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The Effect of Neurocognitive Function on Math Computation in Pediatric ADHD: Moderating Influences of Anxious Perfectionism and Gender

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Abstract

Predictors of math achievement in attention-deficit/hyperactivity disorder (ADHD) are not well-known. To address this gap in the literature, we examined individual differences in neurocognitive functioning domains on math computation in a cross-sectional sample of youth with ADHD. Gender and anxiety symptoms were explored as potential moderators. The sample consisted of 281 youth (aged 8–15 years) diagnosed with ADHD. Neurocognitive tasks assessed auditory-verbal working memory, visuospatial working memory, and processing speed. Auditory-verbal working memory speed significantly predicted math computation. A three-way interaction revealed that at low levels of anxious perfectionism, slower processing speed predicted poorer math computation for boys compared to girls. These findings indicate the uniquely predictive values of auditory-verbal working memory and processing speed on math computation, and their differential moderation. These findings provide preliminary support that gender and anxious perfectionism may influence the relationship between neurocognitive functioning and academic achievement.

Keywords

ADHD; Anxiety; Neurocognitive function; Math achievement; Working memory

Introduction

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder that affects between 5 and 10% of school-age youth [1, 2]. ADHD is associated with significant impairment in academic, social, and family functioning that can persist well beyond childhood. Youth with ADHD underachieve in school compared to their typically-developing peers as early as first grade [3], and continue to exhibit poorer academic skills, report card ratings, standardized test performance, and more failed grades through secondary

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school (e.g., [4, 5]). While core symptoms of ADHD (e.g., inattention, hyperactivity, impulsivity) are known to decrease over time [6], children with ADHD do not catch up academically with their typically-developing peers over time, demonstrating lower rates of high school graduation [7], post-secondary education, and occupational attainment [8]

Much of the academic achievement literature in youth with ADHD has focused on reading achievement [9–11]. In contrast, math achievement remains relatively understudied. While the reading gap between students with and without ADHD shrinks during adolescence, the math achievement gap widens [12]. Children who struggle early on to learn math have later difficulties in processing basic math principles, which places them at a distinct disadvantage long-term [13]. The study of math achievement in ADHD-affected youth is especially relevant, given that math has practical importance for many aspects of independent living and predicts occupational attainment regardless of high school completion [14]. Indeed, as compared to reading ability, math ability in adolescence more strongly predicts socioeconomic status 35 years later for both men and women [15].

ADHD, Math Achievement, and Neurocognitive Dysfunction

Youth with ADHD often suffer from well-characterized neurocognitive deficits relevant to math learning, particularly in areas of processing speed and working memory [16–18]. In fact, measures of intellectual functioning have been adapted to allow omission of processing speed and working memory indices due to the often depressed scores in these domains among children with ADHD (e.g., General Ability Index; [19]). Moreover, indices representing processing speed and working memory are the most powerful neurocognitive predictors of learning disability in children with ADHD [20]. Recent findings indicate that processing speed may be particularly important to a child’s success or lack thereof in the classroom [21]. Children with ADHD demonstrate slower processing speed, which impacts their task fluency and academic performance [22]. Despite the pronounced deficits in working memory and processing speed among children with ADHD, we know very little about the relative contributions of these domains (and their putative moderators) to math achievement. Said differently, it is yet unclear whether working memory and processing speed are equally important to math achievement, and whether these neurocognitive indices are impaired for all, or only some, ADHD-affected youth.

Anxiety and Gender as Moderators of the Relationships Between ADHD and Math Achievement?

Phenomenological investigations of ADHD have identified demographic (i.e., gender) and clinical (i.e., anxiety) features that may influence neurocognitive and academic performance [7, 23], with effects differing by outcome domain. In children with ADHD, gender differences do not emerge on working memory tasks [24, 25] or math abilities [26, 27], with working memory operating as an established predictor of math achievement in both typically-developing and ADHD samples [28–30]. However, girls obtain higher scores on processing speed measures than boys [23, 26] and, as described above, processing speed impacts academic task performance [21]. Interestingly, processing speed is considerably affected by trait anxiety [31]. Yet, despite these findings, the literature has not yet tested the

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respective influences of gender and anxiety on the relationship between neurocognitive abilities and math achievement in ADHD.

