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Executive Functions Contribute Uniquely to Reading Competence in Minority Youth

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Abstract

Competent reading requires various skills beyond those for basic word reading (i.e., core language skills, rapid naming, phonological processing). Contributing “higher-level” or domain-general processes include information processing speed and executive functions (working memory, strategic problem solving, attentional switching). Research in this area has relied on largely Caucasian samples, with limited representation of children from racial or ethnic minority groups. This study examined contributions of executive skills to reading competence in 761 children of minority backgrounds. Hierarchical linear regressions examined unique contributions of executive functions (EF) to word reading, fluency, and comprehension. EF contributed uniquely to reading performance, over and above reading-related language skills; working memory contributed uniquely to all components of reading; while attentional switching, but not problem solving, contributed to isolated and contextual word reading and reading fluency. Problem solving uniquely predicted comprehension, suggesting that this skill may be especially important for reading comprehension in minority youth. Attentional switching may play a unique role in development of reading fluency in minority youth, perhaps as a result of the increased demand for switching between spoken versus written dialects. Findings have implications for educational and clinical practice with regard to reading instruction, remedial reading intervention, and assessment of individuals with reading difficulty.

Keywords

Dyslexia; Attention; Processing Speed; Working Memory; Fluency; Comprehension

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Reading disability (dyslexia) is defined as a neurobiological disorder characterized by difficulties with accurate and/or fluent word recognition, spelling, and decoding (Lyon, Shaywitz, & Shaywitz, 2003). This expanded definition includes difficulties with multiple aspects of reading, beyond isolated word reading, which may contribute to poor comprehension in the absence of word recognition deficits. From the early investigations into dyslexia, researchers such as Orton (1925) and Geschwind (1965) conceptualized competent reading—including fluency and comprehension—as requiring multiple, interrelated, and complex cognitive processes supported by the integration of several concurrently employed brain regions. Motivated by these early theoretical and empirical models, multiple cognitive processes have been studied as contributors to reading ability and disability, including rapid naming, phonological awareness, decoding, oral language, and vocabulary knowledge, with a large and growing body of evidence suggesting that all of these core skills are related to development of reading (Braze, Tabor, Shankweiler, & Mencl, 2007; Cutting & Denckla, 2001; Norton & Wolf, 2012; Shankweiler et al., 1999; Torgesen, 2002; Wolf & Bowers, 1999).

Contributions of executive skills

In addition to these core reading-related skills, other cognitive skills have been identified as critical in development of fluent reading. In particular, processing speed weaknesses have been identified as a core feature of children with reading difficulty, both with and without a comorbid attentional disorder (Jacobson et al., 2011; McGrath et al., 2011; Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005). Although some work has questioned whether rapid naming simply represents a manifestation of general cognitive processing speed (e.g., Catts, Gillispie, Leonard, Kail, & Miller, 2002), the majority of work in this area suggests that both rapid naming and processing speed contribute separately and uniquely to reading (Cutting & Denckla, 2001; Powell, Stainthorp, Stuart, Garwood, & Quinlan, 2007). Speed of information processing appears to set a limit on fluency, defined as accurate and efficient decoding (Breznitz, 2006), which in turn impacts reading comprehension, even when decoding skills are intact (Perfetti, Marron, & Foltz, 1996). In that vein, improved fluency is associated with improved reading comprehension (Berninger, Abbott, Vermeulen, & Fulton, 2006).

More recent work has begun to examine the additional contributions of attention and higher level “executive” control processes to reading competence. Executive function (EF) refers to the skills necessary for independent, goaldirected behavior, including intentionally shifting attention between aspects of the task, holding information in working memory, and problem solving (Denckla, 1994; Jacobson & Mahone, 2012). Competent and fluent reading requires a number of EF skills, beyond the contributions of foundational core reading-related skills, of which three critical components include working memory, attentional switching, and problem solving (e.g., Caretti, Borella, Cornoldi, & De Beni, 2009; Sesma, Mahone, Levine, Eason, & Cutting, 2009; Swanson & Jerman, 2007; Yeniad, Malda, Mesman, van IJzendoorn, & Pieper, 2013). For example, competence in reading comprehension requires application of active cognitive and metacognitive strategies, including the ability to hold previously read information in mind while reading (i.e., working memory); the ability to shift efficiently from one word, idea, or topic to another (i.e., attentional switching); and the ability to integrate multiple pieces of information and simultaneously apply previously learned information to extract “main ideas” (i.e., problem solving). Not surprisingly, individuals with dyslexia commonly show EF deficits in basic visual attention (Bosse, Tainturier, & Valdois, 2007), verbal working memory (Reiter, Tucha, & Lange, 2005), and planning/problem solving (Keeler, 1995; Locascio, Mahone, Eason, & Cutting, 2010; Reiter et al., 2005). Problem solving deficits are associated with reading comprehension difficulties even in the absence of basic word recognition problems (Locascio et al., 2010; Sesma et al., 2009).

