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Neuropsychological Profiles of Adolescents with ADHD: Effects of Reading Difficulties and Gender

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Abstract

Background: Executive function, particularly behavioral inhibition has been implicated as a core deficit specific to Attention-Deficit/Hyperactivity Disorder (ADHD) whereas rapid naming has been implicated as a core deficit specific to reading disabilities (RD). Females may be less impaired in executive function although adolescent females with ADHD have yet to be studied.

Methods: Neuropsychological profiles of four adolescent groups aged 13-16 with equal female representation were investigated: 35 ADHD, 12 RD, 24 ADHD+RD, and 37 normal controls. A semi-structured interview (K-SADS-PL), the Conners Rating Scales and the Ontario Child Health Study Scales were used to diagnose ADHD. RD was defined as a standard score below 90 on at least one of the following: Reading or Spelling of the WRAT3 or Word Attack or Word Identification of the WRMT-R. The WISC-III, Rapid Automatized Naming, Stroop and Stop tasks were used as measures of cognitive and executive function.

Results: The two ADHD groups (ADHD, ADHD+RD) showed deficits in processing speed, naming of objects, poor behavioral inhibition and greater variability in reaction times whereas the two RD groups (RD, RD+ADHD) showed verbal working memory deficits and slower verbal retrieval speed. Only the comorbid group was slower with naming of numbers and colors and had slower reaction times. Regression analyses indicated that incongruent color naming (Stroop) and variability in go reaction time were the best predictors of hyperactive/impulsive ADHD symptoms whereas variability in go reaction time and processing speed were the best predictors of inattentive ADHD symptoms. Speed of letter naming and verbal working memory accounted for the most variability in composite achievement scores. No gender differences were found on any of the cognitive tests.

Conclusions: This study challenges the importance of behavioral inhibition deficits in ADHD and that naming deficits are specific to RD. Further investigation into cognitive deficits in these groups is required.

Key Words: ADHD, RD, adolescents, neuropsychological profiles, gender

Abbreviations: ADHD = Attention-Deficit/Hyperactivity Disorder, RD = Reading Difficulties, SES = socio-economic status), CTRS = Conners Teacher Rating Scale, OCHSS = Ontario Child Health Study Scales, WRAT = Wide Range Achievement Test, WRMT = Woodcock Reading Mastery Test, MDD = Major Depressive Disorder, SAD = Separation Anxiety Disorder, GAD = Generalized Anxiety Disorder, OCD = Obsessive Compulsive Disorder, WISC = Wechsler Intelligence Scale for Children, RAN = Rapid Automatized Naming, SSRT = Stop Signal Reaction Time.

Neuropsychological Profiles of Adolescents with ADHD: Effects of Reading Difficulties and Gender

Attention-Deficit/Hyperactivity Disorder (ADHD) is one of the most prevalent developmental disorders diagnosed in childhood, characterized by excessive activity, short attention span, and impulsivity (APA, 2000). There exists a substantive amount of literature documenting the cognitive and behavioral deficits present in ADHD (e.g., Pennington & Ozonoff, 1996; Tannock, 1998); however, studies differ in the emphasis placed on comorbid disorders, in particular reading difficulties (RD). The overlap between ADHD and RD is substantial and important (Ackerman, Anhalt, & Dykman, 1986; Hinshaw, 1992). For example, epidemiological and clinical studies suggest a co-occurrence of 15% to 40%, even when relatively stringent criteria are used for defining both disorders (APA, 1994; Semrud-Clikeman, Biederman, Sprich-Buckminster, Lehman, Faraone, & Norman, 1992; Shaywitz, Fletcher, & Shaywitz, 1995; Willcutt & Pennington, 2000). Therefore, when studying ADHD, it is important to also investigate the contribution RD can have to the findings in order to establish what deficits are an ADHD phenomenon, an RD phenomenon as well as a combination of both disorders.

A reading disability is a term that applies to children who fail to learn to read despite normal sensory abilities and intellectual capacity and appropriate educational and environmental opportunities. A reading disability can be a life-long language-based disorder in which phonological processing problems, poor spelling, and slower, more effortful rate of reading, persist into adulthood (Bruck, 1992; Denckla, 1993; Maughan, 1995). In adolescence and adulthood, these difficulties are particularly evident when required to read nonwords or unfamiliar words when reading under time constraints (Denckla, 1993; Pennington, Van Orden, Smith, Green, & Haith, 1990). The most reliable indicator of a reading disability is the failure to acquire rapid, context-free word identification skill (Stanovich, 1994).

Our current understanding suggests that there may be cognitive deficits specific to each disorder. For example, there is substantial evidence of mild deficits in motor responses and working memory in ADHD (Barkley, 1997; Tannock, 1998). There is also growing evidence that a failure to inhibit or delay behavioral responses is the fundamental deficit in ADHD as measured by the Stop Task (Nigg, 1999; Oosterlaan, Logan, & Sergeant, 1998; Pliszka, Borcherding, Spratley, Leon, & Irick, 1997; Schachar, Mota, Logan, Tannock, & Klim, 2000) and the Stroop (Lufi, Cohen, & Parish-Plass, 1990; Seidman, Biederman, Faraone, Weber, & Ouellette, 1997a). However, other researchers have found that phonological processing, and not inhibitory control, differentiate ADHD and RD (Purvis & Tannock, 2000). Further, Cohen and her colleagues (2000) caution against attributing executive functioning deficits to ADHD children when they may be more closely associated with language impairment.

Poor phonological processing or linguistic processing appears to be an RD phenomenon. Phonological processing is reported to be a stable trait that is reciprocally related to early reading acquisition and is attributed to impairments in working memory (Wagner & Torgesen, 1987). Rapid naming has also been implicated as a deficit specific to RD (Compton & Carlisle, 1994; Närhi & Ahonen, 1995; Snyder & Downey, 1995) although some researchers have determined that the type of naming being performed (i.e., digits versus colors versus objects) is selectively deficient in different clinical populations. For example, Tannock, Martinussen & Frijters (2000) suggest that impairments in color naming, which involves controlled and effortful semantic processing, is also present in ADHD.

Certainly, the finding that RD and ADHD are each associated with different cognitive deficits provides support for the external validity of the disorders; however, establishing that a specific deficit is primary and unique to ADHD or RD requires evidence that the deficit cannot be explained by comorbid problems. Only inclusion of both disorders into the same study allow us to determine the unique contribution each has to the underlying deficit. Further, equal representation of genders in all groups and the introduction of an older population present as important extensions of what has been a predominantly male-centered research of children typically ranging in age from 8 to 12, due to the greater preponderance of males in clinically-referred samples (APA, 2000). Preliminary studies suggest that ADHD females may be less vulnerable to the executive deficits displayed by boys since ADHD females and control females exhibited similar performance on tests of executive functioning (Seidman, Biederman, Faraone, Weber, Mennin, & Jones, 1997b) although other researchers have suggested that ADHD females may have poorer language functioning (Berry, Shaywitz & Shaywitz, 1985), lower IQs (Gaub & Carlson, 1997) and similar executive functioning (Houghton et al., 1999) as compared with ADHD males. However, it is not known whether these findings generalize to adolescents.

This current study sought to further investigate naming speed and executive deficits in four adolescent groups including an equal representation of females across groups: ADHD, RD, ADHD+RD and normal controls in order to better understand the specific deficits associated with the clinical groups.

