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The Influence of Inattention and Rapid Automatized Naming on Reading Performance

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Abstract

The current study examined the relation between attention, rapid automatized naming (RAN), and reading fluency among typically developing children. A total of 104 third- and fourth-grade children (8–11 years of age) completed RAN measures consisting of four stimuli (letter, digit, color, and object) and an oral reading fluency measure from the Gray Oral Reading Test-Fourth Edition. Correlational and hierarchical regression analyses revealed that all four RAN stimuli, particularly letter RAN, were significant predictors of reading fluency. Additionally, parent and teacher ratings of inattention from the Swanson, Nolan and Pelham-Version Four rating scale predicted RAN after controlling for gender, working memory, and estimated IQ. Further analyses indicated that RAN performance mediated the relation between inattention and reading fluency. Results support the need to consider attentional variables when assessing reading performance, even among typically developing children.

Keywords: Reading; Naming; Attention; Neuropsychology; Regression analysis; Mediation

Introduction

Historically, rapid automatized naming (RAN) measures have been shown to be a useful clinical tool for probing the neuropsychological functions that underlie fluency in speech production and long-term word retrieval (Denckla & Rudel, 1976; Wolf & Bowers, 1999). RAN consistently has been shown to be a significant predictor of reading performance both concurrently (Plaza & Cohen, 2003; Wolf & Bowers, 1999) and longitudinally (Kirby, Parilla, & Pfeiffer, 2003; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004). Low performance on RAN tasks is considered to be a core difficulty among children with reading disorders (RDs; Semrud-Clikeman, Guy, Griffin, & Hynd, 2000; Wolf & Bowers, 1999). RAN has been hypothesized to be related to reading fluency (Schatschneider, Carlson, Francis, Foorman, & Fletcher, 2002), specifically connected-text reading, because of the heightened timing demands and required integration of phonological and lexical processes (Bowers, 1995).

It has been suggested that RAN deficits may be integral for understanding the neuropsychological correlates of attention-deficit/hyperactivity disorder (ADHD; Carte, Nigg, & Hinshaw, 1996; Rucklidge & Tannock, 2002; Semrud-Clikeman et al., 2000; Tannock, Martinussen, & Frijters, 2000; Willcutt et al., 2001). Because RAN performance relies on continuous responding and sustained attention to stimuli in order to perform well, it is expected that RAN tasks may be more challenging for children with attention difficulties. Children with ADHD, Predominantly Inattentive Type, and RDs share similar symptomology that may influence RAN outcomes, such as slower processing speed (Catts, Gillespie, Leonard, Kail, & Miller, 2002; Shanahan et al., 2006; Willcutt, Pennington, Olson, Chhabildas, & Huslander, 2005) and semantic processing problems (Tannock, Banaschewski, & Gold, 2006).

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Although reading has been widely studied and well understood in neuropsychological literature, the role of attention is often underestimated particularly in the translation of print into speech, fluency, and comprehension (Reynolds & Besner, 2006). Children with RD are reported to have higher levels of inattention than their non-RD peers (Willcutt et al., 2005). Moreover, inattention has been associated with reading difficulties in students after controlling for prior reading achievement, IQ, and behavioral problems up to fifth grade (Rabiner, Coie, & Conduct Problems Prevention Research Group, 2000). Children with RD are known to demonstrate higher levels of inattention compared with their same-age peers (Willcutt et al., 2001), suggesting multiple pathways to low performance on RAN measures that include both linguistic and attentional processes. Although the comorbidity of reading and attention problems is generally well established, less is known about how the processes of RAN, which are considered foundational to reading, are influenced by attention.

There is some evidence that the type of stimuli used for the RAN task may be salient to specific types of developmental issues. Alphanumeric RAN (i.e., letters/numbers) appear to be more closely associated with reading (Manis, Doi, & Bhadha, 2000; Savage & Frederickson, 2005), whereas non-alphanumeric RAN (i.e., colors/objects) appear to be more closely associated with attentional processes (Rucklidge & Tannock, 2002; Semrud-Clikeman et al., 2000; Stringer, Toplak, & Stanovich, 2004). A meta-analysis of cognitive deficits in children, adolescents, and young adults with ADHD revealed that color-naming deficits show moderate to large effect sizes ($d = 0.58-0.62$) across the developmental lifespan with little evidence of age-related changes (van Mourik, Oosterlaan, & Sergeant, 2005). Rucklidge and Tannock (2002) found significant differences in performance on color and object RAN tasks between children with ADHD (with and without RD) and with typically developing children. One possible explanation for this finding is that slow color and object naming may be associated with developmental delays in effortful perceptual and/or semantic processing, typically associated with right hemisphere functioning (Tannock et al., 2000). Another explanation is the possibility of more than one plausible name for a given color or object, and asymmetries may likely exist between the labels. For example, object names may differ in word frequency leading to increased attentional demands and the necessity for more careful and detailed processing than recognizing letters or digits. Such impairments in semantic processing have been implicated in children with attention difficulties (Tannock et al., 2006).