However, findings to date regarding contributions of specific executive control skills to reading outcomes are contradictory. For example, in a large twin cohort selected for reading or attentional disorders, Christopher and colleagues (2012) found that working memory uniquely predicted both word reading and comprehension. Likewise, meta-analysis suggests that complex verbal working memory tasks distinguish between good and poor comprehenders (Caretti et al., 2009), although there was substantial variability among studies. Conversely, in a smaller study of children with and without documented RD, several EFs (i.e., planning, verbal working memory, but not inhibition) uniquely predicted reading comprehension—but not basic word reading— across groups, after controlling for core language skills and reading fluency (Sesma et al., 2009). More recent work by Miller and colleagues showed that while intact working memory and nonverbal problem-solving skills support comprehension, planning and organizational skills did not show an effect on comprehension. Planning, but not working memory or problem solving, was the unique predictor of reading fluency (Miller et al., 2014). Although the different measures used across studies limits definitive conclusions, taken together, these findings suggest that in mixed samples of children with and without specific reading difficulty, working memory and problem solving appear to support reading comprehension. Working memory appears to be a less consistent predictor of basic word reading ability and/or reading fluency.

In addition, examination of contributions of EF to reading competence must consider core reading-related (e.g., “domain-specific”) skills as well as executive skills. Many recent prior studies, while examining the impact of various EF skills on reading skills, do not simultaneously consider contributions from well-recognized core reading-related measures such as rapid naming, decoding skills, or vocabulary knowledge (see, e.g., Best, Miller, & Naglieri, 2011; Borella & de Ribaupierre, 2014; Moura, Simões, & Pereira, 2014). As such, the associations among EF skills and foundational reading skills are not taken into account and contributions of EF skills may be inadvertently misspecified.

Limitations of generalizability to readers from minority backgrounds

A significant additional consideration in most existing work in this area, including the previously noted investigations, is that examination of core reading-related processes to reading development has been performed in primarily Caucasian samples, or in samples in which racial/ethnic background is not fully described (e.g., Best et al., 2011; Borella & de Ribaupierre, 2014; Christopher et al., 2012; Locascio et al., 2010; Miller et al., 2014). This observation is critical, because increasing numbers of children of minority backgrounds are being educated in the U.S. school system. According to data from the U.S. census in 2011, 55% of elementary and secondary students were from non-Hispanic White backgrounds, while 23% were Hispanic and 14% were Black (U.S. Census Bureau, 2011; also see National Center for Education Statistics, Institute of Education Sciences, 2012). Furthermore, socioeconomic status/poverty has been negatively associated with EF skills, particularly working memory, both at school entry and beyond (Hackman & Farah, 2009; Hughes, Ensor, Wilson, & Graham, 2010; Noble, McCandliss, & Farah, 2007). Given that racial and ethnic minority status puts children at greater risk for reduced socioeconomic status, weaknesses in executive functioning in youth from minority backgrounds may differentially contribute to low achievement but have not been directly examined. As such, it is not yet clear whether findings regarding contributions of executive control processes to reading competence are generalizable to the growing number of students from minority backgrounds. In summary, the generalizability of previous findings in largely Caucasian samples regarding the role of EF in reading to the growing number of students in this country from minority backgrounds is unknown.

The Present Study

The present study was intended to replicate prior investigations considering the role of EF skills in predominantly Caucasian samples and extend these into a population heretofore under-represented in the extant literature (e.g., African American and Hispanic youth). To our knowledge, there are no published studies examining contributions to reading competence in minority youth. It is not yet clear whether EF skills contribute similarly to reading ability in minority samples relative to other samples or if there are different patterns of EF contribution in minority populations. The present study therefore examined the contributions of core reading related skills, processing speed, and key EF skills such as working memory, problem solving, and attentional switching, to reading competence in a large, multisite sample of youth from minority racial and ethnic backgrounds. We examined predictions of isolated and contextual word reading, reading fluency, and reading comprehension. We hypothesized that although processing speed would likely play a larger role in reading fluency than untimed reading skills, working memory would be critical for all reading outcomes. In addition, given the important of inference-making and drawing conclusions (i.e., fluid reasoning or problem solving) as well as selecting relevant from irrelevant details (requiring attentional shifting) to accurate comprehension of written text (see, e.g., Cain, Oakhill, Barnes, & Bryant, 2001), problem solving and attentional shifting were hypothesized to be significant predictors of comprehension tasks rather than word-level reading, per se.