Method

Subjects

A total of 108 subjects (aged 13 to 16 years) were included in this study: 35 ADHD (20 male and 15 female), 12 RD (6 male and 6 female), 24 ADHD+RD (15 male, 9 female), and 37 controls (18 male and 19 female). Thirty-three (55.9%) of the two ADHD groups were recruited from individuals who were previously assessed in the Department of Psychiatry with a confirmed diagnosis of ADHD in childhood based on a standard clinical interview based on the K-SADS and standardized parent and teacher behavior rating scales. The remaining clinical subjects were recruited through advertisements at pediatric offices as well as from new referrals to the Hospital for Sick Children. The RD group was not actively recruited: they were individuals who responded to our advertisements looking for volunteers for research and subsequently identified as having reading problems through the testing. Adolescents in the control group were recruited through Hospital staff and community resources. Sample characteristics are provided in Table 1.

Insert Table 1 here

Inclusion criteria for the ADHD group: a confirmed diagnosis of childhood ADHD as well as current diagnosis of ADHD (see below). Inclusion criteria for the RD group: standard score below the 25^{th} percentile (SS 90) on at least one of the following subtests: word identification or word attack subtests of the Woodcock Reading Mastery Test-Revised (WRMT-R; Woodcock & Mather, 1989) or the spelling or reading subtests of the Wide-Range Achievement Test (WRAT3; Wilkinson, 1993). This system of classifying the RD group using low achievement scores was used as there is little or no evidence to support the validity of the IQ-discrepancy model (Fletcher et al., 1994) and the purpose was to identify children with reading problems as opposed to a reading disability per se. A cut off of 90 has been used previously in the research and may be a more appropriate cut-off with this age group (Bruck, 1992; Fletcher et al., 1998; Frankenberger & Fronzaglio, 1991; Siegel & Heaven, 1986). Spelling scores were also included as an indicator of overall reading problems due to the extensive literature demonstrating that spelling is just as much an indicator of literacy and language based skills as reading (Burt & Fury, 2000; Kamhi & Hinton, 2000) and has been shown to be one phenotypic marker of dyslexia (Petryshen et al., 2001). Although a standard score of 90 is less than one standard deviation below the mean, because of the age, adolescents who are scoring below 90 are showing significant impairment as compared with their peers. For example, a standard score of 90 translates into a grade equivalency at least 2-3 grades below the norms. Inclusion criteria for the ADHD+RD group: the individual met inclusion criteria for both the ADHD group and the RD group. Exclusion criteria for all groups: 1) an estimated IQ below 80, using the Block Design and Vocabulary subtests of the WISC-III (Wechsler, 1991), and 2) subjects with uncorrected problems in vision or hearing, serious medical problems, such as epilepsy or cerebral palsy, or serious psychopathology, such as psychosis, that would preclude a current differential diagnosis of ADHD. Specific exclusion criteria for the control group: 1) history or current complaints of problems in attention, hyperactivity or impulsivity, 2) full diagnostic criteria were met for a major Axis I disorder, and 3) scores below the 25^{th} percentile on any of the standardized tests of arithmetic, language or reading. All children participating in the study were native English speakers. These exclusion criteria resulted in the exclusion of 15 participants from the analyses.

Diagnostic Protocol for ADHD and other psychiatric disorders: Systematic information about current and lifetime disorders was obtained from both the child and the parent separately using the Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version (K-SADS-PL), an interview which generates both DSM-IIIR and DSM-IV diagnoses. This semi-structured interview has been used extensively to make diagnostic decisions based on DSM criteria and has been validated with children aged 6 to 17 (Kaufman et al., 1997). Behavior rating scales: The Revised Ontario Child Health Study Scales (OCHSS; Boyle, Offord, Racine, Fleming, Szatmari, & Sanford, 1993) and the long versions of the Conners' Rating Scales-Revised (Conners, 1997) were used to assess ADHD as well as internalizing and externalizing disorders including depression, anxiety and conduct disorder. These two instruments provide separate rating forms for parents, teachers and adolescents. The OCHSS also provides separate scales for parent, teacher and adolescent to give an overall estimate of impairment.

To assess for presence or absence of ADHD, the following diagnostic algorithm was used: 1) the child met DSM-IV criteria for ADHD according to the clinician summary based on the K-SADS parent and adolescent interview, 2) met the clinical cutoffs for the externalizing symptoms of ADHD on either one or both of the OCHSS or the Conners teacher questionnaires in order to ensure pervasiveness of symptoms across settings and 3) showed evidence of ADHD symptoms prior to the age of seven established either through a past diagnosis of ADHD or in new cases, according to parental report and school report cards. Impairment was confirmed using the OCHSS across all three informants. The presence/absence of DSM-IV internalizing disorders was based on a clinician summary based on the information gathered from both the parent and adolescent K-SADS interview. Note that the information from the adolescent K-SADS did not supersede parental report for the presence/absence of externalizing symptoms.

Measures of demographic variables

Measures of the socioeconomic status of the family was determined using the Blishen Index (Blishen, Carroll, & Moore, 1987), an index which assigns Canadian occupations with a socio-economic score (SES) from 1 (low SES) to 6 (high SES). A Blishen score was given to the occupations of the parents of all subjects. Highest education level achieved by each parents (from 1 “no high school” to 6 “university degree”) was also used as a measure of economic status.

Dependent measures

Intellectual functioning: A systematic cognitive assessment was performed, using six subtests of the Wechsler Intelligence Scales for Children (WISC-III; Wechsler, 1991): vocabulary, block design, arithmetic, digit span, symbol search and coding.

Naming Speed: Four tests of Rapid Automatized Naming (RAN) were selected: Letters, Numbers, Colors, and Objects. Letters and Numbers were chosen due to their established association with reading difficulties (Denckla & Rudel, 1974). Colors and Objects were selected because of their hypothesized association with more effortful semantic naming and their recently established association with ADHD (e.g., Carte, Nigg, & Hinshaw, 1996; Semrud-Clikeman, Guy, Griffin, & Hynd, 2000a; Semrud-Clikeman, Steingard, Filipek, Biederman, Bekken, & Renshaw, 2000b; Tannock et al., 2000). RAN-Letters consists of five lowercase letters (a, d, o, s,

p) repeated 10 times in random sequence, yielding 50 stimuli presented in five rows of ten items on a chart. RAN-Numbers consists of 5 digits (2, 6, 9, 4, 7), RAN-Colors consists of five colors (red, yellow, black, green, blue), and RAN-Objects consists of five objects (book, chair, dog, hand, star) presented in the same way as RAN-Letters. Total times (in seconds) to name all stimulus items on each chart were the dependent variables. Number stated correctly, number of omissions, additions, deletions, and errors were also assessed as control variables.

Response inhibition (protection from interference): the Stroop Color and Word test (Golden, 1978) was administered. This test yields four dependent measures: number of color words (red/blue/green) named in 45 seconds, number of colors (red/blue/green) named in 45 seconds, number of color names that are printed in a discordant color word named within 45 seconds (e.g., when the word “red” is written in green ink, the subject must respond with “green”), and an interference estimate that measures the ability to suppress a habitual response in favour of an unusual one, taking into account overall speed of naming. T scores are provided by Golden (1978) for the age groups we studied.