Most previous RAN studies have utilized clinical groups, such as children with ADHD and diagnosed RD. Previous ADHD studies often do not separate differences between inattentive and hyperactive-impulsive symptoms (e.g., Carte et al., 1996; Semrud-Clikeman et al., 2000). Groups of children diagnosed with ADHD in the reported studies may have exhibited either predominantly hyperactive, rather than inattentive behaviors, or a combination of both. The heterogeneous nature of the ADHD construct represents a significant limitation in studies that explore the relation between inattention and reading, especially since phenotypic studies noted that inattention is more predictive of reading difficulties than hyperactivity or impulsivity (Willcutt et al., 2001). In addition, most studies of RAN performance in children with RD and/or ADHD have used single-word reading tasks rather than using measures of reading fluency to assess reading skills.

The present study was designed to explore the concurrent relations among different measures of RAN, inattention, and reading fluency skills in a representative sample of third- and fourth-grade children. Because extant research studies primarily have been focused on comparing groups of children with RD or ADHD with control groups, the current study aimed to look more closely at how inattentive behaviors overlap with reading skills among typically developing children with no present clinical diagnoses. This comparison may provide a better understanding of the variability in attention levels among typically developing readers (Mayes, Calhoun, & Crowell, 2000). These findings may contribute to the development of a model of how the domains of reading and attention are inter-related. Researchers and practitioners may also be able to identify and intervene early with children who are considered at risk for developing reading or attention problems.

Three hypotheses were proposed for the study. First, it was hypothesized that all RAN measures would significantly predict reading fluency. Second, it was expected that inattention, assessed by parent and teacher ratings, would significantly predict RAN and would be more highly correlated with color RAN measures. Third, it was hypothesized that the relation between ratings of inattention and reading fluency would be mediated by RAN.

Methods

Participants

Following approval from the Institutional Review Board of the relevant university and the school administration, consent forms and questionnaire packets were distributed to third- and fourth-grade classrooms in three elementary schools from a suburban district in the Midwest. Demographic data were collected using a brief demographic form as part of the questionnaire packet. Out of the 295 questionnaire packets distributed, 108 provided parental consent. Of those who provided consent, two were excluded from the study since the children did not meet criteria to participate in the study. An additional two were excluded due to incomplete responses from the questionnaire packets. Thus, data from 104 participants were collected and analyzed.

Each child was tested either at home or at school based on the choice of the parent. The individual testing took approximately 60 min to complete. Trained graduate assistants administered and scored a portion of the tests. The primary researcher observed and reviewed the testing and scoring completed by graduate assistants to ensure competency and proficiency in standardized test administration and scoring procedures.

Children. Of the 104 children who agreed to participate in the study, 56 were women (54%) and 48 were men (46%). Participants were between ages 8 and 11 (mean age = 9.13). Thirty-nine children (38%) were enrolled in third grade, and 65 children (62%) were enrolled in fourth grade. All children spoke English as their primary language. Ethnicity of the sample was reflective of the school district, where parents identified their child in the following categories: 79% Caucasian, 6% African American, 6% Latino Hispanic, 2% Asian, 2% American Indian, and 5% Biracial.

Parents. Information on parental education and occupation was used to calculate parent socio-economic status using the Hollingshead Four-Factor Index of Socio-Economic Status (1975), one of the most frequently used measures of SES. The index score was calculated from seven educational categories (from grades K-6 to graduate school) and nine occupational categories (from unskilled workers to professional). The scores on the index ranged from 8 to 66. Lower scores reflected less education and lower-level occupation, whereas higher scores reflected more education and higher-ranked occupations. If information from two caregivers was reported, individual scores were first calculated and subsequently averaged.