Method

Recruitment

The sample for the present study was part of the larger, multisite Genes, Reading and Dyslexia (GRaD) Study, a case-control study of reading disability in minority and bilingual youth. The GRaD study recruited children ages 8 to 15 years of African American and/or Hispanic/Latino racial/ethnic heritage at seven sites across the United States, Canada, and Puerto Rico: Albuquerque, New Mexico; Baltimore, Maryland; Boston, Massachusetts;

Boulder and Denver, Colorado; New Haven, Connecticut; Puerto Rico; and Toronto, Canada. Participants were recruited from local community groups, public and private schools, and psychology and developmental pediatric clinics. Telephone screening was completed to determine eligibility prior to obtaining consent for participation; inclusion criteria for participants likely to have a reading disability included either history of poor reading skills (as documented by prior school or clinical testing), report of skills falling below expected level for age or grade, and/or provision of special services in the area of reading. For inclusion of participants likely to be controls, inclusion criteria were “competent reading skills” as identified by reading skills falling at or above current expectations for grade and performance falling above the 40th percentile on standardized school or clinical testing.

Exclusion criteria included nonminority ethnic or racial group membership, foster care placement, preterm birth (<36 weeks gestation), prolonged stay in the NICU after birth (>5 days), history of significant cognitive delays (i.e., prior diagnosis of intellectual disability), significant behavioral problems (e.g., history of oppositional defiant disorder), history of serious emotional/psychiatric disturbances (i.e., major depression, psychosis, or autism spectrum disorder) or chronic neurologic condition (i.e., seizure disorder, developmental neurological conditions, Tourette or other tic disorders, acquired brain injuries), and documented vision or hearing impairment.

For the purposes of the present study, youth enrolled in the GRaD study who indicated Spanish as their first and/or primary language and/or who were receiving English language support (i.e., English as a second language, or ESL programming) were excluded from analyses. Following informed consent from the parents and informed assent from youth participants, in compliance with HIPAA regulations and with approval from institutional review boards, each participant completed the testing battery in a single session, lasting approximately 2 hours. Participants received a $35 gift card for participation.

Participants

Demographic information about the sample is presented in Table 1. The sample contained 761 children (53.1% male), between the ages of 8 and 16 years (M age = 11.74, SD = 2.11). All children were of minority racial and ethnic backgrounds: 44.2% endorsed African American background while 55.8% were of “other” racial backgrounds. Within the African American group, 14.5% endorsed Hispanic ethnicity, within those from other racial backgrounds, 95.0% endorsed Hispanic ethnicity. Of those for whom information about parent education was available (85.9% of the sample), 38.9% of mothers earned a high school diploma or GED, 16.7% completed some college coursework beyond high school, 19.1% completed college, and 11.9% earned an additional graduate degree; 13.4% did not complete high school. The sample is generally comparable to the educational background of women in this country, according to 2012 U.S. census data. Furthermore, just over one third of the present sample was receiving financial assistance with food (35.0%; TANF, Food Stamps, WIC) or other areas of need (36.4%; Medicaid/Husky, Section 8/government assistance with housing).

Measures

Reading assessment included measures of isolated word reading, decoding, noncontextual reading fluency, contextual word reading, and comprehension. In addition, assessment included measures of nonreading skills believed to play an important role in reading competence (e.g., vocabulary knowledge, phonological processing, and rapid naming) as well as domain general skills such as auditory attention, processing speed, and the executive skills of problem solving, attentional shifting, and verbal working memory. Measures selected to assess EF (i.e., problem solving/fluid reasoning, attentional shifting, and verbal working memory) were chosen to reflect those executive skills previously shown or hypothesized to be most related to reading competence. As such, attentional shifting assessed within the context of a rapid naming task (rather than on an unrelated sorting task, for example) is directly relevant to understanding the role of rapid cognitive shifting as it is involved in development of reading competence.

Woodcock–Johnson Tests of Achievement, Third Edition (WJ-III)—Measures of interest from the WJ-III (Woodcock, McGrew, & Mather, 2001) included the Letter-Word Identification and Word Attack subtests. The WJ-III Letter Word Identification subtest is an untimed measure of noncontextual single word reading ability requiring the child to read a list of increasingly complex English words aloud. The Word Attack subtest asks the participant to apply knowledge of English phonology to decode nonwords or pseudowords in isolation. The total score for each subtest represents the number of words read correctly, converted to a standard score based on age norms. Split-half reliability estimates for these subtests and the composite are good (Letter Word: r = .94; Word Attack: r = .87; Basic Reading Skills: r = .95). The two subtest scores are composited to provide the Basic Reading Skills score, which was used as a measure of isolated word reading.