Response Preparation, Selection/Execution, and Inhibition: Detailed descriptions of the Stop task can be found in Nigg (1999), Purvis and Tannock (2000), and Schachar et al. (2000). The Stop task tracking version (Williams, Ponesse, Schachar, Logan, & Tannock, 1999), a variant of the stop-signal paradigm (Logan, 1994) was used to measure the degree of voluntary inhibitory control that the participants can exert over response processes. The paradigm involves two concurrent tasks, a “go” task and a “stop” task. The go task is a choice reaction time task that requires the individual to discriminate between an X and an O by pressing the associated buttons on a separate response box. The stop task (which occurs on 25% of the go task trials) involves the presentation of a tone that informs the individual to stop (inhibit) his/her response to the go task for that trial. Dependent measures are the latency and variability of responses to the go-task and estimated stop-signal reaction time. Participants were excluded from analyses of the Stop task data if one of the following criteria was met: 1) percent inhibition less than 13% or greater than 85%, or 2) SSRT less than 50 msecs (Schachar et al., 2000) as such performance would yield questionable estimates of their SSRT. Five individuals (3 ADHD (2F, 1M), 1 RD (F), and 1 ADHD+RD (1 M) were excluded.

Test behavior: After each individual was tested, the tester rated that individual on all eighteen DSM-IV ADHD criteria with respect to how often she observed any specific ADHD behaviors from “never or rarely” (0) to “very often” (3), resulting in total scores that ranged from zero to 54. This scale was a modified version of the ADHD Rating Scale-IV: School Version (DuPaul, Power, Anastopoulos, & Reid, 1998).

Procedures

The interviews and the tasks (total 6 hours) were carried out in the research unit of a large paediatric health sciences research centre in metropolitan Toronto. The local institutional review board approved the study and written informed consent and assent (for children under the age of 16) were obtained from parent and adolescent respectively. Questionnaire packages were sent to the adolescent's teachers with the consent of the parents. A Ph.D. level clinical psychologist (JR) conducted all psychiatric interviews. The performance measures were administered in a set order by psychology graduate students blind to the diagnostic status of the child. All subjects were reimbursed for costs of parking and lunch.

Clinical subjects who were receiving psychostimulant (dextroamphetamine or methylphenidate) medication (40% (n=14) of the ADHD group and 41.7% (n=10) of the ADHD+RD group) discontinued this treatment 24 hours before the day of testing because of the known effects of methylphenidate on cognitive functioning (e.g., Berman, Douglas, & Barr, 1999). Five (14.3%) of the ADHD and one (4.2%) of the ADHD+RD were taking a medication other than a stimulant (e.g., fluoxetine, sertraline, bupropion, citalopam). Three participants were on a combination of a stimulant and another medication. These other medications were not discontinued. None of the controls were taking medications.

Statistical Analyses

Results were analyzed using the Statistical Package for the Social Sciences-Windows version 9. Multivariate and univariate analyses of variance (MANOVA & ANOVA) were used to examine group differences. All the subscales of each measure were entered in one test of MANOVA (e.g., all the WISC-III subscales). Wilks' lambda was used as the overall test of significance and if the overall omnibus F was significant ($p < .05$), the subsequent univariate analyses were interpreted. Specific group differences were examined with post-hoc Tukey tests using a p value of .05. Chi-square analyses were used for group comparisons of the dichotomous variables. Based on the observed group differences, exploratory stepwise regression analyses were performed to establish which variables accounted for the most variability in ADHD and RD symptomatology. For simplicity, when the ADHD and ADHD+RD group are different from the other groups these groups will be referred to as the ADHD groups, when the RD and the ADHD+RD groups are different from the others, this combination of groups will be referred to as the RD groups.

Results

Sample Characteristics

There were no group differences in age and mother's level of education; however, there were group differences in socio-economic status (SES) and father's level of education: normal controls had a higher SES than the ADHD+RD group and fathers of the control group had completed more years of education than the fathers of the ADHD+RD group (Table 1). There were no group differences in gender distribution across the four groups (χ^2 (3 N = 108) = 1.327, p = .723). There were no observed group differences in marital status χ^2 (12 N = 108) = 18.062, p = .114): 89.2% (n=33) of the parents of the control group were married versus 60% (n=21) of the ADHD group, 75% (n=9) of the RD group and 58.3% (n=14) of the ADHD+RD group. Not unexpectedly, there were group differences in estimated FSIQ. Post-hoc tests indicated that the three clinical groups had significantly lower scores on Estimated Full Scale IQ as compared with the controls.

Table 1 also illustrates those variables used for diagnostic purposes. Group differences were found for the ADHD hyperactive/impulsive symptoms and inattentive symptoms as assessed by the KSADS, the OCHSS and the CTRS. Post-hoc analyses revealed that although all three clinical groups showed more inattentive symptoms than the controls, the ADHD groups had significantly more inattentive symptoms than the RD only group. Group differences were also noted on the measure of impairment; post-hoc analyses revealed that the two ADHD groups were reporting themselves as more impaired than the normal controls. These group differences were also noted by the teacher reports. Further, parents of the two ADHD groups reported more impairment in their children than both the parents of the RD group and the normal control group. As expected, there were group differences on the measures of achievement. The two RD groups had lower reading (as measured by both the WRAT3 and the WRMT-R) and spelling scores than the ADHD group and the normal control group. Further, although better than the RD groups, the ADHD group also had worse spelling than the controls.

There were also group differences in number of individuals with a comorbid diagnosis: (χ^2 (3 N = 108) = 29.499, p < .001), with the clinical groups, by definition, having more comorbid diagnoses than the control group but no differences among them: 48.6% (n=17) of the ADHD group, 26.7% (n=2) of the RD group, and 54.2% (n=13) of the ADHD+RD group had a comorbid diagnosis. The number and percentage within each group who met criteria for an Axis I diagnosis are displayed in Table 2. This table also includes information on ADHD subtypes within the ADHD groups.

Insert Table 2 here

Cognitive Variables

With respect to the intellectual and cognitive profiles (Table 3), the patterns of results indicated that the ADHD groups struggled more with the subtests of the Processing Speed Index whereas the RD groups struggled more with the subtests of the Freedom from Distractibility Index. More specifically, post-hoc tests indicated that the RD groups had significantly lower scores on the Freedom from Distractibility Index as compared with the controls. The ADHD+RD group was also more impaired on the Freedom from Distractibility Index (both arithmetic and digit span) than the ADHD group and the controls. The comorbid group recalled less digits forward and backwards than both the ADHD group and the control group. The two ADHD groups showed more impairment on the Processing Speed Index (both Coding and Symbol Search) than the control group.

Insert Table 3 here

On the RAN, a number of intriguing group differences emerged (Table 4). Overall, it appears that the RD groups were slower at naming letters whereas the ADHD groups were slower at naming objects as compared with the normal controls. Further, post-hoc tests revealed that the ADHD+RD group was slower in naming letters than the ADHD group and control group but slower at naming objects than the RD group and control group. The ADHD+RD group was more impaired in color naming than the controls, ADHD group and RD group. The comorbid group was also slower at naming numbers than the ADHD and control group. There were no group differences in number of omissions, additions, deletions, and errors across all four naming tests, suggesting that the slower responses in the various clinical groups were due to slower retrieval rather than mediated by inaccurate retrieval. Indeed the number of errors across the four tasks was less than one error in all groups, an expected low number given the age of the participants.