Anxiety symptoms and disorders are also the most common comorbidity in pediatric ADHD (e.g., [32]) next to disruptive behavior disorders. As described above, anxiety is associated with greater impairment in response speed and motor speed in children with ADHD [33]. Therefore, among children with ADHD who are already at risk for deficits in processing speed, the effect of anxiety may result in additive impairment in math achievement. Moreover, anxiety is a construct comprised of multiple domains, not all of which may be relevant to achievement (e.g., concerns about separation from parent at night are unlikely to extend to the classroom, while perfectionism concerns may impact a child's perseveration on correct answers and interfere with timed-task performance). Given the gender differences in ADHD, 3:1 in population-based studies (2:1 boys to girls in population-based studies; [34]), and anxiety (1:2, boys to girls; [34]) diagnoses, anxiety may play an important role in the impact of neurocognition on math performance in youth with ADHD. Therefore, in this empirical investigation, we specifically sought to examine the potential influences of gender and anxiety on the relationship between processing speed and math achievement in pediatric ADHD.

Clinical Relevance and the Present Study

What is the clinical relevance of exploring predictors and moderators of math achievement in youth with ADHD? While evidence-based pharmacological and behavioral interventions that address the core symptoms of ADHD have been associated with short-term increases in academic achievement for one to two years as measured by standardized tests [35], these interventions do not generate any acceleration in academic acquisition after the early improvement [36, 37]. This leaves affected youth in the lower range of educational attainment than those without ADHD [36, 37]. Thus, experts have called for additional research to identify the underlying neurocognitive deficits (e.g., working memory and processing speed) and associated characteristics that might be more directly targeted to improve the real world academic and occupational outcomes of ADHD-affected children and adolescents [38, 39].

Therefore, the goals of this study were to address current gaps in the literature in regards to identifying predictive and interactive roles of neurocognitive processes, gender, and anxiety associated with math computation deficits in a cross-sectional sample of youth diagnosed with ADHD. Specifically, our aims were to test neurocognitive predictors (i.e., processing speed, working memory) of math computation, and explore gender and anxiety (in particular, anxious perfectionism and anxious coping) as potential moderators of this relationship. First, consistent with prior literature, each gender and anxiety have been individually associated with deficits in processing speed [23, 25, 40]. Second, anxiety appears to protect against the detrimental effects of ADHD [33, 41]. Third, poorer working memory and processing speed have been associated with lower math computation [28, 29]. Based on each of these findings, we hypothesized that each of these variables would significantly contribute to our final model (main effects). As prior studies have only examined the influence of a single variable on either processing speed or math achievement (i.e., main effects), the literature on how these variables might interact to influence achievement are lacking. Testing these variables (i.e., gender, neurocognitive performance, anxious perfectionism) in the same model may have implications for understanding underlying processes that influence math achievement in ADHD, as well as clinical implications for identifying subsets of youth who have acute impairment in math achievement. Thus, we also made exploratory hypotheses that we might find interactions between gender, anxious perfectionism and/or coping, and neurocognitive performance in predicting math computation. Specifically, given that anxiety has been associated with each slower processing speed and poor academic performance, and that girls demonstrate on average faster processing speed relative to boys (thereby potentially protecting against the negative effects of anxiety on math performance), we hypothesized that boys with high levels of anxiety and low processing speed would demonstrate the poorest performance on a timed math computation task.

Methods

Participants

Participants were 281 children and adolescents ages 8–15 recruited by an NIMH-funded center supporting translational research to enhance cognitive control (ClinicalTrials.gov Identifier: NCT00429273; [42]). This project investigated the differential effects of several medication treatments on symptom, cognitive, and biological endpoints, such as cognitive control in ADHD and in chronic tic disorders. Youth were recruited from the greater Los Angeles area through flyers, radio ads, and school and health practitioner referrals. For the purpose of the current study, baseline measures were used and participants were not taking medications when assessed.

Demographics and relevant descriptive statistics are presented in Table 1 for the full sample and by gender. Participants were 70% male, ages 8–15 (M = 10.46, SD = 1.94), 24.9% self-identified as ethnic minority (Hispanic/Latino), and 29.4% identified as racial minority (16.7% African American, 0.3% Hawaiian/Pacific Islander, 7.1% Asian, 5.3% other). One-third of the sample had a comorbid externalizing disorder (ODD or CD) and one-third a comorbid anxiety disorder (specific phobia, GAD, social phobia, separation anxiety). Approximately 3% of the sample exhibited a > 2 standard deviation discrepancy between a full scale IQ estimate and math computation, which would suggest the presence of a math learning disability.

