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COMPARISON OF READING DEVELOPMENT ACROSS SOCIOECONOMIC STATUS

IN THE UNITED STATES

A Dissertation Presented to
The Faculty of Social Sciences
University of Denver

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

by

Beatriz MacDonald Wer, M.A.

August 2014

Advisor: Bruce F. Pennington, Ph.D.

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Author: Beatriz MacDonald Wer, M.A.

Title: COMPARISON OF READING DEVELOPMENT ACROSS SOCIOECONOMIC STATUS IN THE UNITED STATES

Advisor: Bruce F. Pennington, Ph.D.

Degree Date: August 2014

Abstract

It is well known that higher parental socioeconomic status (SES) predicts better child reading outcomes, but little work has been done to unpack this finding. The main overall question addressed by this project was whether cognitive models of the two main reading outcomes, single word reading (SWR) and reading comprehension (RC), performed similarly across levels of parental SES. The current study predicted a differential relation between parental SES and both predictors and outcomes because of the known large relation between parental SES and child oral language development. Three questions examined the mediating effects of cognitive predictors on the relation between parental SES and reading outcomes, the moderating effects of SES on the developmental trajectories of reading outcomes, and the strength of the relationship between SES and the two reading outcomes. Participants were part of two large and comprehensive datasets: the cross-sectional Colorado Learning Disability Research Center (CLDRC; n=1554) sample, and the International Longitudinal Twin Study (ILTS; n=463 twin pairs) sample. In terms of cognitive predictors, the relation between SES and SWR was disproportionately mediated by two language skills, vocabulary (VOC) and phonological awareness (PA). For the RC models, both SWR and oral listening comprehension (OLC) did not disproportionally mediate the relation between RC and SES; however, full mediation was not exhibited. With regard to the trajectory of reading outcomes, SES moderated the starting values of SWR and RC, and the slopes of

SWR development. When performance on the control measures of early reading skills (e.g., print knowledge, vocabulary, and decoding skills) was included in the models, the moderating effects of SES were completely accounted for by these measures. In terms of outcomes, SES had a stronger relation to RC than to SWR, especially at later ages. These findings have implications for interventions aimed at improving reading outcomes in children from lower SES families.

Acknowledgements

Funding was provided by the National Institutes of Health (P50 HD027802 for the Colorado Learning Disabilities Research Center and R01 HD038526 for the Colorado component of the International Longitudinal Twin Study [ILTS]). I thank the twins and their families who participated in this research.

I would like to express my deepest gratitude to Dr. Bruce F. Pennington for his patience, guidance, and support throughout my graduate career. I would also like to thank my committee members, Drs. Richard Boada, Omar Gudino, Jan Keenan, as well as, Drs. Richard Olson and Sharolyn Pollard-Durodola for their intellectual insight. I would also like to acknowledge the many individuals who collected and entered the data.

I would like to thank my family for their unconditional moral support, love, and encouragement provided all the way from Guatemala. I particularly would like to acknowledge my support network that was with me during every step of this process.

Finally, this dissertation is dedicated to the children and families with whom I work every day. *Gracias* for the inspiration and motivation to persevere as a researcher, clinician, and teacher.

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Introduction

It is well-documented that reading outcomes vary across demographic groups in the United States, with children in lower socioeconomic status (SES) families performing worse than children in higher SES families (Nation's Report Card, 2011). Children in this lower performing group, then must differ in their balance of risk and protective factors for reading outcomes from children of higher SES. What is unclear is whether these differences in risk and protective factors are simply global or *uniform* (more of the same risk factors vs. fewer of the same protective factors in the lower performing groups than in the higher performing groups) or *differential* (a different profile of risk and protective factors in the lower vs. higher performing groups). In other words, does the development of reading follow the same path across children of different SES backgrounds or do the predictors, trajectory, and pattern of reading outcomes vary as a function of parental SES?