On the Stroop, post-hoc tests showed that both the RD and ADHD+RD groups named fewer words than the normal controls. In contrast, both the ADHD and the ADHD+RD groups named fewer colors than the normal controls. The comorbid group also named fewer words than the ADHD only group. Further, the comorbid group was more impaired than all three of the other groups in the incongruent task of color/word, naming less color/words. The ADHD group also named fewer colors in the incongruent naming task than the normal controls. There were no group differences in interference scores.

Table 4 also shows stop-signal paradigm performance for all subjects. The probability of inhibition was close to 50%, indicating that the tracking algorithm was working well. No difference in probability of inhibition was observed among the four groups. The pattern of results suggests that the ADHD groups are most impaired on this task. Specifically, post-hoc tests revealed that the ADHD groups showed more variability in reaction time compared with the normal controls although the combined group showed the most impairment by being more impaired than the ADHD and RD groups as well. Further, the ADHD+RD group had fewer correct responses (percent correct) and slower go reaction times than the normal controls. Finally, both the ADHD and the ADHD+RD groups had a slower SSRT than the normal controls. No group differences were observed on test behavior suggesting that the testing situation did not have differential effects on the four groups of adolescents.

Insert Table 4 here

Gender effects

The individual groups were compared across gender on the naming and inhibitory tasks: no gender differences were found on the Stop, the Stroop or the RAN (Table 5), suggesting that these two groups are equally impaired in tasks tapping into behavioral inhibition and naming speed. Effect sizes were also calculated to verify whether the lack of gender differences within the ADHD groups was due to lack of power to detect group differences. Effect sizes were calculated according to Cohen's (1988) effect size correlation ($r_{xy} = d / (d^2 + 4)$ where $d = (M_1 - M_2)/ \surd((SD_1^2 + SD_2^2) / 2)$). Effect sizes confirmed the F tests. Previous results using this data set have yielded significant gender differences in Processing Speed and Vocabulary on the WISC-III (Rucklidge & Tannock, 2001), with ADHD males shower slower processing speed and ADHD females showing lower vocabulary scores.

Insert Table 5 here

Covariates

All of the analyses were rerun controlling for presence of at least one comorbid disorder (e.g., ODD, CD, MDD), Estimated Full Scale IQ, socio-economic status and father's level of education, all variables which were correlated with the dependent variables as well as showing group differences. FSIQ was not used as a covariate for the WISC-III data. None of these covariates affected the overall pattern of results; all group differences remained significant.

Exploratory Regressions

Given that the four group comparisons revealed that there was a split in cognitive deficits across the four groups with the RD groups showing more problems with tasks requiring verbal working memory and verbal retrieval whereas the ADHD groups showed more problems with processing speed and inhibition, regression analyses were performed to determine specifically how much of the variability in ADHD symptoms and achievement scores could be accounted for by these tests as well as which tests may be accounting for the most variability. Three regressions were performed using the following dependent variables: ADHD inattentive symptoms and ADHD hyperactive/impulsive symptoms (as assessed by the overall clinician summary of the K-SADS interview) and RD composite (average of: WRMT-R Word Identification and Word Attack, and WRAT3 Reading and Spelling). Age was entered in the first block as not all cognitive variables were standardized scores; this procedure was used to covary for age. In the second block, for the ADHD symptoms, the following variables were entered: WISC Coding, WISC symbol Search, Object Time, SD Go Reaction Time, SSRT, Stroop T Color and Stroop T Color/Word. For RD composite, the following predictors were entered in Block 2: Freedom from Distractibility, Letter Time, and Stroop T Word. These variables were chosen based on the results

Deleted: deficits

of the four group comparisons and only those variables where both groups (i.e., ADHD and ADHD+RD for prediction of ADHD symptoms, and RD and ADHD+RD for prediction of reading composite scores) were more impaired than the normal controls were entered in the regression. A stepwise regression analysis was used in order to determine which variables would account for the greatest variance in the dependent variables. Transformation and removal of outliers were not required for valid regressions. All five of those individuals who had met the exclusion criteria for the stop task were removed from the regression analyses. All regressions were performed with and without the control group. As this made no difference to the overall pattern of results, only the data using the entire sample is presented. There were also no differences whether the raw scores or T scores were used.

Comment [RT1]: Page: 16
But Julia, this statement is inconsistent with the first sentence of the Abstract which states that inhibition is believed to be specific to ADHD and naming speed specific to RD. So, why would you not enter each of these variables at Step 2 (e.g., inhibition, stroop at Step 2 for hyp/imp and inatt. With other variables entered at step 3).

Table 6 displays the correlations among the best predictor variables, the unstandardized regression coefficients (B), the standardized regression coefficients (β), the squared semi-partial correlation (sr_i^2), R^2, R, and adjusted R^2 using ADHD inattentive symptoms as the dependent variable. R for the regression was significantly different from zero, $F(3, 94) = 15.664$, $p < .001$. SD Go Reaction Time entered first into the equation, followed by WISC Coding. These two predictors contributed significant unique variance (sr_i^2) to the prediction of ADHD inattentive symptoms (sr_i^2 for a predictor is the amount by which R^2 is reduced if that predictor is deleted from the regression equation, thus representing the unique contribution of the predictor to R^2 in that set of predictors). SD Go Reaction Time accounted for 10.8% of the variability in ADHD inattentive symptoms and WISC Coding accounted for 9.9%. Altogether the predictors accounted for 33.3% (31.2% adjusted) of the variability in ADHD inattentive symptoms, with SD Go Reaction Time being a slightly more important predictor. None of the other variables significantly contributed to the regression equation.

Insert Table 6 here

Table 7 displays the regression analysis using ADHD hyperactive/impulsive symptoms as the dependent variable. R for the regression was significantly different from zero, F (3, 94) = 8.239, $p < .001$. Stroop T Color/Word entered first into the equation, followed by SD Go Reaction Time. These two predictors contributed significant unique variance (sr_i^2) to the prediction of ADHD hyperactive/impulsive symptoms. T Color/Word accounted for 6.5% of the variability and SD Go Reaction Time accounted for 6.1%. Altogether the two predictors predicted 20.8% (18.3% adjusted) of the variability in ADHD hyperactive/impulsive symptoms, with T Color/Word being the most important predictor. None of the other variables significantly contributed to the regression equation.

Insert Table 7 here

Table 8 displays the regression analysis using composite RD score as the dependent variable. R for the regression was significantly different from zero, F (3, 95) = 44.589, $p < .001$. Letter Time entered first into the equation, followed by WISC-III Freedom from Distractibility. These two predictors contributed significant unique variance (sr_i^2) to the prediction of composite RD score. Letter Time accounted for 16.8% of the variability and WISC-III Freedom from Distractibility accounted for 6.4%. Current age also accounted for a small amount of the variability (1.9%). Altogether the three predictors predicted 58.5% (57.2% adjusted) of the variability in composite RD score, with Letter Time being the most important predictor. None of the other variables significantly contributed to the regression equation.

Insert Table 8 here

Discussion

This study is one of the first to look at naming speeds and executive function in three different clinical groups of adolescents: ADHD, RD, and RD+ADHD as well as to investigate gender differences within these groups. The design enabled us to document specific and possibly unique deficits related to both ADHD and RD as well as determine whether a dissociation of deficits existed between the two conditions. Further, given the reasonably large sample size, regression analyses enabled us to investigate which tests of cognitive function may best explain the variance in the symptoms inherent in the two symptom clusters of ADHD and in reading ability.