Procedure

Prior to initiation of any study procedures, all participants and their parents provided written informed consent and assent and parental permission under procedures approved by the university Institutional Review Board. Participants met the following criteria: (a) full diagnostic criteria for ADHD Inattentive type (ADHD-I) or ADHD Combined type (ADHD-C), (b) CGI-S ≥ 4, (c) IQ ≥ 70 as estimated by the two subscale Wechsler Abbreviated Scale of Intelligence [43], and (d) completed the assessment battery relevant for this study. The assessment was completed in a single clinic visit and consisted of self- and parent-report questionnaires and a neuropsychological assessment battery. It was decided a priori that youth with a diagnosis of predominantly hyperactive/impulsive ADHD would be excluded from the current analysis given that prior work has found hyperactivity/impulsivity to have little predictive value for any neurocognitive domain [44]; for this reason, three children enrolled in the original study with the ADHD-hyperactive/impulsive subtype were excluded from the present investigation. Cognitive measures were administered by bachelor-level research assistants who were trained and supervised by a licensed psychologist.

Diagnostic Evaluation

ADHD diagnoses were determined using the Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version (K-SADS-PL; [45]). The K-SADS-PL is a well-validated semi-structured diagnostic interview of present and lifetime psychopathology in children and adolescents that are reflective of DSM-IV-TR diagnoses [45]. The K-SADS-PL was conducted with parent and child separately by a licensed psychologist, or advanced doctoral students in clinical psychology supervised by a licensed psychologist. Each case was presented to a consensus panel consisting of a senior child psychiatrist and child psychologist.

Neurocognitive Domains

Neurocognitive function was operationalized by two domains: working memory and processing speed. The specific tasks selected were those that have empirical support as areas of deficit in youth with ADHD [18, 46] and are important for achievement in math [47]. Tasks were included as individual predictors rather than indices due to the established need for a greater understanding of the respective contributions of working memory components from individual tasks [29]. Age-corrected standard scores were calculated, per WISC-IV scoring rules.

Working memory was assessed with the two subtests of the Wechsler Intelligence Scale for Children—Fourth Edition (WISC-IV; [48]), and one supplementary measure from the WISC-IV Integrated Battery (Spatial Span Backward; [48]). In the Digit Span Backward subtest, children are required to repeat 2–9 digits backwards. In Letter-Number Sequencing, children reorder a string of alternating numbers and letters into letters in alphabetical order and numbers in numeric order. In Spatial Span Backward, the child first watches the experimenter touch a series of blocks in different spatial locations and then responds by touching the reverse pattern of spatial locations, with an increasing number of blocks in each trial. As in other investigations, in this study Digit Span Backward and Letter-Number Sequencing were used to assess auditory-verbal working memory, while the Spatial Span Backward subtest was used to assess visuospatial working memory (e.g., [16, 18, 20, 24]). Scaled scores were used for each subtest.

Processing speed was assessed with the WISC-IV Coding subtest scaled scores, in which a key is presented to the child that pairs numbers and symbols. The child was then given 2 min to write the corresponding symbol below 90 numbers presented in a grid. Coding measures visual-motor processing speed and complexity, as well as motor coordination and working memory.

Abbreviated Full-Scale IQ (FSIQ) was used as a covariate in analyses and, as in other studies assessing cognitive functioning in youth, was calculated from the Vocabulary and Matrix Reasoning subtests of the Wechsler Abbreviated Scale of Intelligence (WASI; [43]), with standard scores calculated. A brief estimate of FSIQ was included to control for variability in intellectual functioning characterized by only the domains less susceptible to the presence of neurodevelopmental disorders (i.e., verbal comprehension and perceptual reasoning; [19]).

Anxiety

Anxiety symptoms from selected domains (described further below) were assessed using the Multidimensional Anxiety Scale for Children (MASC; [49]). The MASC is a 39-item, 4-point Likert, rating scale completed by youth. Items across four subscales are rated on a 4-point scale from 0 (“Never true about me”) to 3(“Often true about me”), which are summed for a total score, as well as subscale scores assessing harm avoidance (perfectionism, anxious coping subscales), social anxiety (humiliation/rejection, public performance subscales), physical symptoms, and separation anxiety. The MASC is well-validated and has demonstrated robust psychometric properties in community and clinical samples, including in youth with ADHD diagnoses (e.g., [50, 51]).