Of the 104 parents who provided consent to participate in the study, 99 were women (95%). Parental socio-economic status was generally middle class (mean Hollingshead index score = 42.80, $SD = 11.63$, median = 44.00; Hollingshead, 1975), although there was wide variability in scores ranging from 14 (low SES) to 66 (high SES).

Teachers. Fifteen teachers agreed to participate in the study. Demographic data included teacher's educational level and years of teaching experience in elementary school. Six were third-grade teachers (40%), and nine were fourth-grade teachers (60%). Three teachers were men. Out of the 15 teachers, eight had completed a master's degree or higher. The average number of years teaching elementary school was 17.1 years. However, when comparing gender, male teachers taught an average of 2.3 years, whereas female teachers taught an average of 21.1 years.

Exclusion criteria. Children with any learning, physical, social-emotional, or behavioral disorder were excluded from the study. Children receiving special education services at their school for a reading disability, speech/language impairment, autistic spectrum disorder, or ADHD were also excluded. Additional exclusion criteria included individuals who had a previous or current diagnosis of a psychological disorder (e.g., depression), a neurological disorder (e.g., traumatic brain injury), or cognitive impairment (i.e., mental retardation).

Sample size. Regarding sample size needed for the study, a statistical power approaching .80 is considered adequate for rejecting the null hypothesis if it were false. For multiple regression procedures with four independent variables, given an α level of 0.05, assuming a medium effect size, and statistical power level of .80, the total recommended sample size was at least 100 participants (Cohen, 1988).

Variables and Measures

Rapid automatized naming. Four rapid naming subtests were administered from the Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 1999): Rapid Digit Naming, Rapid Letter Naming, Rapid Color Naming, and Rapid Object Naming. Each subtest contained stimuli in a randomized order for a total of 72 items, arrayed in four horizontal rows of nine items per row across two pages. Prior to exposing the test pages, each participant was presented with practice items to determine ability to discriminate the stimuli. No participant was unable to name the stimuli or experienced difficulty in understanding the task.

Scaled scores by age were determined based on the speed at which each participant completed the task. The Rapid Naming Composite standard score was based on the performance of the two alphanumeric RAN tasks combined, whereas the Alternate Rapid Naming Composite standard score was based on the performance of the two non-alphanumeric RAN tasks combined. Reliability coefficients for the RAN subtests on the CTOPP are, respectively: 0.79 for objects, 0.87 for digits, and 0.82 for both color and letter subtests.

Reading fluency. Oral reading fluency was assessed using the Gray Oral Reading Test-Fourth Edition (GORT-4; Wiederholt & Bryant, 2001). The GORT-4 is an individually administered, norm-referenced measure of oral reading fluency, used to assess individuals from 6 to 18 years of age. Children were asked to read paragraphs aloud of increasing difficulty. Deviations from the text, such as self-corrections, omissions, substitutions, insertions, and loss of place, were noted as errors. Multiple scaled scores by age were derived from the child's reading including rate and accuracy, which is used to determine reading fluency. Scaled scores are provided for rate, accuracy, and fluency. For the present study, oral reading fluency scores were analyzed. Internal consistencies are high ($\geq$0.90), as well as test–retest reliability.

Inattention. The Swanson, Nolan and Pelham-Version Four (SNAP-IV) rating scale was used to assess inattentive behaviors (Swanson, 1992; Swanson et al., 2001). Both parents and teachers were asked to complete the first 20 items, as they addressed the core symptoms that related to the ADHD criteria outlined in the DSM-IV-TR (2000): inattention (items #1–9) and hyperactivity-impulsivity (items #11–19). Item numbers 10 and 20 of the scales were also completed but not included in the analyses as they provided overall estimates of each domain and were not used when scoring. When completing the scale, parents and teachers were asked to indicate the frequency that they observed each ADHD symptom during the past 6 months. Frequency ratings consisted of a Likert-like scale rating from 0 to 3 points: "not at all," "just a little," "quite a bit," or "very much." Only ratings from both parent and teacher ratings of inattention (items #1–9) were used and then summed to form a new variable of overall inattention: Combined Inattention. Data analyses were conducted using only the Inattention subscale from the SNAP-IV, as it was the primary variable in the study.