After controlling for SES, father's level of education, presence of a comorbid diagnosis and full scale IQ, a dissociation of deficits was found between the ADHD and RD adolescents adding some further evidence of separable cognitive profiles. The ADHD groups (regardless of RD status) demonstrated slower processing speed (WISC coding and symbol search), were slower at naming objects and had greater difficulties with inhibiting responses, as indicated by slower SSRTs, as well as greater variability in responses (SD Go Reaction Time on the Stop Task). The ADHD groups were also much slower in naming colors and incongruent color/words as measured by the Stroop (TColor and TColor/Word). On the other hand, the RD adolescents (regardless of ADHD status) had poorer achievement scores, poorer verbal working memory (as measured by WISC-III Freedom from Distractibility) and were much slower with naming letters (RAN) and color words (Stroop TWord). Even more intriguing was that having both ADHD and RD produced additional cognitive deficits including slower rates of naming numbers and colors and overall slower reaction times and less accuracy in responses on the Stop Task (Go Reaction Time and Percent Correct). The comorbid group was also more impaired in mental arithmetic (WISC-III Arithmetic) and working memory (as measured by both digits forward and backward) than the ADHD group.

Comment [RT2]: Page: 18
Here is where I have the most problem with the interpretation based mainly on the factorial analysis, because close inspection of the data would lead to the main conclusion that ADHD+RD are the most impaired and showed spcific problems in in digits forward/backward, RAN colors/numbers, Strrop color/word. Vocab, and variability of gorRT (according to post hoc tests). Moreover, given that this ADHD sample was comprised primarily of Inattentive type, the current findings are consistent with the hypothesis that Inatt+RD may be a unique subtype, as proposed by Wilcutt et al in their recent studies (2000). Essentially, the conclusions would be very different if you based the interpretation on an analysis of 4 groups with post hoc test. As far as I can tell from the post hoc tests reported, ADHD groupos (ADHD, ADHD+RD) particularly impaired in Processing Speed (particularly coding), RAN objetcs, Strrop color naming, SSRT, whereas RD groups (RD, ADHD+RD) specifically impaired in FD and Strrop word (and academics).

This pattern of results adds further evidence that poor inhibition is likely a cognitive deficit specifically related to ADHD symptomatology, confirming the many previous reports (e.g., Oosterlaan et al., 1998, Schachar et al., 2000) indicating that individuals affected with ADHD are impaired in response inhibition. This study now documents this impairment in an adolescent sample. However, stronger and possibly more important effects were noted in variability of response on the Stop Task and processing speed. Further, an intriguing but less documented finding was the results indicating that ADHD may be linked to slower retrieval of color and object information, possibly reflecting difficulties in controlled semantic processing, as determined previously by research with a younger ADHD cohort (Tannock et al., 2000). Present findings add to the growing literature linking color naming deficits with ADHD (Brock & Knapp, 1996; Carte et al., 1996; Nigg, Hinshaw, Carte, & Treuting, 1998; Semrud-Clikeman et al., 2000a; Semrud-Clikeman et al., 2000b; Tannock et al, 2000).

The results also document specific cognitive deficits inherent in individuals with reading difficulties. The two RD groups showed greater impairments on the Freedom from Distractibility Index, suggesting that poor verbal working memory may be one core RD deficit, contrary to Barkley's model of executive functioning that implicates poor working memory as an ADHD phenomenon (Barkley, 1997). The data also suggested that the RD groups were slower to name letters (RAN) and were impaired on naming color words (Stroop T Word), suggesting that the naming of letters and words is a more effortful task for this population, findings that have been shown in younger RD populations (e.g., Denckla & Rudel, 1974; Snyder & Downey, 1995). Although these findings are consistent with how the RD group was defined, the fact that even in adolescence the act of naming basic letters continues to be compromised, speaks to how the disability impairs the ability to perform even the most simple tasks. These name-retrieval deficits occurring at a basic level of functioning may be significant contributors to the complex behavioral difficulties seen in these populations.

Comment [RT3]: Page: 19
But post hocs indicate that ADHD+RD were more impaired than other groups.

These results also raise the possibility that ADHD+RD may be a specific subtype in that only when both disabilities are present will an individual begin to show severe impairment in speed of naming of numbers and colors as well as slower response times and less accuracy with responses. Investigation of actual group means clearly shows that even though all three clinical groups may have been impaired as compared with the normal controls, the comorbid group appears more clinically impaired than all of the other groups in that this group is often one standard deviation below an average T score (50) or Standard Score (100). The group mean on speed of naming colors is particularly striking in that the comorbid group is between 7 and eleven seconds slower on average than all of the other three groups. Certainly, this data supports the results of other researchers who have suggested that the combination of ADHD with a reading problem results in a unique cognitive profile (e.g., Wilcutt, Pennington, & DeFries, 2000).

Regression analyses were used to attempt to clarify the significance of the documented group differences. The incongruent color/word naming task (Stroop T Color/Word) and variability in reaction time (SD Go Reaction Time) were the best predictors of variability in the hyperactive/impulsive symptoms of ADHD whereas variability of reaction time (SD Go Reaction Time) and processing speed (WISC-III Coding) were the best predictors of the variability in the inattentive symptoms of ADHD. Of course it is important to note that although significant predictors were found, a large percentage of variability continues to be unaccounted for (ranging from four fifths to two thirds depending on the ADHD symptom cluster), suggesting that these cognitive tasks do not explain a large percentage of the variability in symptoms, emphasizing again the need to find more sensitive ADHD cognitive measures. With respect to RD predictors, letter naming speed was by far the best predictor, accounting for one fifth of the variability in composite achievement scores, followed by verbal working memory (WISC-III Freedom from Distractibility). Together these two variables accounted for over half the variability in achievement scores, a percentage that is not only statistically significant but also of great clinical

Comment [RT4]: Page: 20
But cognitive abilities as measured by the specific tasks) do account for about one-third of variance in inattention symptoms, which is pretty substantial

relevance.

The combination of the post-hoc findings and the regression results has wide implications. Problems with inhibiting responses have been theorized as consistent deficits present in ADHD. The Stop Task has been viewed as a solid measure of inhibition of response. Further, Barkley's model of behavioral inhibition (Barkley, 1997) suggests that the inhibition deficits are reflected in the hyperactivity/impulsive symptoms and not in the inattentive spectrum of symptoms. The current findings of inhibitory deficits in an ADHD sample comprised mainly of the Predominantly Inattentive Type challenge this view that the problems with inhibition are unique to those individuals with ADHD, Predominantly Hyperactive/Impulsive Type or Combined Type. However, perhaps of even more importance is the fact that inhibition response times (SSRT) was not found to be a unique predictor of either inattentive or hyperactive/impulsive ADHD symptoms, indeed the variability in reaction times was a better predictor for both inattentive symptoms and hyperactive/impulsive symptoms than SSRT. In addition, variability in response times was found to be a unique predictor of both the hyperactive/impulsive symptoms as well as the inattentive symptoms, further challenging the view that a specific cognitive deficit can be linked to only cluster of ADHD symptoms. These results challenge the tenet that poor behavioral inhibition is one of the core deficits of this disorder.