We elected to use subscale, rather than total MASC, scores in order to specifically examine the respective contributions of four anxiety domains that might have particular relevance to neurocognitive performance and/or math computation (anxious perfectionism, anxious coping, humiliation, and public performance). Other subscales from the MASC (i.e., physical symptoms and separation anxiety) were excluded due to their theoretical irrelevance to the constructs under study. In all analyses, MASC subscale raw scores were used, rather than age- and gender-corrected t-scores, as gender was an a priori primary predictor in analyses. Therefore, interpretation of results corresponds to unit change in anxiety symptoms from that subscale rather than t-score change. Cronbach’s alpha in this sample was .41 for perfectionism, .60 for anxious coping, .85 for humiliation/rejection and .62 for public performance.

Math Computation

Math computation was the primary outcome, as measured by the Wide Range Achievement Test, 4th Edition (WRAT4) Math Computation subtest standard score, which is a well-validated measure of math computation [52] and, as in other research studies (e.g., [53, 54]), was used in this investigation as a measure of general mathematical academic skills. This subtest is a 15 min task in which the individual completes a series of paper and pencil math problems of increasing difficulty. In the present study, the term math computation is used to refer to specific analyses and outcomes in this investigation. In contrast, the term math achievement is used to refer to prior findings from the literature that specifically assess achievement and/or when we refer to a child’s placement in classrooms, grades, participation in math courses in college, job selection, etc.

Statistical Analyses

An alpha level of .05 was used for all statistical tests. Corrected tests for unequal variances were used when appropriate based on Levene's test for equality of variances. Pearson Chi square tests were run to determine gender differences in rates of any anxiety or externalizing diagnosis, or ADHD subtype; no between-group differences were found for comorbid externalizing disorder or ADHD subtype. Independent samples t-tests were conducted to determine group differences by gender on variables of interest. Prior to conducting analyses, we explored the distribution of each study variable. To address our primary aim, multiple regression was conducted to examine the effects of anxiety as a potential moderator of the relationship between neurocognitive task performance and math computation scores.

Age, WISC-IV standard scores, and FSIQ were grand mean centered. Covariates (age, FSIQ), neurocognitive predictors for working memory (Digit Span Backward, Letter-Number Sequencing, Spatial Span Backward) and processing speed (WISC-IV Coding), anxiety (perfectionism, anxious coping, humiliation/rejection, public performance), and gender, as well as all two-way interactions were entered into a simultaneous multiple regression model predicting math computation outcome (WRAT4 Math Computation). Per a priori hypotheses, three-way interactions were also included in the initial model and subsequent models for simple effects when significant. Regression parameter estimates and significance were evaluated to determine which variables were statistically significant in the prediction of math computation scores. Residual plots were also examined to determine the validity of multiple regression assumptions.

The final reduced model only included significant higher order and respective lower order interactions and individual predictors. Although not statistically significant, age and visuospatial working memory (Spatial Span Backward) were retained in the final model as predictors of math computation scores, given their theoretical importance and prior empirical support for these variables as relevant to math achievement [12, 28]. Finally, post-hoc probing of the three-way interaction was conducted using standard convention (e.g., [55]). Simple slopes were calculated for low and high (± 1 SD) values of perfectionism and statistical significance of slopes at one standard deviation above and one standard deviation below the grand mean level of anxious perfectionism were evaluated to determine at what level of anxious perfectionism the interaction between Coding and gender was significant.

Results

Characteristics of the Sample

As would be expected, girls in this sample met for significantly more comorbid anxiety diagnoses relative to boys (X^2 (1, N = 281) = 9.644, p = .002). There were no significant differences between girls and boys on any MASC subscales, age, FSIQ, or symptoms of inattention and hyperactivity (see Table 1). The only gender differences on neurocognitive variables indicated that girls performed significantly better on WISC-IV coding compared to boys (t(270) = −2.531, p = .012). Bivariate Pearson correlations are provided in Table 2.