A recent study examining the psychometric properties of the full SNAP-IV revealed overall reliability was acceptable (Bussing et al., 2008). Internal consistency for parent and teacher ratings was high ($\geq$0.94). Inter-rater reliability between parent and teacher ratings was 0.49 for inattention. Even though the scale does not use age-specific normative cutoff points, analyses of SNAP-IV scores by age in the psychometric study did not support the notion of developmental amelioration of ADHD-related behaviors during the elementary school years (Bussing et al., 2008). Estimates revealed a small effect size for parent inattention ratings (0.33) and teacher inattention ratings ($<$0.2) comparing 8–10-year-olds to 11-year-olds. This finding is consistent with other studies reporting negligible to small age effects (Conners, 1997).

Estimated IQ. Children also completed a brief standardized measure of verbal and non-verbal cognitive ability. A two-subtest combination of the Wechsler Intellectual Scale for Children-Fourth Edition (WISC-IV; Wechsler, 2003) short form (Sattler, 2008) was administered to each child participant. The administration of a short form is a reasonable strategy in research studies and in clinical situations where intellectual functioning is not the primary purpose of the assessment (Sattler & Dumont, 2004). The two selected subtests were *Vocabulary* and *Matrix Reasoning*. This particular dyad of subtests is reported to have high internal consistency (Vocabulary = 0.86; Matrix Reasoning = 0.85). The scaled scores from these two subtests were summed to yield a composite score, which was then prorated to an estimated Full-Scale IQ score. The reliability and validity coefficients of the short form are 0.93 and 0.87, respectively.

Working memory. The *Digit Span* subtest of the WISC-IV was administered to each child in order to assess auditory sequential working memory. A scaled score from this subtest was recorded. The internal consistency for the subtest is 0.87.

Data Analyses

Distributions of all variables were examined, and log transformations were used for several variables showing excessive skewness. Hierarchical regression analyses were conducted to examine relations between ratings of inattention, RAN performance, and reading skills, while controlling for background variables (i.e., gender, parent SES, working memory, and estimated IQ). Separate regression analyses were run to examine the relation between RAN performance and reading fluency and between RAN performance and inattention. The presence of mediation effects was tested using hierarchical regression according to the guidelines recommended by Baron and Kenny (1986). Standardized coefficients were calculated to examine changes in coefficients with the addition of the mediator (RAN) to the model. Sobel's z-statistic (Sobel, 1988) was calculated to assess the significance of changes in the coefficients. The appropriate unstandardized regression coefficients and standard errors were used in the calculation of the Sobel test by employing an interactive calculation tool provided by Preacher and Leonardelli (2001).

Results

Descriptive statistics of the experimental measures of inattention, RAN, and reading fluency scores are presented in Table 1. Generally, children performed in the average range on all measures as expected. An intercorrelation matrix of the primary

Table 1. Descriptive statistics

Variable/measure	Mean	*SD*	Range
Age (years)	9.13	0.73	8.00–11.00
Parent SES (Hollingshead Index)	42.80	11.63	14.00–66.00
WISC-IV			
Estimated Full-Scale IQ[a]	100.19	11.88	79.70–140.60
Digit Span	9.63	2.23	4.00–16.00
GORT-4			
Reading Rate[b]	11.08	2.40	6.00–17.00
Reading Accuracy[b]	10.96	2.22	6.00–1700
Reading Fluency[b]	10.98	2.47	5.00–18.00
CTOPP			
Digit RAN[b]	10.49	2.03	6.00–15.00
Letter RAN[b]	10.30	2.15	5.00–20.00
Color RAN[b]	8.88	2.44	2.00–14.00
Object RAN[b]	8.94	2.54	3.00–15.00
Rapid Naming Composite[a]	102.37	11.73	76.00–145.00
Alternate Rapid Naming Composite[a]	93.62	14.01	58.00–127.00
SNAP-IV			
Parent Rating of Inattention[c]	0.71	0.61	0–3.00
Teacher Rating of Inattention[c]	0.64	0.85	0–3.00
Combined Inattention	1.36	1.26	0–5.33

Notes: WISC-IV = Wechsler Intellectual Scale for Children-Fourth Edition; GORT-4 = Gray Oral Reading Test-Fourth Edition; CTOPP = Comprehensive Test of Phonological Processing; RAN = rapid automatized naming; SNAP-IV = Swanson, Nolan and Pelham-Version Four.
[a]Scores from these measures are based on a standard score, mean = 100, $SD = \pm 15$.
[b]Scores from these measures are based on a scaled score, mean = 10, $SD = \pm 3$.
[c]Scores from these measures are based on a raw score: 0 (Not at all) to 3 (Very Much).