Given that variability of response is a better predictor of ADHD symptomatology than inhibition response times also suggests that the Stop Task may be tapping into several higher order functions as opposed to one specific deficit of impulse control. In this task, there is the requirement of holding instructions in working memory, having to pay attention for an extended period of time on a tedious task, and having to selectively differentiate information given visually and auditorily. Although there may be different impairments in these various functions across individuals with ADHD, the behavioral manifestations may still be the same, despite one individual having a deficit in the processing of visual information, another struggling with working memory and yet another not being able to pay attention long enough to respond accurately. It is then not surprising that the best predictor variable of this task is variability in response times, a finding that is also consistently documented in the literature (see Douglas, 1999 for a comprehensive review; Kuntsi, Oosterlaan, & Stevenson, 2001; Kuntsi & Stevenson, 2001; Scheres, Oosterlaan, & Sergeant, 2001). Further, our results may be similar to those of Leth-Steensen and colleagues (2000) who found that although ADHD boys show overall slower reaction times, their analyses indicated that the slower ADHD responses arose because of a greater proportion of abnormally slower responses and not due to a generalized slowing of all responses. It is possible that the slower SSRTs documented in our ADHD sample simply reflects the greater variability of inhibition processes with a higher number of long SSRTs.

Along these same lines of challenging poor inhibition as one of the fundamental problems of individuals with ADHD, it is important to note that there were no group differences on a measure of interference (Stroop Interference), a variable often implicated as tapping inhibitory responses but one that also controls for overall naming speed. The lack of a group difference on this interference score suggests that slowed responses on the incongruent color/word task were not an artifact of poor inhibition of responses but rather an overall slower retrieval of names. Interestingly, in a sample of focal lesion patients, left dorsolateral frontal lobe damage was associated with slow color naming and bilateral superior medial frontal damage was associated with slowed response on the incongruent condition of the Stroop, but no interference deficit was observed (Stuss, Floden, Alexander, Levine, & Katz, 2001). These results, in combination with ours, challenge the clarity of the relationship between frontal lobe deficits and poor inhibition.

Further, when interpreting the finding that Stroop Color/Word was the best predictor of ADHD hyperactive symptoms, it is important to consider the group differences on all the Stroop measures. As mentioned, although the ADHD groups were slower to name on all three Stroop tasks, there were no group differences in interference scores. Therefore, the fact that the Stroop Color/Word task accounted for the largest variability in hyperactive/impulsive symptoms is likely to be more a reflection of the demanding nature of this task across a number of cognitive processes (processing speed, naming speed and inhibition of responses) than simply a reflection of the interference nature of the task.

Based on the specific group differences that were found, the Stroop might tap into the deficits inherent to ADHD better than the Stop task, perhaps because it taps two critical aspects of cognitive processing believed to be deficient in ADHD (control and monitoring). A recent study using a task-switching version of the Stroop found that color naming activated the dorsolateral prefrontal cortex and the incongruent naming task activated the anterior cingulate cortex in a cohort of normals (MacDonald, Cohen, Stenger, & Carter, 2000) indicating that these brain regions may be associated with the cognitive deficits inherent in ADHD.

Finally, slow processing speed is clearly also an important variable in the expression of ADHD, in particular the inattentive symptoms. It is important to consider that the specific subtest of the WISC Processing Speed Index that showed greater clinical impairment in the ADHD groups was Coding. Why is Coding more problematic for the ADHD population than Symbol Search? We hypothesize that the task requirements are quite different. Coding requires both spatial span and spatial working memory in order to hold line/shape in mind and to retrieve motor pattern from long-term memory whereas symbol search appears to be primarily a task of shape discrimination and matching with lower demands on working memory. In addition, coding also requires a detailed motor response, and therefore, the execution of the task requirements involves the integration of several different brain processes.

No gender differences were found on the executive measures within the ADHD groups, indicating that the females are as impaired as males on their level of inhibition, response execution and naming speed. That there were no gender differences in executive functioning supports other research (e.g., Castellanos et al., 2000; Houghton et al., 1999; Kuntsi et al., 2001) and challenges our thinking of how we conceptualize females with ADHD. One of the few studies documenting neuropsychological functioning in ADHD females was one performed by Seidman and his colleagues (1997b). Although the results suggested that ADHD females are less impaired on tests of executive function than ADHD males, interpretation of these results was limited by the significant number of females taking psychostimulants at the time of the assessment. Our current study suggests that once the effect of the stimulant medications is removed, females are as impaired as males in tests of executive function. Our results remain robust even when those adolescents taking medications other than psychostimuants were excluded from the analyses.

Limitations and Future Directions

There are a number of limitations to this research that hinder the generalizability of the results. First, most of our ADHD group, unlike most research conducted with younger cohorts, met criteria for ADHD, Predominantly Inattentive Type. Therefore, the results cannot be generalized to our understanding of the Hyperactive/Impulsive Type and the Combined Type. The low number of adolescents meeting full criteria for Predominantly Hyperactive/Impulsive meant that comparisons between the subtypes of ADHD could not be made. Future studies could compare these groups on the cognitive measures in a search for ADHD specific markers. Relatedly, the ADHD sample had a much higher number of internalizing problems than externalizing, likely a result of the low number of ADHD/HI in the sample. This difference in the comorbid profile as compared with much of the current research needs to be taken into consideration when interpreting the results. Along these same lines, although controlling for comorbid diagnoses did not change the overall pattern of results, it would be important to assess the effect internalizing and externalizing problems have on the cognitive variables measured. Future research could further subdivide groups according to these other psychiatric problems.

Second, the control group was not a clinical control group and therefore group differences may have been inflated. Future replications should use clinical controls. Third, the RD group is not a clinical group in the sense that they were not identified according to DSM-IV descriptors. Although many research studies have challenged the use of a discrepancy model in the identification of learning disabilities (e.g., Fletcher et al., 1994), these results must be interpreted and extended to our understanding of Reading Disorders with great caution. Finally, the number of RD-only was small, leaving open the possibility that a lack of group differences on some measures was a result of lack of power rather than a reflection of equal performance across groups.

Clinical Implications

Over the last decade, clinical research in ADHD has emphasized the need to determine whether there are any instruments available that can identify the specific deficits inherent in ADHD. Currently, clinical practice dictates that the best measure that we currently have is an interview reviewing the ADHD symptoms. Given the problems in this method of diagnosis, there is a great need to identify reliable and valid laboratory measures of ADHD. The Stop Task has been one measure that has shown that ADHD populations have greater difficulties with inhibition. Certainly, our study has shown that individuals with ADHD have greater difficulty with inhibition of a preplanned response. However, when compared with other measures, it is accounting for less variability in ADHD symptomatology than processing speed, incongruent color/word naming and variability in reaction times. The results also suggest that there may be unique cognitive identifiers for the inattentive symptoms and the hyperactive/ impulsive symptoms, once again shaking our conceptualization viewing these two sets of symptoms as part of one disorder. Unfortunately, none of these measures tap consistently into a core deficit that we can with confidence administer to identify these affected individuals. Further research is necessary to continue to investigate how we can measure this construct we know as ADHD.