Anxiety Moderates Relationship Between Neurocognitive Domains and Math Computation

First, per our hypotheses, a full regression model was run to determine significant main and interaction effects. Results revealed a three-way interaction between the MASC anxious perfectionism subscale, WISC-IV Coding, and gender (β=0.14, p=.01). See Table 3 for the final reduced regression model. WISC-IV Letter-Number Sequencing (β = .334, p < .001) and Digit Span Backward (β = .121, p = .019) also predicted performance on WRAT4 Math Computation, even when controlling for the significant effects of FSIQ (β = .339, p < .001). WISC-IV Spatial Span Backward provided no significant prediction of WRAT4 Math Computation through main effect or interaction (β = −.034, p=.522). Neither main effects nor interaction effects for the anxious coping, public performance, and humiliation/rejection subscales were significant and thus were excluded from the final model.

Finally, the three-way interaction was probed post-hoc based on standard guidelines and convention [55] at ± 1 standard deviation (SD) of anxious perfectionism (MASC). There was a main effect of WISC-IV Coding, such that WISC-IV Coding was a significant predictor of WRAT4 Math Computation at low (*−1 SD;* β = .45, p<.001) and mean levels (β=.25, p<.001) of anxious perfectionism, however was no longer a predictor at high levels of anxious perfectionism (+ *1 SD;* β = .05, p = .50). In regards to the three-way interaction, at low levels of perfectionism (*−1 SD*), slower performance on the WISC-IV Coding predicted poorer WRAT4 Math Computation for boys, as compared to girls (simple slope β=−.282, p=.001), but not at the mean value of anxious perfectionism (simple slope β=−.100, p=.087) or 1 SD above the mean (simple slope β=.083, p=.392). In visual examination of simple slopes (Fig. 1), Coding did not appear to affect WRAT4 Math Computation for girls at low levels of anxious perfectionism. However, level of anxious perfectionism did appear to impact the relationship between Coding and WRAT4 Math Computation for boys.

Discussion

The current study sought to delineate the potentially unique and independent contributions of two neurocognitive domains—processing speed and working memory—on math computation scores in a sample of youth with ADHD. We also specifically explored the potential main effects and/or moderating roles of gender and self-reported anxiety symptoms. Consistent with hypotheses, auditory-verbal working memory significantly predicted math computation scores. Of the auditory-verbal working memory tasks, Letter-Number Sequencing demonstrated the strongest relationship (Cohen's d=0.76) with math computation scores. This finding is consistent with existing literature in typically developing youth [29]. Development of problem-solving strategies with age may partially explain the relative contribution of visuospatial and auditory-verbal working memory to math computation. Use of inefficient, time intensive and demanding procedural strategies (e.g. counting out loud or on fingers; [56]) in early years are slowly replaced by more efficient fact retrieval from memory [57].

Of note, processing speed (Coding) demonstrated the second-largest relationship (Cohen's d=0.52) to math computation for children with ADHD in this sample. Results of prior studies have been mixed in regards to the contribution of processing speed to math achievement in typically developing youth [58, 59], but many investigations with null findings used tasks that tapped verbal (e.g., RAN) as opposed to non-verbal and motor-dependent (e.g., WISC-IV Coding) processing speed [60]. Establishing the central role of auditory-verbal working memory and processing speed to math computation as a proxy for math achievement in children with ADHD extends the prior literature and responds to calls for the need to empirically examine the respective contributions of working memory components from individual tasks [29], with the ultimate long-term goal of targeting more precise areas of impairment with specific intervention strategies.

Moreover, we found a three-way interaction between anxiety, gender, and processing speed in predicting math computation scores in this sample of youth with ADHD. While social anxiety and anxious coping did not significantly contribute to our model, anxious perfectionism had opposite effects on girls compared to boys on the relationship between processing speed and math. Contrary to our hypothesis, at low levels of anxious perfectionism, boys with poorer processing speed did not perform as well on the math computation measure as girls with slow processing speed. It may be possible that aspects of anxious perfectionism (e.g., following rules, obeying authority figures) impact males with ADHD differently than females (e.g., do boys at low levels of anxious perfectionism procrastinate, work slowly, or lose focus because they don't experience internal urgency or are less motivated by praise/consequences from parents and teachers?). Conversely, at high levels of anxious perfectionism, there were no significant differences in the relationship between processing speed and math computation scores for boys and girls with ADHD. Interestingly, processing speed was not a predictor of math computation at high levels of anxious perfectionism, potentially implying the need for sensitivity in the consideration of moderating factors when predicting math computation scores. Studies of the relationship between processing speed, gender, and math achievement in typically developing youth are an essential next step. Convergent findings in typically developing youth would suggest that consistency in intervention approaches targeting math achievement across youth (both with ADHD and without) is appropriate, while divergent findings may suggest differences in mechanisms of learning that may be important indicators of intervention targets.