Test of Word Reading Efficiency (TOWRE)—The TOWRE (Torgesen, Wagner, & Rashotte, 1999) is an assessment of the child's single word reading and single pseudoword decoding isolated (noncontextual) word fluency under timed conditions. The child is asked to read as many individual words (Sight Word Efficiency) or nonwords (Phonetic Decoding Efficiency) of increasing length and difficulty as possible in 45 seconds. Scores for Sight Word Efficiency and Phonetic Decoding Efficiency represent the number of correctly read words within the time limit, relative to age norms. The TOWRE Total Word Reading Efficiency score is a composite of performance on both the Sight Word Efficiency and Phonetic Decoding Efficiency tasks; reliability for the Total score is excellent (test–retest r = .93–.94).

Standardized Reading Inventory, Second Edition (SRI)—The SRI (Newcomer, 1999) is an individually administered contextual reading test, requiring approximately 30 minutes, depending on child age and ability, that consists of 10 passages of increasing difficulty, ranging from preprimer to an eighth grade level. Oral reading accuracy is assessed and students are then asked to answer a series of comprehension questions, after each passage is removed from view. Participants read as many passages as are required to obtain both a basal and ceiling; most children will not read all 10 passages, as the passage reading start point is determined by performance on a contextual vocabulary task. Scores are obtained for word recognition accuracy and comprehension on each passage; the total score in each skill area is converted to a norm-referenced standardized score. Reliability coefficients are high at all age intervals (ranging from .88 to .97). Test–retest reliability coefficients range from .83 to .92 across ages and subscores.

Peabody Picture Vocabulary Test, Fourth Edition (PPVT-4)—The PPVT-4 (Dunn & Dunn, 2007) is an untimed measure of receptive vocabulary knowledge; the participant is required to point to one of four pictures that best indicates the target word presented. Total raw scores (correct responses) are converted to age-normed standardized scores; reliability is excellent (split-half r = .94).

Comprehensive Test of Phonological Processing (CTOPP)—The Elision subtest of the CTOPP (Wagner, Torgesen, & Rashotte, 1999) is an untimed measure of the individual's ability to say a given word and then say what is left after dropping designated sounds. The Blending Words subtest requires the child to combine individual sounds in sequence to form words. Raw scores are converted to age-normed standard scores. The Elision and Blending Words subtests together compose the Phonological Awareness composite of the CTOPP; this composite measure was used as an estimate of the child's phonological processing skills. Within the age range of the present sample, reliability of the Phonological Awareness composite is adequate (α = .91; test–retest r = .84).

Rapid Automatized Naming and Rapid Alternating Stimulus Tests (RAN)—The Letters subtest from the RAN (Wolf & Denckla, 2005) is a measure of speeded lexical retrieval, requiring the child to rapidly name a series of five lowercase letters (repeated randomly in 5 rows of 10 letters) as quickly as possible without making mistakes. Time to completion is recorded and converted to an age-referenced standard score; reliability is excellent (test–retest r = .90). The Rapid Alternating Stimulus (RAS) Letters and Numbers subtest was conceptualized (Wolf, 1986) as a way to assess processes involved in switching and disengaging attention to rapid-naming tasks (see also Norton & Wolf, 2012). The RAS tasks offer a unique measure of attentional switching within the context of a reading related task. The RAS requires the child to alternate between two types of symbol sets (i.e., letters, numbers); the alternation of stimuli type increases the requirement for shifting cognitive set and disengaging attention from the preceding stimulus or set (a component of EF). The child is asked to quickly name a series of randomly repeated letters and numbers; time to completion is converted to an age-referenced standard score. Reliability is excellent (test–retest r = .90). For the purposes of the present study, the RAS Letters and Numbers score was regressed on the RAN Letters score, with the standardized residuals saved as a new variable representing the "attentional switching" component of the alternating task, minus the rapid naming component. This process helps to reduce the multicollinearity among the variables included in the regression models and the extent to which the switching task is confounded by letter-naming retrieval fluency.

Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV)—The WISC-IV (Wechsler, 2003) Processing Speed Index (PSI) is composed of the Coding and Symbol Search subtests and provides an estimate of the participant's processing speed as measured by rapid completion of pencil-and-paper tasks. The Digit Span subtest requires both forward repetition and backward sequencing of a series of numbers presented orally. For the purposes of the present study, the Digit Span Forward scaled score was used as a measure of brief verbal attention (WISC-IV Technical Manual; Wechsler, 2003, p. 16); the Digit Span subtest scaled score (including both forward and backward conditions) was used as a measure of working memory (with Digit Span Forward already in the model). The Matrix Reasoning subtest assesses nonverbal abstract problem solving and fluid reasoning (Wechsler, 2003, p. 16). Total raw scores are converted to age-normed standardized scores. Reliability of these measures is strong (split-half Spearman Brown; Digit Span: r = .87, Matrix Reasoning: r = .89; test–retest, Coding: r = .85, Symbol Search: r = .79).