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Table 1

Sample Characteristics: Means and Standard Deviations

Variable	Controls (NC) (n=37)		ADHD (n=35)		RD (n=12)		ADHD+RD (n=24)		F (3, 104)	Contrasts [a]
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Age	14.95	1.10	15.18	1.36	15.08	1.28	14.86	1.43	.365	
Mother's Education	5.31	1.24	5.12	1.24	5.60	.70	4.81	1.25	1.226	
Father's Education	5.56	1.08	4.94	1.08	5.7	.67	4.43	1.57	4.544**	NC>ADHD+RD
Blishen Index	4.59	.85	4.23	1.19	4.00	1.60	3.63	1.17	3.710*	NC>ADHD+RD
WISC-III										
Estimated FSIQ	111.03	13.15	102.20	8.73	99.92	13.98	101.13	12.06	5.105**	NC>ADHD, RD, ADHD+RD
Vocabulary	11.77	2.68	10.29	2.09	9.25	1.60	8.54	2.23	9.811***	NC>ADHD+RD, RD & ADHD>ADHD+RD
Block Design	12.06	3.35	10.49	1.88	10.75	3.49	11.54	3.89	1.672	
K-SADS - In. Symptoms	.19	.70	6.60	2.00	1.67	2.10	6.96	1.12	156.927***	ADHD, ADHD+RD>RD>NC
H/I Symptoms	.22	.53	2.54	2.17	.67	.98	3.21	2.48	18.611	ADHD, ADHD+RD>NC, RD
CTRS (T scores)										
DSM In	41.92	13.17	66.66	17.61	52.67	22.04	68.04	17.97	18.701***	ADHD, ADHD+RD>RD, NC
DSM H/I	42.81	13.58	65.71	20.03	47.67	19.64	63.45	20.81	11.927***	ADHD, ADHD+RD>NC & ADHD>RD
OCHSS										
ADHD Teacher report	.81	1.85	10.6	7.37	4.67	7.14	11.79	5.41	26.864***	ADHD, ADHD+RD>RD, NC
Parent Impairment	1.16	1.89	6.94	3.89	2.08	2.19	7.00	3.91	27.815***	ADHD, ADHD+RD>NC, RD
Teacher Impairment	.11	.52	4.37	4.19	2.58	3.40	4.25	3.48	13.828***	ADHD, ADHD+RD>NC

Deleted: 25.01***
51.376***
4.575*
62.890***
19.987***
17.008***
8.527**
5.295*
95.694***
14.889***
148.827***
97.824***
115.963***

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Main Effect ADHD
Main Effect RD
2-Way ADHDXRD
11.085**
6.229*
5.620*
4.527*
18.108***
340.367***
8.376***
42.179***
31.346***

Adolescent Impairment	1.49	1.66	4.54	3.47	3.75	3.17	6.13	4.07	12.042***	ADHD, ADHD+RD>NC
WRAT3 (SS)										
Reading	111.24	7.44	105.71	7.61	90.83	10.02	87.21	13.27	39.517***	NC, ADHD>RD, ADHD+RD
Spelling	112.22	8.24	103.91	7.88	87.92	11.34	81.42	10.43	65.859***	NC>ADHD>ADHD+RD, RD
WRMT-R (SS)										
Word ID	106.14	5.56	103.94	7.86	87.00	8.31	85.96	13.41	36.521***	NC, ADHD>ADHD+RD, RD
Word Attack	103.97	6.74	102.00	5.51	87.08	8.56	87.08	8.21	42.513***	NC, ADHD>ADHD+RD, RD

Note: [a] Tukey's HSD, $p < .05$, CTRS = Conners Teacher Rating Scale, OCHSS = Ontario Child Health Study Scales, WRAT = Wide Range Achievement Test, WRMT = Woodcock Reading Mastery Test, ADHD = Attention-Deficit/Hyperactivity Disorder (In = inattentive, H/I = hyperactive/impulsive), SS = Standard Scores, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Table 2

Comorbid Diagnoses by Clinical Group

Comorbid Diagnosis: n (%)	ADHD (n=35)	RD (n=12)	ADHD+RD (n=24)
ADHD In. current	30 (85.7)	0 (0)	16 (66.7)
ADHD H/I current	2 (5.7)	0 (0)	2 (8.3)
ADHD Combined current	3 (8.6)	0 (0)	6 (25)
ADHD In. past	20 (57.1)	0 (0)	9 (41.2)
ADHD H/I past	0 (0)	0 (0)	2 (8.3)
ADHD Combined past	15 (42.9)	0 (0)	13 (54.2)
ODD current	13 (37.1)	1 (8.3)	6 (25)
ODD past	13 (37.1)	0 (0)	7 (29.2)
CD current	4 (11.4)	0 (0)	1 (4.2)
CD past	5 (14.3)	0 (0)	5 (20.8)
MDD current	3 (8.6)	0 (0)	1 (4.2)
MDD past	7 (20)	0 (0)	7 (29.2)
Dysthymia	4 (11.4)	0 (0)	1 (4.2)
SAD past	6 (17.2)	0 (0)	4 (16.7)
GAD current	8 (22.9)	0 (0)	5 (20.8)
GAD past	8 (22.9)	0 (0)	3 (4.2)
OCD current	1 (2.9)	0 (0)	0 (0)
OCD past	2 (5.7)	0 (0)	1 (4.2)
Social Phobia past	1 (2.9)	1 (8.3)	2 (8.3)
Enuresis past	8 (22.9)	1 (8.3)	4 (16.7)
Tics current	0 (0)	0 (0)	2 (8.3)
Tics past	3 (8.6)	0 (0)	4 (16.7)

Note: MDD = Major Depressive Disorder, SAD = Separation Anxiety Disorder, GAD = Generalized Anxiety Disorder, OCD = Obsessive Compulsive Disorder

Table 3

Cognitive Processing Problems by Group: Means and Standard Deviations

Variable	NC (n=37)		ADHD (n=35)		RD (n=12)		ADHD+RD (n=24)		F (df = 3, 99)	Contrasts[a]
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
WISC-III (Standard Scores)										
Freedom from Distractibility	107.83	14.22	102.00	14.34	95.33	12.90	84.09	13.74	14.088***	NC>ADHD+RD, RD & ADHD>ADHD+RD
Processing Speed	117.63	13.89	99.12	17.31	110.92	19.01	102.61	16.22	8.398***	NC>ADHD, ADHD+RD
Arithmetic	11.60	3.16	10.00	3.18	9.50	3.83	6.96	2.95	9.798***	NC, ADHD>ADHD+RD
Digit Span	10.80	3.00	10.39	2.88	9.33	2.50	7.17	2.64	8.593***	NC, ADHD>ADHD+RD
Coding	12.34	3.23	8.39	3.33	11.42	4.17	9.04	3.70	8.714***	NC>ADHD, ADHD+RD
Symbol Search	14.11	3.16	10.91	4.12	12.25	3.65	11.61	3.06	5.083**	NC>ADHD, ADHD+RD
Raw Digits Forward	10.11	2.61	9.94	2.25	9.75	1.96	7.87	1.74	5.351**	ADHD, NC>ADHD+RD
Raw Digits Backward	7.23	1.80	6.73	2.10	6.25	1.82	4.96	1.80	6.964***	ADHD, NC>ADHD+RD

Note: [a] Tukey's HSD, $p < .05$, WISC = Wechsler Intelligence Scale for Children, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