Should these findings be replicated, they have several clinical implications for intervention. There are several evidence-based treatments developed for youth with ADHD, anxiety, and/or academic difficulties. Components of these interventions that may be applicable to all three problem areas may include behavioral interventions, pharmacotherapy, a combination of behavioral intervention and pharmacotherapy [61, 62], and/or classroom- and school-based services [63]. Given the present findings, increasing attention to detail through intervention may result in improved math performance for boys low in perfectionism who are also slow processors.

The mean score of math computation in this ADHD sample was within the normal range; this is consistent with prior studies, which have found that while youth with ADHD score within the normal range on standardized measures of math computation, these scores are still significantly lower than those of youth without ADHD [64]. Further, prior work has demonstrated that youth with ADHD exhibit pronounced weaknesses in their classroom academic performance on math despite average scores on standardized measures such as those used in the present study [4, 5]. Nonetheless, future studies might attempt to replicate the current findings in a population of children with ADHD and significantly impaired math ability. As disparity in math academic achievement grows over time, it is essential that researchers are able to identify mechanisms by which important neurocognitive, demographic, and clinical factors may influence a child's ultimate achievement, success in, and pursuit of math.

Although youth with ADHD performed in the normal range (on average) on math computation tasks in this sample, our interaction effect provides preliminary support for anxiety's influence on math computation scores for boys with high anxious perfectionism and low processing speed. A logical supposition would be that anxiety may also affect youth's true academic achievement in the classroom. These findings imply that assessment of anxiety might be included when youth are assessed for ADHD and academic achievement, and there are several free and for-purchase measures of self- and parent-reported anxiety for use by clinicians and neuropsychologists (e.g., MASC, [49], SCARED, [65]).

There are several limitations of this study. As this was a sample consisting solely of youth with ADHD, findings may not necessarily generalize to typically-developing youth or specifically those youth with ADHD and comorbid learning disabilities. In addition, although the diagnostic procedures were rigorous and clinician-assigned following a semi-structured interview, the study lacked multi-method, multi-informant (e.g., teacher) ratings for ADHD diagnosis. Future work in this area may replicate and extend the current findings to other samples. In addition, although the MASC is one of the most well-validated measures of anxiety symptoms in children and has been used in seminal child anxiety and ADHD trials [61, 62], the reliability for the anxious perfectionism scale was low in this sample. In order to validate the findings from the present study, it is critical that future efforts replicate the current findings using more reliable measures of anxious perfectionism, including not only parent and child rating scales, but also performance-based behavioral measures. Additionally, since the original data collection, new versions of some measures (i.e., MASC2; [66]; WASI2; [67]; WISC-V; [68]) have been released. Finally, in the present study math computation ability was determined using a lab task, and future research should examine actual classroom and academic performance.

We also cannot rule out other factors that may account for the relationships found herein. These include, but are not limited to, other neurocognitive or executive functioning domains (e.g., inhibitory control), cognitive (e.g., negative thinking), emotional (e.g., persistence during distress/frustration), physiological, or temperamental correlates, as well as compensatory strategies that girls and boys may utilize during task performance. In addition, although some constructs (e.g., math achievement, processing speed) can be further broken down into sub-components (e.g., math fluency, quantitative reasoning, etc.), we included broad categories of these constructs because the relationship between these have not yet been studied. Moreover, for math computation in particular, our task reflects the broad range of types of problems used in standardized achievement testing in schools. Given our findings, future studies may further decompose these broad constructs to identify relevant underlying processes. Future studies using experimental methods are needed to specifically examine task persistence, state anxiety throughout neurocognitive and math tasks, and whether anxious perfectionism in ADHD functionally leads to avoidance of school-based tasks and subsequently interferes with learning.

The current results replicate and extend prior findings by specifically examining differential prediction of several components of neurocognition, while considering gender and anxiety, two important contributors to functional impairment in ADHD. While auditory-verbal working memory and processing speed were both significant predictors of math computation scores, visuo-spatial working memory was not. Moreover, boys with low levels of anxious perfectionism and poor processing speed are more impacted on math computation compared to girls. Together, the present findings support the need for greater exploration of the role of processing speed in math achievement, and the potential role for interventions that are based on improving automaticity of mathematics processes.