Data Analysis Plan

Zero-order correlations among the EF measures and reading outcomes were examined. Subsequently, contributions of core reading constructs (vocabulary [PPVT-4], phonological processing [CTOPP Phonological Awareness composite], rapid naming [RAN Letters]), auditory attention (WISC-IV Digit Span Forward), processing speed (WISC-IV PSI), and EFs (working memory, problem solving, set shifting) to each of the reading outcomes of interest (i.e., contextual and isolated word reading, fluency, and comprehension) were examined through a series of hierarchical linear regression analyses. A consistent hierarchical model was used across each of the analyses, which included demographic risk variables (child age and sex) in the first block, followed by core reading constructs and attention in the second block, processing speed in the third block, and the EF measures of problem solving, working memory, and set shifting in the fourth and final block of each regression. Since level of maternal education was not available for all participants, the regression models were rerun in the subsample for whom this variable was available in the same manner, including maternal education level in the first block with other demographic risk variables.

Results

As reported in Table 1, performance means for the sample across reading, processing speed, and EF measures were largely within the average range, based on published norms. Skewness and kurtosis statistics, and examination of normality plots fell within the acceptable range for each of the reading outcomes. Consistent with planned overrecruitment of poor readers, frequency of reading difficulty in this sample was relatively higher than that seen in population samples: 18.9% of the sample performed below the average range (SS < 85) on the WJ-III Basic Reading Skills composite, 30.3% on the TOWRE Fluency composite, 47.6% on SRI Word Reading Accuracy, and 38.2% on SRI Passage Comprehension.

Overall, the executive measures were significantly correlated (zero-order) with the reading outcome measures (see Table 2), with working memory showing the strongest associations across tasks. The average correlation between working memory and the reading measures was .495, the average correlation between problem solving and the reading measures was .362, and the average correlation between switching and reading measures was .191.

Regression analyses examined the additional contributions of processing speed and the executive skills of working memory, problem solving, and shifting to reading performance, after controlling for core reading related skills (see Table 3). In all analyses, core reading-related skills contributed substantially to reading competence, accounting for 51% (contextual word reading) to 63% (isolated word reading) of the variance in performance on the reading outcome measures (see Table 4).

Non-contextual single word reading

For prediction of single word reading in isolation (measured by the WJ-III Basic Reading Skills composite), core reading related skills entered in the second block accounted for 56.9% of the variance in performance. Processing speed, as measured by the WISC-IV PSI, was not a significant additional predictor. However, the EF measures accounted for an additional small but significant proportion of variance ($\Delta R2 = .039$), $F(10, 757) = 126.05$, $p < .001$. Examination of standardized beta weights (see Table 4) revealed that only working memory and shifting accounted for a significant proportion of the remaining variance. The model as a whole accounted for 62.8% of the variance.

Contextual word reading

Examining contributions of the core reading-related variables to contextual word reading accuracy as measured by the SRI Word Recognition score, core reading-related skills (e.g., vocabulary, phonological processing, rapid naming, and auditory attention) accounted for 36.9% of the variance in performance. After controlling for the core reading-related skills, processing speed was a significant predictor of contextual reading accuracy and accounted for an additional 2.7% of the variance in children's performance. Executive skills likewise accounted for a significant proportion (7.7%), $F(10, 757) = 77.81$, $p < .001$, of the remaining variance, with both working memory and shifting as significant predictors within the block. The total model explained 51.0% of the variance.

Reading fluency

Core reading-related skills explained 46.0% of the variance in isolated word reading fluency, as measured by the TOWRE total score. After accounting for core reading-related skills, both processing speed (2.3% of the variance) and executive skills (5.8%), $F(10, 757) = 98.41$, $p < .001$, added significantly to predictions of performance on isolated word reading fluency tasks, with both working memory and shifting (but not problem solving) contributing to prediction. The total model accounted for 56.8% of the variance in children's word reading fluency.

Reading comprehension

Core reading-related skills accounted for 51.1% of the variance in children's reading comprehension performance, as measured by the SRI Passage Comprehension score. After accounting for these contributions, processing speed added a small, yet significant proportion of variance (1.5%). Executive skills explained an additional 4.5%, $F(10, 757) = 110.78$, $p < .001$, of the variance in reading comprehension outcomes for minority youth. Notably, both verbal working memory and nonverbal problem solving, but not shifting, accounted for unique variance in reading comprehension. The total model accounted for 59.7% of the variance in children's reading comprehension performance. Notably, these results remained the same when controlling for word reading.