This study addressed three specific questions:

First, do some predictors account for more of the differences in reading outcomes across SES groups than others, relative to how well they account for reading outcomes without considering SES? The literature in the field presents conflicting evidence regarding which predictors of reading skill are more strongly affected as a function of SES. Chall,

Jacobs, and Baldwin (1990) coined the term ‘4th Grade slump’ to describe the phenomenon that children in a low-SES environment perform equally through third grade in literacy and language development in comparison to a normative sample. However, beginning with the fourth grade, the children in the low-SES environment exhibit signs of a slump. The ability to define words is the first skill to demonstrate a slower rate of progress in comparison to word recognition and reading comprehension, which are the last skills to demonstrate a slower rate (Chall et al., 1990). In contrast, other studies have found that children from low-SES backgrounds are more likely to demonstrate weaknesses in phonological awareness (Bowey, 1995; Hecht, Burgess, Torgesen, Wagner, & Rashotte, 2000; Raz & Bryant, 1990; Whitehurst & Lonigan, 1998) and vocabulary and language skills (Dickinson & Tabors, 2001; Hart & Risley, 1995; Hoff, 2003; Korat, Klein, & Segal-Drori, 2007; Snow, 1993; Snow, Barnes, Chandler, Goodman, & Hemphill, 1991; Tabors & Snow, 2001) *prior* to entering grade school or during earlier years of grade school. In the current study, mediation and moderation analyses were conducted to address this difference in the literature, which are a novel contribution. For Question 1, I hypothesized that measures of higher-level language skills (e.g., vocabulary and listening comprehension) would account for relatively more of the differences in reading outcome (reading comprehension and single word reading) across SES than measures emphasizing more basic language or cognitive processes (e.g., rapid serial naming and processing speed), consistent with previous research (Bowey, 1995; Hecht et al., 2000; Raz & Bryant, 1990). Again, by “relatively,” I mean relative to their predictive effect without considering SES.

Second, do growth curves for the development of single word reading and reading comprehension differ as a function of parental SES? I hypothesized that the starting points would be lower and the slopes would be flatter for children from lower SES backgrounds than those of higher SES backgrounds.

Third, with regard to reading outcomes, are there differences in the strength of the relationship between reading outcomes (reading comprehension versus single word reading) and SES? I hypothesized that the association of between reading comprehension and SES would be stronger than that of single word reading and SES, specifically in later stages of reading development when the readers transition from *learning to reading* to *reading to learn* (Chall et al., 1990).

The goal of the proposed research was to answer these three questions about reading development as a function of SES. Differences in the pattern of reading development as a function of parental SES were predicted because of the well-documented problems in language development in lower SES groups (Hart & Risley, 1995; Hoff, 2003; Korat et al., 2007; Snow, 1993). For instance, children from lower SES backgrounds build their vocabularies at a slower rate than children from higher SES backgrounds (Hoff, 2003). These hypotheses were tested in two separate datasets, the cross-sectional Colorado Learning Disability Research Center (CLDRC) sample of school-age twins (DeFries et al., 1997), and the International Longitudinal Twin Study (ILTS) population sample of preschool age twins from the United States who were followed into early school age (see Byrne et al., 2006, 2007; Christopher et al., 2013; Olson et al., 2011; Samuelsson et al., 2005). The advantages across these datasets included large sample sizes (CLDRC n=1,554

composed of 1,377 twin members, and 177 singleton siblings; ILTS n=463 twin pairs) and appropriate measures for reading outcomes and cognitive predictors of reading skill.

The current study is important for both theoretical and practical reasons. The theoretical significance of this study was to test whether the effects of SES on reading outcomes were partially or wholly accounted for by the set of cognitive predictors that are typically related to reading development; in other words, is there model equivalence across parental SES? . Model equivalence has been tested extensively and is well supported across alphabetic languages and atypical groups, such as children with developmental dyslexia, selectively poor reading comprehension (i.e., ‘poor comprehenders’), intellectual disability, Down Syndrome and hyperlexia (Cardoso-Martins et al., 2009; Gough & Tunmer, 1986; Nation, 1999; Nation & Norbury, 2005; Pennington et al., 2012; Rack, Snowling & Olson, 1992). However, the equivalence of these models has not been examined across SES in the same country, which is a main goal of the current study.

This gap in the literature is surprising because children in lower SES environments have well documented higher rates of reading problems (i.e. a much discussed achievement gap) (Bowey, 1995; Chall & Jacobs, 2003; Nation’s Report Card, 2011; Raz & Bryant, 1990; Share, Jorm, MacLean, Matthews, & Waterman, 1983). Although we might expect equivalence across SES levels for these models due to the robustness of previous research, this assumption has not been formally examined in children from lower SES backgrounds. Testing if the cognitive predictors of reading skill fully mediate the relationship between SES and reading outcomes would indicate equivalence across SES levels. Partial mediation would suggest that there are other factors aside from the cognitive predictors of reading skill that

account for such relationship. If there is only partial mediation, then it would be important to find what else about SES influences reading outcomes. Answering these questions is theoretically important to extend and refine well-established models of reading development.