Table 2. Intercorrelations between reading fluency and experimental measures

	2	3	4	5	6	7	8	9
1. Estimated IQ	.46**	.57**	0.08	0.18	.25*	.16	−.22*	−.27**
2. Digit Span (Working Memory)		.33**	.24*	.20*	.25**	.24*	−.21*	−.20*
3. Reading Fluency			.52**	.60**	.48**	.47**	−.37**	−.31**
4. Digit RAN				.75**	.52**	.58**	−.22*	−.14
5. Letter RAN					.52**	.57**	−.29**	−.25*
6. Color RAN						.80**	−.42**	−.35**
7. Object RAN							−.31**	−.27**
8. Parent Rating of Inattention								0.47**
9. Teacher Rating of Inattention								

Note: RAN = rapid automatized naming.
*$p < .05$.
**$p < .01$.

variables of interest was also constructed (Table 2). Inspection of these intercorrelations revealed that reading fluency was positively correlated with estimated IQ and RAN performance and negatively correlated with parent and teacher ratings of inattention. Beyond this, the strongest correlation of reading fluency was the letter RAN task ($r = .60$, $p < .01$), whereas the strongest correlation of parent and teacher ratings of inattention was the color RAN task ($r = -.42$, $p < .01$). The correlation between parent and teacher ratings of inattention was significantly correlated ($r = .47$, $p < .01$). A one-way ANOVA was conducted to determine whether there were significant differences between boys' and girls' inattention levels. Parents rated boys significantly higher on inattentive behaviors than girls, $F(1,102) = 5.13$, $p < .05$. In addition, teachers rated boys significantly higher on inattentive behaviors than girls, $F(1,102) = 16.67$, $p < .001$.

Relation between RAN and Reading Skills

Results of the hierarchical regression analyses predicting reading fluency from RAN are presented in Table 3. After controlling for background variables (e.g., gender, parental SES, working memory, and IQ), both the Rapid Naming

Table 3. Regression analyses of RAN composites separately predicting reading fluency

	b	SEb	β	Model R^2	ΔR^2
Step 1					
Gender	0.28	0.30	0.06	.34**	
Parental SES	0.03*	0.02	0.13		
Working Memory	−0.04	0.08	−0.04		
Estimated IQ	0.09**	0.02	0.44		
Step 2					
Rapid Naming Composite	0.11**	0.01	0.52	.60**	.26
Step 1					
Gender	0.11	0.37	0.02	.34**	
Parental SES	0.04*	0.02	0.20		
Working Memory	0.01	0.09	0.01		
Estimated IQ	0.09**	0.02	0.44		
Step 2					
Alternate Rapid Naming Composite	0.06**	0.01	0.37	.45**	.11

Note: RAN = rapid automatized naming.
*$p < .05$.
**$p < .01$.

Composite—$\Delta R^2 = .26$, $F(1,98) = 68.29$, $p < .001$—and Alternate Rapid Naming Composite—$\Delta R^2 = .11$, $F(1,98) = 29.74$, $p < .001$—were significant predictors of reading fluency, accounting for a large proportion of unique variance (26% and 11%, respectively). Estimated IQ and parental SES also predicted reading fluency. However, neither gender nor working memory provided any significant variance in reading fluency.

Of the four individual RAN tasks, letter RAN contributed the most to the model accounting for an additional 24% of the variance in reading fluency, $\Delta R^2 = .24$, $F(5,98) = 58.66$, $p < .001$, and was the strongest correlate with reading fluency ($r = .60$, $p < .01$). As for the other RAN tasks, digit RAN was also a significant predictor of reading fluency accounting for an additional 21% of the variance in the model, $\Delta R^2 = .21$, $F(5,98) = 47.35$, $p < .001$. Color RAN also contributed to reading fluency, providing an additional 9% of the variance, $\Delta R^2 = .09$, $F(5,98) = 16.32$, $p < .001$. Similarly, object RAN added significantly to the prediction of reading fluency, contributing an additional 11% of the variance in reading fluency, $\Delta R^2 = .11$, $F(5,98) = 21.77$, $p < .001$.