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Deleted: Main Effect RD
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Deleted: 25.366***
Deleted: 14.788***
Deleted: 9.006**
Deleted: 13.878***
Deleted: 4.423$^{*, b, c}$
Deleted: 14.759***
Deleted: 17.764***
Deleted: 6.393$^{*, b}$
Deleted: 4.484$^{*, b}$
Deleted: 6.289*
Deleted: 4.798$^{*, a, c}$
Deleted: 11.259***

Table 4

Naming Speed and Executive Functioning by Group: Means and Standard Deviations

Variable	NC (n=37)		ADHD (n=35-32)		RD (n=12-11)		ADHD+RD (n=24-23)		F (3, 104-99)	Contrasts [a]
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
RAN-Numbers (sec)	16.72	2.68	18.08	3.52	19.46	3.19	22.80	5.93	12.275***	ADHD+RD>ADHD, NC
Letters	16.11	2.49	18.30	3.63	20.44	3.33	24.45	7.04	19.064***	ADHD+RD, RD>NC & ADHD+RD>ADHD
Colors	27.26	5.44	31.57	6.15	29.49	4.51	38.54	14.05	9.260***	ADHD+RD>ADHD, RD, NC
Objects	30.32	4.78	34.72	6.08	30.56	3.61	37.46	10.23	6.773***	ADHD, ADHD+RD>NC & ADHD+RD>RD
Stroop Test (T scores)										
T Word	49.65	5.79	45.90	7.15	42.92	6.18	38.60	7.20	14.121***	RD, ADHD+RD>NC & ADHD+RD>ADHD
T Color	50.97	8.14	44.23	6.16	45.33	6.68	39.38	8.89	11.967***	ADHD, ADHD+RD>ND
T Color-Word	58.97	11.36	52.00	10.91	52.92	11.59	42.58	9.06	11.273***	ADHD+RD>ADHD, RD, NC & ADHD>NC
T Interference	57.16	10.92	56.09	9.49	56.50	9.30	51.83	5.49	1.728	
Response execution										
Go Reaction Time (msec)	403.77	105.16	439.74	106.71	438.84	148.90	505.68	123.18	3.727*	ADHD+RD >NC

Deleted: values and significance
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Deleted: 8
Deleted: Main Effect ADHD
Deleted: Main Effect RD
Deleted: 7.905**
Deleted: 20.039***
Deleted: 11.480***
Deleted: 32.766***
Deleted: 14.450***
Deleted: 6.828*
Deleted: 15.898***
Deleted: 8.213**
Deleted: 24.871***
Deleted: 15.535***
Deleted: 10.601**
Deleted: 14.307**
Deleted: 11.436***
Deleted: 4.156$^{*, a, d}$
Deleted: 4.013$^{*, b, c, d}$

SD Go Reaction Time	122.51	54.27	177.18	85.50	134.85	54.68	233.95	100.42	10.776^{***}	ADHD, ADHD+RD>NC & ADHD+RD>ADHD, RD
Percent correct	96.52	4.18	93.54	5.94	95.43	3.98	91.92	8.16	3.370^{*}	NC>ADHD+RD
Response inhibition										
Percent correct	49.61	2.95	48.10	4.80	50.00	2.11	48.06	6.04	1.204	
SSRT (msec)	152.41	51.69	216.46	122.05	180.55	59.10	220.03	112.46	3.651^{*}	ADHD, ADHD+RD>NC
Test Behavior	.78	1.08	1.47	2.12	.73	1.27	2.35	4.16	2.247	

Note: [a] Tukey's HSD, $p < .05$, RAN = Rapid Automatized Naming, SSRT = Stop Signal Reaction Time, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Deleted: 20.790^{***}

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Table 5

Naming Speed and Executive Functioning by Gender: Means and Standard Deviations

Variable	Female ADHD (n=24)		Male ADHD (n=35)		F Values and Significance (df = 1, 59)		
	Mean	SD	Mean	SD	F ratio	P value	Effect Size
RAN-Numbers	20.38	4.29	19.73	5.74	.223	.639	.06
Letters	21.00	5.11	20.67	6.69	.042	.838	.03
Colors	35.18	12.10	33.88	9.59	.213	.646	.06
Objects	36.13	9.26	35.63	7.27	.054	.817	.03
Stroop Test							
T Word	43.96	7.93	42.23	8.04	.666	.418	.11
T Color	43.33	7.81	41.51	7.66	.791	.378	.12
T Color-Word	50.67	11.81	46.46	10.49	2.070	.156	.19
T Interference	56.67	8.70	52.77	7.78	3.241	.077	.23
Response execution							
(male=33, female=22)							
Go Reaction Time	495.30	93.65	448.65	128.94	2.126	.151	.20
SD Go Reaction Time	226.32	101.22	183.99	88.88	2.678	.108	.22
Percent correct	91.72	8.30	93.63	5.86	1.011	.319	.13
Response inhibition							
Percent correct	47.97	5.49	48.16	5.25	.017	.898	.01
SSRT	243.10	130.40	201.19	106.06	1.714	.196	.17
Test Behavior	1.95	2.15	1.76	3.68	.051	.822	.03

Note: RAN = Rapid Automatized Naming, SSRT = Stop Signal Reaction Time

Table 6

Standard Regression Analysis for Variables Predicting ADHD Inattentive Symptoms

Variables	ADHD Inattentive symptoms	Age	SD Go Reaction Time	WISC Coding	B	SE B	β	$\underline{sr_i}^2$ (unique)
Age	-.024				.126	.228	.048	.002
SD Go Reaction Time	.480***	-.195*			1.39E2***	.004	.362	.108
WISC Coding	-.474***	-.004	-.373***		-.295***	.079	-.339	.099
Means	3.76	15.02	168.43	10.31				
SD	3.39	1.28	88.11	3.89				
$R^2 = .333$ [a], Adjusted $R^2 = .312$, R = .577 ***								

* $p < .05$, ** $p < .01$, *** $p < .001$, [a] Unique variability = .209; shared variability = .124

Table 7

Standard Regression Analysis for Variables Predicting ADHD Hyperactive/Impulsive Symptoms

Variables	ADHD H/I symptoms	Age	Stroop Color/Word	SD Go Reaction Time	B	SE B	β	$\underline{sr_i}^2$ (unique)
Age	-.043				-9.66E2	.145	-.006	.000
Stroop Color/Word	-.379***	-.061			-4.42E2**	.016	-.278	.065
SD Go Reaction Time	.377***	-.195*	-.372***		6.09E2**	.002	.273	.061
Means	1.55	15.02	52.64	168.43				
SD	1.97	1.28	12.35	88.11				

$R^2 = .208$ [a], Adjusted $R^2 = .183$, R = .456 ***

[*] $p < .05$, [**] $p < .01$, [***] $p < .001$, [a] Unique variability = .126; shared variability = .082

Table 8

Standard Regression Analysis for Variables Predicting RD Composite

Variables	Composite RD Score	Age	Letter Time	FD	B	SE B	β	sr_i^2 (unique)
Age	-.065				-1.703**	.629	-.182	.032
Letter Time	-.695***	-.182			-1.192***	.192	-.529	.168
WISC Freedom from Distractibility (FD)	.636***	.065	-.616***		.232***	.060	.322	.064
Means	99.59	15.04	19.11	99.69				
SD	12.02	1.29	5.34	16.71				

R^2 = .585[a] , Adjusted R^2 =.572, R = .765***

* $p < .05$, ** $p < .01$, *** $p < .001$, [a] Unique variability = .264; shared variability = .321