This research has practical significance as well, specifically to help guide intervention efforts aimed at trying to close the achievement gap found in lower SES children. If we hope to close this reading achievement gap, it seems logical that we should first understand whether the gap is greater in some reading skills and predictors than in others.

In the sections that follow, I will review current literature bearing on the 1) the achievement gap, 2) the relationship of SES and reading development and language, 3) well-established models of reading development (for both single word reading and reading comprehension), and 4) motivate the questions addressed by the present study.

The SES Achievement Gap

SES is probably the most widely used variable in education research in order to understand demographic differences in academic performance and it is well documented that lower levels of parental education, occupational status, and income are associated with poorer early reading abilities (Snow, Burns, & Griffin, 1998). Moreover, SES group differences in early single word reading and reading comprehension skills have been well documented (Bowey, 1995; Chall & Jacobs, 2003; Raz & Bryant, 1990; Share et al., 1983). In a comprehensive literature review, Scarborough and Dobrich (1994) found that, on average, SES accounted for approximately 7-9% of the variance in reading achievement. White (1982) conducted a meta-analysis with the aim to determine the significance of the relationship between SES and academic achievement (e.g. general academic performance, verbal skills,

math and science) based on research published between 1918 and 1975. Sirin (2005) updated the meta-analysis conducted by White (1982) with research published between 1990 and 2000. The average correlation between SES and academic achievement in the analysis performed by White was 0.343 (SD= .204, k= 219¹; White, 1982), as compared with Sirin's average correlation of 0.299 (SD = .169, k = 207). Both correlations were described as a medium level of association (Cohen, 1988). These three reviews (Scarborough & Dobrich, 1994; Sirin, 2005; White, 1982) suggest that around 7 to 12 percent of the variance in reading outcomes can be predicted by SES. Although it is often assumed in this research that parental SES correlations with child reading outcomes, behavior genetic research on both SES and reading suggest that genes mediate some portion of this correlation. Since this study was not designed to measure this effect, we will return to this issue in the Discussion.

Theoretically, it is clear that parental SES is, for the most part, longitudinally prior to child reading outcomes. It obviously does not make sense that child reading outcomes cause parental SES. Hence, parental SES could be one cause of child reading outcomes, thus explaining the correlations just reviewed, or both parental SES and child reading outcomes could be related to an unknown third variable (e.g. genes shared by parent and their biological children). In the models to be tested here, we will treat parental SES as a longitudinally prior independent variable, and child reading outcomes as a dependent variable, and then attempt to disentangle what it is about parental SES that affects child reading outcomes.

¹ This notation indicates number of studies

It is also important to acknowledge that there is variability in how SES is measured across different studies. Although SES has been at the core of a very active field of research, there seems to be an ongoing dispute about its conceptual meaning and empirical measurement in studies conducted with children and adolescents (Bornstein & Bradley, 2003). On the one hand, Duncan, Featherman and Duncan's (1972) definition of the tripartite nature of SES incorporates parental education, parental income and parental occupation as the three main indicators of SES (Gottfried, 1985; Hauser, 1994). On the other hand, researchers also have chosen to use an individual student's SES or an aggregated SES based on the school that the student attends (Caldas & Bankston, 1997) or the neighborhood where the student resides as SES indicators (Brooks-Gunn, Duncan, & Aber, 1997). The meta-analyses previously presented selected studies that used either of those forms of measuring SES (e.g. Hollingshead Index, parental income, or eligible for free or reduced lunch). The current study employed a novel way of coding parental occupation using the International Socioeconomic Index (ISEI; Ganzeboom, De Graaf, & Treiman, 1992; Ganzeboom & Treiman, 1996).

In the literature, the Hollingshead Index (Hollingshead, 1975) is the gold standard to calculate a 2-factor SES index score. Years of education and occupation are coded using an education scale (1 to 7, 7 being the highest level of education) and an occupation scale (1 to 9, 9 being the highest paying occupations). Then, occupation is weighted by a factor weight of 5 and education with a factor weight of 3, and an average is computed. Therefore, SES is a categorical variable with restricted variance. The Hollingshead Index has not been updated since the 1970s and new occupations have been created and old occupations have ceased to

exist. In contrast, The ISEI coding system classifies occupations using a 10 to 90 scale (90 being the highest occupation), providing a wider variance range, and it was recently updated in 1996. The current research contributed a new method of coding occupation and creating an SES factor score using confirmatory factor analysis, which permitted for parental SES to be modeled as a continuous variable.