Relation between Inattention and RAN

When the Combined Inattention variable was entered in the regression analyses, it significantly contributed to the Rapid Naming Composite, $\Delta R^2 = .05$, $F(5,98) = 5.20$, $p < .05$, explaining 5% of the variance. Ratings of inattention also contributed to the Alternate Rapid Naming Composite, $\Delta R^2 = .08$, $F(5,98) = 10.26$, $p < .01$, explaining 8% of the variance when background variables were controlled. Among the four RAN tasks, the strongest correlate of parent and teacher ratings of inattention was the color RAN task ($r = -.42$ and $-.35$, respectively, $p < .01$).

When inattention was further explored by separating parent and teacher ratings, only the parent ratings remained consistently significant in explaining 5% of the variance in the Rapid Naming Composite, $\Delta R^2 = .05$, $F(5,98) = 5.01$, $p < .05$, but not teacher ratings of inattention, $\Delta R^2 = .03$, $F(5,98) = 2.74$, $p < .10$. When the Alternate Rapid Naming Composite was the dependent variable, parent ratings of inattention significantly contributed 7% of the variance, $\Delta R^2 = .07$, $F(5,98) = 8.71$, $p < .01$, and teacher ratings of inattention contributed 5% of the variance, $\Delta R^2 = .05$, $F(5,98) = 5.92$, $p < .05$, when background variables were controlled.

Relation between Inattention, RAN, and Reading

Two-step regression models were developed to determine whether inattention predicted reading skills without controlling for RAN. Thereafter, three-step regression models were developed to test the proposed hypotheses with RAN included. Background variables were entered in the first step, whereas the two RAN composites were entered separately in the second step. The third step included the Combined Inattention variable.

Before controlling for RAN performance, results showed that Combined Inattention significantly predicted reading fluency, $\Delta R^2 = .04$, $F(5,98) = 5.71$, $p < .05$, accounting for approximately 4% additional variance. However, when both RAN composites were individually controlled, no significant relation was found between inattention and reading fluency. Given the

Table 4. Regression analyses with RAN as the mediator variable

Independent variable	Dependent variable	b	SEb	β	t	ΔR^2
Rapid Naming Composite						
Combined Inattention	Reading Fluency	−0.42*	0.18	−0.21	−2.39	.04
Combined Inattention	Rapid Naming Composite	−2.30*	1.01	−0.25	−2.30	.05
Rapid Naming Composite (controlling for inattention)	Reading Fluency	0.11**	0.01	0.51	7.81	.23
Combined Inattention (controlling for Rapid Naming Composite)	Reading Fluency	−0.17	0.14	−0.09	−1.21	.01
Alternate Rapid Naming Composite						
Combined Inattention	Reading Fluency	−0.42*	0.18	−0.21	−2.39	.04
Combined Inattention	Alternate Rapid Naming Composite	−3.63**	1.14	−0.33	−3.20	.08
Alternate Rapid Naming Composite (controlling for inattention)	Reading Fluency	0.06**	0.02	0.34	4.08	.09
Combined Inattention (controlling for Alternate Rapid Naming Composite)	Reading Fluency	−0.21	0.17	−0.11	−1.19	.01

Notes: RAN = rapid automatized naming. Hierarchical regressions controlled for children's background variables (i.e., gender, parent SES, working memory, and estimated IQ).
*$p < .05$.
**$p < .01$.

previous findings that inattention predicted RAN and that RAN predicted reading fluency, additional analyses were conducted to determine whether RAN performance mediated the relation between inattention and reading fluency (Table 4).

Sobel's z-statistic was used (Sobel, 1988) for mediation analyses. When the Rapid Naming Composite was incorporated into the mediation analyses, the result was significant (Sobel's $z = -2.22$, $p = .026$). This finding suggests that the inclusion of alphanumeric RAN significantly decreased the strength of the relation between inattention and reading fluency, such that the standardized regression coefficients changed from −.21 to −.09. In a separate mediation analysis, the inclusion of the Alternate Rapid Naming Composite (color and object RAN) also significantly decreased the strength of the relation between inattention and reading fluency scores (Sobel's $z = -2.14$, $p = .031$), such that the standardized regression coefficients changed from −.21 to −.11. The relation between inattention and reading fluency in the model therefore was not significant when the direct influence of RAN was included in the analysis (Table 4).