Controlling for maternal education level

Level of maternal education completed was available on a subsample of participants. Including maternal education with other demographic risk variables (child sex, age) on the first step of the regression models did not substantively change the pattern of findings. Examining single word reading, after controlling for child sex, age and level of maternal education, core reading-related skills, and processing speed, EF skills accounted for an additional significant 4.0%, $F(11, 650) = 105.22$, $p < .001$, of the variance. For contextual word reading, after controlling for the demographic variables, reading-related skills, and processing speed, EF skills accounted for an additional 7.2%, $F(11, 650) = 61.09$, $p < .001$, of the variance. For fluency, the final block with EF measures accounted for an additional 5.6%, $F(11, 650) = 82.46$, $p < .001$, of the variance. For reading comprehension, the final block with EF measures accounted for an additional 4.4%, $F(11, 650) = 89.84$, $p < .001$, of the variance.

Discussion

Existing research suggests that, consistent with the expanded definition of dyslexia (Lyon et al., 2003), there are multiple pathways to reading competence that require a combination of core language skills, efficient processing speed, and intact EFs. The present study adds to and expands on this literature by demonstrating that these associations are also true for children from minority racial and ethnic backgrounds. As hypothesized, in this sample, even after controlling for core reading-related skills and processing speed, working memory remained a significant contributor to each of the reading outcomes examined, both at the single word level and for contextual reading tasks (see Table 3). In addition, attentional switching added unique variance to prediction of word recognition and reading fluency, while strategic problem-solving skills contributed uniquely to reading comprehension. Of note, the unique proportion of variance accounted for by these EF skills was greater when predicting "higher level" reading skills (i.e., contextual word reading, reading fluency, and reading comprehension), compared to the relatively small proportion of variance accounted for in single word recognition. Although we previously hypothesized that attentional switching and problem solving would contribute to comprehension (due to the role of attentional switching in efficiently discriminating relevant from irrelevant details and problem solving in making inferences and drawing conclusions), results suggest that problem solving—but not switching- is important for reading comprehension. Switching appears to be most relevant for fluency; given that attentional switching was measured on a timed task and the associations for switching were stronger for fluency—which is timed—than for comprehension—which is untimed, shared variance related to this aspect of measurement may be the most parsimonious explanation for this association. The overall pattern of prediction (see Table 3) was most similar for contextual word reading (SRI Word Reading Accuracy) and single word reading fluency (TOWRE Total), again possibly reflecting the timed nature of these tasks.

Compared to prior studies in predominantly Caucasian samples (e.g., Locascio et al., 2010; Sesma et al., 2009), the present data suggest a different emphasis among predictors of reading competence for minority youth, with a potentially greater relative contribution of executive control skills, and a differential pattern of associations with working memory, problem solving, and attentional switching. For example, prior work has suggested that working memory may play a specific role in comprehension, whereas processing speed may be most important for isolated word reading (Christopher et al., 2012); our findings suggest that—with core reading-related processes already in the model—processing speed does not contribute uniquely to single word reading in this sample of minority readers. However, working memory contributes to multiple aspects of reading competence (with larger effects on contextual word reading and fluency than comprehension).

These findings raise a number of clinical and educational implications, which become particularly salient when considering the increasing number of minority youth being taught to read in America's public schools. An understanding that EFs play an important role in reading competence, and potentially in a slightly different constellation relative to Caucasian youth, might be important for reading specialists or teachers working to build reading skills in struggling readers of minority backgrounds. Strategies incorporating metacognitive and working memory skills in reading instruction (see, e.g., Carretti, Caldarola, Tencati, & Cornoldi, 2014) may be more effective in supporting the combination of required skills. Findings also raise the question whether reading curricula might not be equally effective across school systems or regions of the country where minority density varies. Furthermore, these findings suggest that assessment of minority youth referred for reading failure ought to include evaluation of core executive skills as well as reading-related abilities.

In addition, there may be several hypotheses to explain the different patterns of findings observed in our sample relative to prior work examining reading in primarily Caucasian samples. In the United States, many African American students are speakers of African American English (AAE), which has a number of morphological and phonological features that differ systematically from Standard American English (Craig, Thompson, Washington, & Potter, 2003), and which are inversely related to performance on standardized reading outcomes (e.g., Charity, Scarborough, & Griffin, 2004; Connor & Craig, 2006; Craig & Washington, 2004; Craig, Zhang, Hensel & Quinn, 2009). Furthermore, as students age, they shift from AAE toward Standard English, facilitating development of "code-switching" (Craig & Washington, 2004). This skill appears to be present as early as the preschool years (Connor & Craig, 2006) with "failure to code-switch" associated with poorer elementary reading achievement (Craig et al., 2009). Switching requires not only development of metalinguistic awareness, but also attention to setting and task cues as well as cognitive flexibility, all of which represent EFs. It may be that children who successfully code-switch are more competent with attentional switching generally, which may support improved reading fluency; future research may help to further elucidate this specific link, as this study did not obtain measures of AAE density or code-switching.