Additional data on the SES gap is provided by the recent National Assessment of Educational Progress (NAEP) report (2011), which documented the reading progress of fourth-graders in the United States (Nation's Report Card, 2011). Reading achievement level is assessed using a test that examines the student's ability to read and understand literary and informational texts as well as integrate and interpret the content in order to answer reading comprehension questions. Students' eligibility for the National School Lunch Program (NSLP) is used in NAEP as an indicator of family income. Figure 1 presents the reading achievement-level scores from 2003 to 2011 and the score gap between the *not eligible for free lunch* group and the *eligible for free lunch* group is a stable and persistent finding (Nation's Report Card, 2011).

The effect sizes (Cohen's *d*) for reading achievement-level scores in 2011 among the three groups, *not eligible for free lunch*, *eligible for reduced-price lunch*, and *eligible for free lunch* are as follows: effect size between *not eligible for free lunch* and *eligible for reduced-price lunch* was a medium effect of 0.49; the effect size between *eligible for reduced-price lunch* and *eligible for free lunch* was a small effect of 0.34; and, the effect size between *not eligible for free lunch* and eligible for free lunch was a large effect of 0.83 (Nation's Report Card, 2011). Moreover, among fourth-graders who scored below the 25th percentile in 2011, 74% were eligible for free or

reduced-price school lunch. In contrast, among fourth-graders who scored above the 75th percentile, 23% were eligible for free or reduced price school lunch. Overall, the NAEP report of 2011 reading achievement level scores demonstrates that the SES achievement gap continues to be an issue affecting reading performance at a national level.

Hecht and colleagues (2000) investigated the relationship between SES (calculated using Hollingshead Index) and single word reading as well as reading comprehension using latent growth curve modeling, which is pertinent to Question 2 above. They reported that differences in growth of reading skill depended on the time interval that was considered (Hecht et al., 2000). During Kindergarten to 1st Grade, SES differences in growth of decoding skills were completely accounted for by control variables (general verbal intelligence and prior word reading skills). For the subsequent grades, SES differences in growth of single word reading and reading comprehension skills persisted when all other variables were controlled. The correlations between SES and the reading outcomes were as follows: word reading skills at Kindergarten, 1st Grade, 2nd Grade, 3rd Grade, and 4th Grade, 0.18, 0.29, 0.44, 0.44, and 0.46, respectively; reading comprehension skills at 2nd Grade, 3rd Grade, and 4th Grade, 0.40, 0.44, and 0.44, respectively. The findings thus echo results of the NAEP for reading comprehension and extend the findings to single word reading; yet, what happens beyond 4th grade when children transition from *learning to read* to *reading to learn*. Little research has explored if the correlation between reading outcomes (reading comprehension versus single word reading) and SES becomes weaker, more stable, or stronger in middle school and high school. For Question 3, it was speculated that decoding skills reach asymptote in later grades, whereas reading comprehension skills may continue to

develop, leading to a stronger correlation between reading comprehension and parental SES than single word reading and parental SES. Such a stronger correlation would be consistent with my hypothesis that high-order language-based skills (e.g., oral listening comprehension and vocabulary) are more influenced by parental SES than are lower level cognitive predictors of child literacy outcomes.

Additionally, Hecht and colleagues (2000) demonstrated that the association of single word reading and SES persists in later grades even when prior word reading skills are accounted for, providing evidence that lower SES is associated with a lower trajectory of reading development. The findings of Hecht et al. (2000) are inconsistent with the findings of the '4th Grade slump' study (Chall et al., 1990) because Hecht and colleagues document trajectory differences in reading development starting at 2nd Grade not at 4th Grade.

Hence, Question 2 in the current study asked whether and when SES influences the growth of single word reading and reading comprehension. These results will address the inconsistent findings in the previous literature (i.e. those of Chall et al., 1990 vs. Hecht et al., 2000). This study has an advantage over those previous two studies because of the larger sample size of the ITLS dataset (n=463 twin pairs). The sample sizes of the previous were 30 and 107 participants, respectively.