Discussion

The current study examined the relation between inattention and RAN on reading performance, particularly oral reading fluency. A number of previous studies have demonstrated that children with ADHD perform more poorly on specific RAN measures relative to control groups (e.g., Carte et al., 1996; Semrud-Clikeman et al., 2000; van Mourik et al., 2005). This study expands the literature by focusing on inattention, the component of ADHD shown to be most strongly related to reading difficulties (e.g., Willcutt et al., 2005). Results demonstrated that parent and teacher ratings of inattention predicted RAN speed in addition to oral reading fluency. In addition, RAN performance across all stimuli had a mediating effect in relation between inattention and reading fluency.

Although the children who participated in the study were typically developing children with no history of learning disabilities, ADHD, neurological, or psychological problems, they performed variably across reading, RAN, and attention measures. In general, stronger relations between RAN and reading skills have been found in samples of relatively poorer readers or those with reading disabilities (e.g., Compton, Davis, DeFries, Gayan, & Olson, 2001; Davis, Knopik, Olson, Wadsworth, & DeFries, 2001). The significant finding between these variables among normally developing readers suggests that variable levels of attention and/or reading ability did not necessarily impair their academic or daily functioning.

In contrast to previous research indicating that only letter and digit RAN (but not color or object RAN) predicted reading fluency (e.g., Savage & Frederickson, 2005), all four RAN stimuli contributed to reading fluency. Letter RAN explained the most variance (24%) and was more strongly associated with reading fluency than other RAN stimuli. This finding suggests that in addition to heightened timed demands involved in RAN tasks, there may be additional phonological and/or orthographic aspects present in alphanumeric RAN stimuli, likely absent in non-alphanumeric RAN stimuli.

Inattention and RAN

The combined (parent and teacher) ratings of inattention had a negative influence on both RAN composites. This finding suggests that higher levels of attention are needed to perform well on all four RAN tasks even among normally performing children. Among the four stimuli, color RAN was the strongest correlate of parent and teacher ratings of attention. A fairly common hypothesis among the neuropsychological studies suggests that non-alphanumeric tasks are better predictors of executive control of attention (Stringer et al., 2004; Tannock et al., 2006). Letters and digits are over-learned and emphasized more so than colors and objects as children have increased exposure to reading and mathematics at school. Thus, for typically developing children, letter and digit RAN tasks may become more automatic and require less attention to complete than color and object RAN tasks.

As with reading scores, children's attention levels were variable in both home and school settings. Overall analyses from both parent and teacher ratings indicate 5%–8% of the variance in RAN performance is attributed to inattention. In addition, regression analyses indicate a relatively weaker relationship between teacher ratings of inattention and RAN performance than with parent ratings. Teacher ratings of inattention did not contribute sizeable variance in predicting letter and digit RAN performance. Because some of the children in this study did not have any notably severe academic or behavioral issues in school, classroom teachers might not have rated the children's classroom behaviors as problematic as their parents would rate their children at home. In addition, schools often provide more environmental structure in order for children to focus their attention than at home. Nevertheless, further studies should explore these rating differences between informants among typically developing children, since it was difficult to determine whether these disparities were due to rater biases or that children's behaviors were actually dissimilar across both settings.

Several parents rated their children relatively high on inattention, even though these children had no prior history of ADHD. Regression analyses indicated that higher levels of inattention were significantly related to lower performance in RAN and reading fluency measures. Both alphanumeric and non-alphanumeric RAN mediated the relation between ratings of inattention and reading fluency. Thus, it is likely that children with higher levels of inattention would have difficulty with RAN tasks given its timed demands, adversely affecting their performance on reading fluency measures. Similar to reading, attention lies along a continuum and thus should be carefully monitored when exploring variability in reading performance.

Successful completion of RAN tasks requires the integration of multiple neural connections. When a reader attends to and recognizes a stimulus on a page, the visual cortex sends the information to the left angular gyrus, a region in the parietal lobe, and subsequently into Wernicke's area, which is responsible for understanding written and spoken language. The information is then translated into an auditory form and comprehended, and sent into Broca's area, located in the frontal lobe, where speech production (oral or silent) occurs (Geschwind & Fusillo, 1966). However, if breakdown occurs in one or more of these connections, this would result in slower RAN speed. Therefore, successful performance requires that all these processes be synchronous. Among typically developing children, RAN speed and reading performance have been associated with white matter integrity in the left temporal lobe (Nagy, Westerberg, & Klingberg, 2004). Neuroimaging studies can further address whether children who have low levels of attention also exhibit similar neurological activity when completing RAN tasks.