Furthermore, a bilingual advantage has been shown on tasks requiring attentional switching and control, even as early as preschool (Bialystok, 1999; Engel de Abreu, Tourinho, Martin, & Bialystok, 2012). As such, executive skills may play an important role in acquisition of language-based skills in children from bilingual or nonmainstream backgrounds. The increased facility with "code-switching" across development seen in a subgroup of this population may support flexibility in attentional switching, with better capability in this area contributing to stronger ability to shift attention to relevant aspects of a passage and thus, better reading competence. Notably, even at young ages, children exposed to other languages outperform their monolingual peers on the dimensional change card sorting task, a measure of inhibition and attentional switching (Bialystok, 1999; Bialystok & Martin, 2004). Interestingly, the present findings suggest that attentional switching was not a significant predictor of reading comprehension in this sample, but this EF contributed instead to the "upstream" or foundational reading skills of single word reading and reading fluency.

A second possible explanation for the pattern of findings is that the genotype-phenotype link for reading competence has yet to be clarified in youth from non-Caucasian backgrounds, and may not follow the same association as has been observed in predominantly Caucasian samples (Fisher et al., 2002; Grigorenko et al., 1997). Findings in Caucasian samples have implicated regions of chromosomes 6 and 15 (Eicher et al., 2014; Grigorenko et al., 1997), 11 (Kegel & Bus, 2013), and 18 (Fisher et al., 2002), among others. Evidence to date regarding gene × environment interactions further suggests that heritability of reading skills appears to be moderated by parental factors, such as education (Friend, DeFries, & Olson, 2008; Pennington et al., 2009); thus, in a minority sample with a wider range of SES, heritability may vary from estimates based on predominantly Caucasian samples. Furthermore, some data suggest a genetic basis for individual differences in executive skill (e.g., Barnes, Dean, Nandam, O'Connell, & Bellgrove, 2011; Friedman et al., 2008), which may interact with genetic correlates of reading, complicating the clinical picture. The present data were collected as part of a larger study intended to examine genetic contributions to dyslexia in minorities, and further work in this area should help to clarify the role of genetic associations with each of the processes required for competent reading. Interestingly, preliminary findings from genetic analyses of a specific region of chromosome 6p (DCDC2 intron READ1) in the present sample suggest that effects of a specific allele within this region may vary in conferring risk versus protective effects in Caucasians relative to African Americans (Powers et al., in press). Ultimately, neuroimaging studies will also serve to elucidate the brain–behavior relationships in this group and help determine whether findings from primarily Caucasian samples can be generalized to readers or nonreaders from minority backgrounds. Better understanding of these contributions may help to more appropriately target remediation (e.g., Norton & Wolf, 2012).

Finally, results may differ from prior research due to methodological factors. Specifically, measures administered do not entirely overlap with those used in other studies of reading in nonminority samples, limiting comparisons that can be made. Different covariates and different methods of measuring participants' demographic or risk variables across studies may also yield different patterns of association. Notably, the inconsistent inclusion of reading domain-specific skills in studies examining contributions of EF to reading outcomes limit direct comparisons of EF (e.g., variance accounted for) across studies. Finally, the choice of reading outcomes may also contribute to differing findings, regardless of participant racial or ethnic background.

Strengths of the present study include the large sample size from multiple sites across the continental United States, Canada, and Puerto Rico, the focus on children from minority backgrounds, and inclusion of multiple measures of reading and reading-related skills. At the same time, limitations must be noted: the subsample of the larger GRaD study that was examined for the present study was selected for English-speakers; thus findings may not generalize to English language learners or fully bilingual children. Furthermore, the degree to which children of Hispanic ethnicity may have spoken Spanish is not clear, even if English was their primary/preferred language. Direct measures of AAE dialect density or feature production were not obtained as part of the GRaD study, so examination of the relation between these language characteristics and reading outcomes in this sample was not possible. In addition, participants were recruited based on the relative presence or absence of parental concerns with reading. As such, children with the full range of subthreshold reading difficulties may not be represented in this sample. Nevertheless, to our knowledge, findings represent the largest examination of reading and related cognitive skills in children from minority backgrounds, and suggest the importance of speed and executive skills to competent reading in this group.