SES and Language and Reading Development

The predictors of single word reading skills are invariant across countries and alphabetic languages (Caravola, Volin, & Hulme, 2005; Ziegler et al., 2010), and these predictors include alphabet knowledge, phonological awareness, and rapid serial naming. In addition, dyslexia (poor single word reading skill which is clinically significant because it

results in functional impairment) exists in every language studied, despite differences in orthography across these languages (Caravola et al., 2005; Peterson & Pennington, 2012). However, there is less research examining whether this invariance extends to different levels of SES within the United States. Although the cognitive predictors of single word reading are invariant across countries and languages, it is possible that the reading profiles of children who speak the same language (i.e. English) in a specific country (i.e. the United States) vary as a function of SES. In fact, as discussed next, some previous research does support this claim.

One important predictor of literacy skills that is associated with SES early on in development is vocabulary and verbal conceptual skills. On average, parents with higher levels of education speak more than 2,000 words per hour to their children in comparison to working-class parents and parents on welfare (Hart & Risley, 1995). In early development, differences in income and parental education are associated with differential frequency of beneficial reading and oral language activities at home (Hart & Risley, 1995; Hoff, 2003; Korat et al., 2007; Snow, 1993). Impaired reading development is associated with vocabulary deficits in both children from a lower SES background and children with limited proficiency in English (Dickinson & Tabors, 2001; Snow et al., 1991; Tabors & Snow, 2001). This finding is important because vocabulary knowledge acquired before 1st Grade has been found to be a predictor of later word-level reading skills as well as reading comprehension (Catts, Fey, Zhang, & Tomblin, 1999; Dickinson & Tabors, 2001; Olson et al., 2011; Scarborough, 1990; Schatschneider, Fletcher, Francis, Carlson & Foorman, 2004; Snow,

Baines, Chandler, Goodman, & Hemphill, 1991; Snowling, Gallagher, & Frith, 2003; Storch & Whitehurst, 2002).

Behavioral genetics research has also documented variability in the components of shared-environment and genetics for vocabulary skills. Longitudinal analyses using the International Longitudinal Twin Study (ILTS) sample have shown that vocabulary skills at preschool have a strong shared-environmental component and weak genetic component (Olson et al., 2011). This pattern changes significantly in 2nd Grade and 4th Grade because genetic and shared-environmental influences were found to be more equally influential. This finding was also demonstrated in the study of S. A. Hart and colleagues (2009). One potential explanation for this trend is that there is more environmental variability before schooling/prekindergarten and the reading curriculum shared across schools is more uniform (Hart & Risley, 1995) so in turn vocabulary skills become more genetically influenced in 2nd Grade and 4th Grade. This would suggest that vocabulary development is more amenable to environmental influences, such as different levels of SES.

Considering the relationship between vocabulary knowledge and reading comprehension, the NAEP report of 2011 added an assessment component to measure vocabulary knowledge (Nation's Report Card, 2011) in the United States. This new national effort evaluates vocabulary skills with the goal of capturing the fourth-graders' ability to use their knowledge of word meanings to understand the text they read. Instead of asking fourth-graders to define a word, the NAEP assessment examines word meaning within the context of a specific passage. These findings from the 2011 NAEP report not only provide information on the current state of vocabulary knowledge at a national level but also allow

us to compare how vocabulary knowledge relates to reading comprehension (also assessed by NAEP tools) (Nation's Report Card, 2011).

Relevant findings from the Nation's Report Card (2011) on vocabulary knowledge include that among fourth-graders who scored below the 25th percentile on the vocabulary scale, 73 percent were eligible for free or reduced-price school lunch. Among fourth-graders who scored above the 75th percentile on the vocabulary scale, 24 percent were eligible for free or reduced-price school lunch. The effect size (Cohen's *d*) for vocabulary knowledge scores between *not eligible for free lunch* and *eligible for free lunch* was a large effect of 0.86, larger than the effect sizes for the achievement gaps from this same study reviewed earlier. Moreover, fourth-graders who scored higher on the NAEP vocabulary knowledge questions also scored higher in the reading comprehension assessment portion of the NAEP (see Figure 2). Overall, these findings demonstrate that vocabulary in children from a low-SES background are weaker in comparison to those of children from a high-SES background, and that the effect size is quite similar to that for reading comprehension. This is a potential limitation because vocabulary knowledge was measured within the context of reading comprehension.