Summary

Youth with ADHD often suffer from well-characterized neurocognitive deficits relevant to math learning, particularly in areas of processing speed and working memory. Because determinants of math achievement in attention-deficit/hyperactivity disorder (ADHD) are not well studied, we examined individual differences in neurocognitive functioning, specifically working memory and processing speed, domains on math computation in a cross-sectional sample of youth with ADHD. Gender and anxiety were explored as potential moderators. The sample consisted of 281 youth (aged 8–15 years; 70% male) diagnosed with DSM-IV-TR ADHD. Neurocognitive tasks assessed auditory-verbal working memory, visuospatial working memory, and processing speed. Auditory-verbal working memory and processing speed significantly predicted math computation. A three-way interaction revealed that at low levels of anxious perfectionism, slower processing speed predicted poorer math computation for boys compared to girls. These findings indicate the complex and discrete predictive values of auditory-verbal working memory and processing speed on math computation, and their differential moderation. These findings are unique in identifying gender and anxious perfectionism for both theoretical models and empirical studies of academic achievement.

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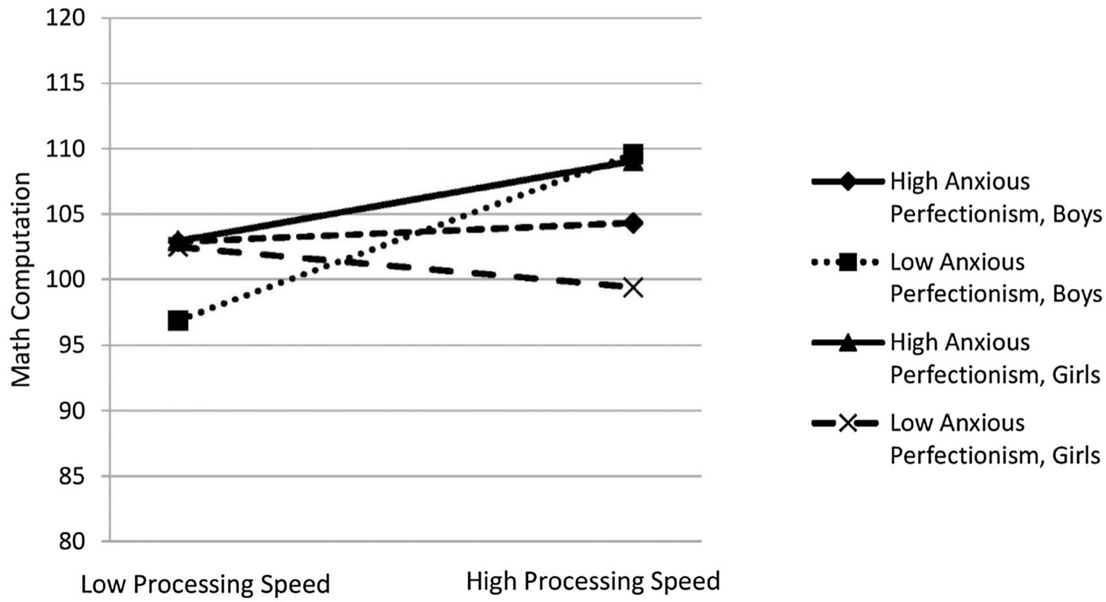

Fig. 1.

Three-way interaction between gender, anxious perfectionism, and Coding in predicting math achievement: Simple slopes. High values correspond to 1 standard deviation above the mean and low values correspond to 1 standard deviation below the mean for anxious perfectionism and processing speed