Limitations

The results of the current study should be interpreted in light of the following limitations.

Parents who agreed to participate in the study might have children with suspected reading or attention difficulties, and thus were more likely to participate in the study than parents who have children with little to no academic or behavior difficulties. Even though parents had the option of requesting their child's testing results, only one parent made such a request. The sample size was also a limitation; with a larger sample, power would have increased, and it is possible that additional relations would have been significant given the large number of variables included in the study. Inclusion of children with RD or ADHD was also considered for the study; however, considering that participants were recruited from a school district than a clinical setting, it would have been difficult to recruit enough children with these clinical diagnoses in order to make appropriate comparisons with typically developing children. Thus, the absence of clinically established diagnoses in the sample requires that caution be taken when extrapolating data to children diagnosed with RD or ADHD.

Assessing children's reading comprehension was also initially included as part of the study. The GORT-4 provides a reading comprehension measure. For this test, the examiner reads five multiple-choice questions to the child about the short passage the child had just read. Some researchers have suggested that the comprehension measure does not accurately assess readers' true understanding of the text. Keenan and Betjemann (2006) found that children could answer the multiple-choice comprehension questions from the GORT-4 with above-chance accuracy without reading the passage or the questions themselves. In addition, it was not unusual for many children to achieve fluency ceiling before comprehension ceiling on the GORT-4. For these reasons, the GORT-4 comprehension measure was eventually removed for the study. Future studies may want to include a reading comprehension task when exploring children's reading performance.

Because attention was one of the primary variables in the study, additional measures of sustained attention, processing speed, or executive functioning (e.g., continuous performance tests, CPTs) used in clinical and research settings could be useful to explore the cognitive aspects of attention (Barkley, 1997), rather than solely relying on behavior rating scales. As such, these data would be gathered based on individual student performance rather than solely from observation conducted by parents or teachers. Visual and auditory CPTs can be used to assess whether there are differences between sustained visual and auditory attention, since RAN and reading tasks require the integration of both domains.

Future Directions

The results from this study emphasize the utility of brief assessments such as RAN in predicting reading performance, even among children who do not exhibit significant reading difficulties. Slower RAN speed suggests difficulties with executive control of attention, likely related to abnormal fluctuations or breakdown of neural connections (Misra, Katzir, Eolf, & Poldrack, 2004). Although these fluctuations may provide a basis for understanding levels of inattention, they may also allow for more direct assessment of factors contributing to specific reading skills, particularly fluency and comprehension among typically developing children. Future research should also examine the association between inattention, RAN, and reading comprehension, since comprehension often requires more attentional and cognitive resources than fluency. In addition, researchers can also address whether rapid serial naming is more related to inattention and reading ability than RAN given its increased cognitive demands in switching between various stimuli (e.g., letter-color-letter). Longitudinal studies can also be helpful to look at the utility of RAN in predicting reading outcomes in each grade level.

This study provides additional support for psychologists and researchers to assess attention and reading problems on a continuum, rather than determining whether they are simply present or absent (Mayes et al., 2000). Other findings have implications for practitioners when diagnosing RD or ADHD; if a child does not meet diagnostic criteria for the disorder, the child may still have some degree of attention or a reading difficulty, as clinical symptoms or behaviors occurring at a subthreshold level may warrant intervention.

Neuroimaging research can be particularly useful in enhancing knowledge and understanding of the theoretical constructs behind RAN. Misra and colleagues (2004) conducted an fMRI study with average adult female readers to evaluate the neural substrates underlying RAN performance using letter and object stimuli. For both RAN tasks compared with control tasks, activation was found in neural regions associated with eye movement control and attention as well as regions previously implicated in reading tasks, including the inferior frontal cortex, temporal-parietal areas, ventral visual stream. Future research should explore the neural activation in children, both average and dyslexic readers, performing RAN and reading tasks. Neuroimaging studies can also provide a better understanding about the specific constructs underlying RAN by highlighting its neurological correlates. These correlates can then be used in evaluating the various theoretical positions that have been proposed involving RAN and reading.

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Conflict of Interest

None declared.

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