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Table 1

Sample Descriptives and Demographics.

Demographics/descriptives	**Construct assessed**	***M*(*SD*)**
Sex (% male)		53.1
Race (%)		
African American		44.2
Other		55.8
Ethnicity (%)		
African American and Hispanic		14.5
Other and Hispanic		95.0
Age (years)		11.74(2.11)
PPVT SS	Vocabulary	97.56(14.99)
CTOPP Phonological Awareness SS	Phon. processing	94.05(13.96)
WJ-III Word Attack SS	Phon. decoding	94.75 (11.01)
WJ-III Letter-Word ID SS	Word reading	95.77(13.77)
WJ-III Basic Reading Skills SS	Word decoding	95.07(12.84)
RAN Letter Naming SS	Rapid naming	101.77(13.84)
RAN 2-Set Switching	Switching	101.25(14.05)
TOWRE Total Word Reading Efficiency SS	Fluency	92.69(16.10)
SRI Word Reading Accuracy ScS	Contextual word reading	7.11 (4.17)
SRI Passage Comprehension ScS	Comprehension	7.69 (4.03)
WISC-IV Digit Span ScS	Working memory	8.94 (2.83)
WISC-IV Matrix Reasoning ScS	Problem solving	9.49 (2.84)
WISC-IV Processing Speed SS	Processing speed	93.21 (14.11)

Note. CTOPP = *Comprehensive Test of Phonological Processing;* Phon. = phonological; PPVT = *Peabody Picture Vocabulary Test* (4th ed.); RAN = *Rapid Automatized Naming;* ScS = scaled score; SRI = *Standardized Reading Inventory;* SS = standard score; TOWRE = Test *of Word Reading Efficiency;* WISC-IV = *Wechsler Intelligence Scale for Children* (4th ed.); WJ-III = *Woodcock–Johnson Test of Achievement* (3rd ed.).

Table 2

Correlations Among Executive Measures and Reading Outcome Measures.

Reading outcome measure	Working memory	Problem solving	Switching
WJ-III Basic Reading Skills	.510	.380	.196
SRI Word Recognition	.514	.326	.187
TOWRE Total	.455	.306	.238
SRI Passage Comprehension	.471	.418	.135

Note. All correlations significant at $p < .001$. Problem solving = Matrix Reasoning score; SRI = *Standardized Reading Inventory;* switching = residualized *Rapid Alternating Stimulus* score; TOWRE = *Test of Word Reading Efficiency;* WJ-III = *Woodcock–Johnson Test of Achievement* (3rd ed.); working memory = Digit Span score.

Table 3

Pattern of Contributions of Executive Skills to Reading Outcomes Based on Hierarchical Multiple Regression Analyses (in Table 2).

Executive skill	Single word reading	Contextual word reading	Fluency	Comprehension
Processing speed	−	+	+	+
Problem solving	−	−	−	+
Working memory	+	+	+	+
Shifting	+	+	+	−

Note. Significant relations indicated by +; nonsignificant relations indicated by −.

Table 4

Hierarchical Multiple Regression Analyses Predicting Reading Domains.

Reading domain	Predictor	β	*p*	ΔR^2(block)	Total model R^2
Single word reading	Demographics		.028	.009	.628
	Core reading-related skills		<.001	.578	
	Processing speed		.091	.002	
	Executive functions		<.001	.039	
	Problem solving	.018	.484		
	Working memory	.296	<.001		
	Switching	.096	<.001		
Contextual word reading	Demographics		.001	.018	.510
	Core reading-related skills		<.001	.387	
	Processing speed		<.001	.027	
	Executive functions		<.001	.077	
	Problem solving	−.034	.266		
	Working memory	.459	<.001		
	Switching	.098	<.001		
Reading fluency	Demographics		.005	.014	.568
	Core reading-related skills		<.001	.474	
	Processing speed		<.001	.023	
	Executive functions		<.001	.058	
	Problem solving	−.030	.287		
	Working memory	.392	<.001		
	Switching	.154	<.001		
Reading comprehension	Demographics		.006	.013	.597
	Core reading-related skills		<.001	.524	
	Processing speed		<.001	.015	
	Executive functions		<.001	.045	
	Problem solving	.064	.019		
	Working memory	.337	<.001		
	Switching	.031	.196		

Note. In each regression, demographic variables (child age and sex) were entered on the first block, core reading-related measures of vocabulary, decoding, rapid naming, and attention were entered in the second block, followed by processing speed in the third block, and executive function measures (*Wechsler Intelligence Scale for Children* [4th ed.] Matrix Reasoning, Digit Span, residualized *Rapid Alternating Stimulus*) in the final block.