Table 1

Demographic and clinical characteristics for full sample and by gender

	Total	Male	Female	Test statistic	p value	Effect size
Demographics						
Total	281	197	84			
Age	10.46 (1.94)	10.41 (1.92)	10.56 (1.97)	t=−0.65	0.51	−0.08
Race: % caucasian	69.04	65.99	76.19			
Clinical						
Comorbid externalizing (%)	33.81	32.99	35.71	X^2 (1)=.20	.66	.03
Comorbid anxiety (%)	34.16	28.42	47.62	X^2 (1)=9.64	.002	.19
ADHD type				X^2 (1)=2.84	.09	.10
Inattentive (%)	53.02	49.75	60.71			
Combined (%)	46.98	50.25	39.29			
Inattentive symptoms	7.94 (1.12)	7.93 (1.11)	7.96 (1.13)	t=−.24	.81	−.03
Hyperactive symptoms	4.79 (2.66)	4.96 (2.65)	4.40 (2.66)	t=1.60	.11	.19
Total scores on variables of interest						
WISC-IV SSB	9.76 (2.71)	9.91 (2.64)	9.40 (2.84)	t=1.43	0.16	0.17
WISC-IV DSB	9.23 (2.81)	9.31 (2.88)	9.03 (2.64)	t=0.77	0.44	0.09
WISC-IV LNS	9.46 (2.82)	9.51 (2.82)	9.33 (2.82)	t=0.50	0.62	0.06
WISC-IV coding	8.24 (3.01)	7.94 (3.05)	8.95 (2.79)	t=−2.53	0.01	−0.31
MASC perfectionism	8.20 (2.19)	8.18 (2.31)	8.24 (1.90)	t=− 0.22	0.83	−0.03
MASC anxious coping	8.88 (3.12)	8.85 (3.16)	8.96 (3.04)	t=−0.28	0.78	−0.03
MASC humiliation fears	7.56 (4.45)	7.30 (4.44)	8.15 (4.45)	t=−1.46	0.14	−0.18
MASC public performance	4.91 (3.08)	4.91 (3.25)	4.90 (2.69)	t=0.02	0.99	0.00
Math	103.39 (14.32)	103.55 (14.93)	102.99 (12.83)	t=0.32	0.75	0.05
FSIQ	103.17 (13.49)	104.11 (13.65)	100.94 (12.93)	t=1.80	0.07	0.22

WISC-IV SSB WISC-IV spatial span backward, *WISC-IV DSB* WISC-IV digit span backward, *WISC-IV LNS* WISC-IV letter-number sequencing. For effect size calculations, Cohen's d used for t tests and Cramer's V used for X^2 tests

Table 2

Correlations between variables of interest

	1	2	3	4	5	6	7	8	9	10
1. WRAT4 math computation	1									
2. FSIQ	.467**	1								
3. WISC-IV coding	.325**	.215**	1							
4. WISC-IV letter-number sequencing	.500**	.369**	.229**	1						
5. WISC-IV digit span backward	.280**	.245**	.170**	.272**	1					
6. WISC-IV spatial span backward	.234**	.304**	.222**	.327**	.310**	1				
7. MASC anxious perfectionism	0.083	0.073	0.012	0.037	−0.031	0.111	1			
8. MASC anxious coping	0.038	−0.022	−0.03	0.046	0.028	0.065	.458**	1		
9. MASC humiliation/rejection	0.042	−0.068	−0.06	−0.008	−0.01	0.001	.209**	.300**	1	
10. MASC public performance	−0.035	−0.1	−0.015	−0.015	0.013	−0.009	.167**	.232**	.532**	1

** $p < .01$

Table 3

Predictors of math achievement

	B	*SE B*	β	t	p value	Cohen's d	R^2	Tolerance	VIF
Gender	0.05	1.52	0.00	0.03	.97	.00		.92	1.08
Age	0.73	0.37	0.10	1.97	.05	.24		.89	1.12
Full scale IQ	0.35	0.06	0.34	6.23	.00	.77		.76	1.31
Perfectionism	0.09	0.35	0.01	0.25	.81	.03		.74	1.36
WISC-IV letter-number sequencing	1.65	0.27	0.33	6.10	.00	.76		.75	1.33
WISC-IV digit span backward	0.60	0.26	0.12	2.35	.02	.29		.85	1.18
WISC-IV spatial span backward	−0.18	0.28	−0.03	−0.64	.52	−.07		.76	1.27
WISC-IV coding	1.18	0.28	0.25	4.20	.00	.52		.65	1.55
Perfectionism*WISC-IV coding	−0.43	0.12	−0.19	−3.46	.001	−.43		.77	1.29
Gender*WISC-IV coding	−0.93	0.54	−0.10	−1.72	.09	−.21		.67	1.49
Perfectionism*gender	1.07	0.80	0.08	1.33	.18	.16		.69	1.46
Perfectionism*WISC-IV coding*gender	0.78	0.31	0.14	2.54	.01	.32	0.44	.71	1.42