, which have only been validated in school, community, or ADHD samples (Becker, 2021). We decided to choose the K-SCT Rating Scale because it has well validated psychometric properties and has both parent and teacher versions. In addition, we did not have access to the information about the severity of RD or any formal diagnosis of ADHD or other comorbidities that these participants may have had. However, we used a cutoff score of the ADHD-RS total score to get an estimate of the presence of ADHD in this study population at baseline. Also, not all participants were in the study for all five survey periods, so the power in the longitudinal analyses was less than the cross-sectional baseline analyses. Finally, there was some missing data because of some data points being dropped due to incomplete questionnaires. This was better accounted for in the longitudinal analysis with the mixed-effects models, which is better at handling missing data compared to other methods for repeated measures analyses.

This is the first prospective cohort study to show an association between SCT and anxiety and academic performance in children with RD, both cross-sectionally and over time, and to show that these relationships are moderated by ADHD-IN symptoms. Considering that individuals with RD struggle with academic challenges and higher rates of internalizing symptoms, these results imply that having SCT may further exacerbate these outcomes, particularly among those *without* ADHD-IN. Our findings suggest that intervention programs or therapeutics specifically targeted to improve SCT (not just ADHD) should be developed for the RD population, which may then have the potential to improve academic performance and mental health as well.

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Supplemental Material

Supplemental material for this article is available online.

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Matthew Davis received his BS in Psychology from Santa Clara University in 2018. Since then, he has worked as lab manager at the University of California, San Francisco in Dr. Hendren and Fumiko Hoeft's brainLENS lab. During his time there, he has worked on several NIH R01 grants exploring the neural and behavioral mechanisms of language. His primary research focus has been on the relationship between sluggish cognitive tempo and learning disorders, particularly dyslexia and ADHD. He has presented multiple posters on this topic. He is currently a Clinical Trial Assistant at Global Blood Therapeutics, where he researches treatments for sickle cell disease.

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