Another important predictor of literacy skills that varies across SES is phonological awareness, the individual's awareness of speech sounds and access to the sound structure of oral language. Phonological awareness is typically measured with tasks that require deleting, counting, or reordering sounds within spoken syllables (Wagner, Torgesen, & Rashotte, 1999). Children from lower-SES backgrounds are also more likely to demonstrate weaknesses in phonological awareness than children from higher-SES backgrounds (Bowey,

1995; Hecht et al., 2000; Raz & Bryant, 1990; Whitehurst & Lonigan, 1998). For measures of phonological awareness, Bowey (1995) reported a large effect size (Cohen's *d*) of 1.98 for the Sound Identity Task and a large effect size of 1.22 for the Phoneme Identity Task when comparing the High-SES (n=23) and Low-SES (n=25) groups.

Four studies have examined SES differences in reading related abilities (e.g. phonological awareness, vocabulary, etc.) (Bowey, 1995; Hecht et al., 2000; Noble, Farah & McCandliss, 2006; Raz & Bryant, 1990). Raz and Bryant (1990) found significant SES group differences in word decoding and reading comprehension skills in a group of first-graders, while controlling for general intelligence. When phonological awareness skills were also taken into account, SES differences only remained for reading comprehension skills, suggesting that phonological awareness fully mediates the relationship between SES and decoding, but not between SES and reading comprehension. Bowey (1995) reported a similar result in a sample of high-SES (n=23) and low-SES (n=25) children in 1st Grade. She reported significant SES group differences in decoding skills, even while controlling for general intelligence and general oral language skills. Again, SES group differences in decoding skills were completely accounted for when phonological awareness in Kindergarten was a predictor.

Hecht and colleagues (2000) extended these findings to include reading measurements in 4th Grade as well as adding other reading predictors (i.e. rapid serial naming and print knowledge). Hecht et al. (2000) found the following correlations between parental SES and reading predictors: Print knowledge = 0.41, phonological awareness = 0.31, rapid serial naming = 0.18, and general verbal intelligence = 0.31. Although the rapid serial naming

correlation with SES was significant ($p < 0.05$), it is a small value in relation to the medium values of the other predictors. This is consistent with the effect sizes that show that the mean difference between high- and low-SES for the Wechsler Intelligence Scale for Children (WISC-IV) Verbal Comprehension Index is greater (Cohen's d effect size = 1.59) in comparison to that of the WISC-IV Processing Speed Index (Cohen's d effect size = 0.54) (Sattler & Dumont, 2008)².

In terms of general reading development, biometric growth curve analyses of early reading have used twin data from the United States (Christopher et al., 2013^a; Logan et al., 2013; Petrill et al., 2010) and Scandinavia and Australia (Christopher et al., 2013^b). The ILTS sample employed in this study was part of these studies. These growth curve analyses provide evidence that within a year of consistent literacy instruction (Kindergarten to 1st Grade), variance in how quickly reading skills develop is generally more influenced by individual differences (genetic factors) than by shared environmental influences (environmental factors). Although small, shared environmental influences have an impact in early literacy development. Therefore, unpacking what factors are included in the shared environmental influences (e.g., parental occupation, parental years of education, health care access, school environment) is relevant. This study extends previous studies by modeling reading development using SES as a moderating factor. The research has found negative correlations between intercept (starting values) and slope (growth over time) (Christopher et

² The Assessment of Children: WISC-IV and WPPSI-III Supplement book by Sattler & Dumont (2008) did not include individual score for the Vocabulary subtest of the Verbal Comprehension Index by SES status. For the Parental Education (8 years or less group): N = 108, VCI mean = 86, VCI standard deviation = 12.1, PSI mean = 97, PSI standard deviation = 14.5. For the Parental Education (College Graduate), N = 547, VCI mean = 108, VCI standard deviation = 14.2, PSI mean = 105, PSI standard deviation = 14.9.

al., 2013^a; Christopher et al., 2013^b). Children across all SES backgrounds start with low reading scores (low intercept), which rapidly increase over time (steeper slopes). I hypothesize that even with a steep increase in growth, children from lower SES backgrounds will, on average, have lower starting values and flatter slopes, than those of children from higher SES backgrounds.

I next turn to how the findings discussed in this section relate to well-established models of single word reading and reading comprehension. This relation is important because the universality of these models has been tested extensively across alphabetic languages and atypical groups, (Cardoso-Martins, Peterson, Olson, & Pennington, 2009; Gough & Tunmer, 1986; Nation, 1999; Nation & Norbury, 2005; Pennington et al., 2012; Rack et al., 1992) and they are well supported. However, the universality of these models has not been examined as much in the low-SES group.

Models of Single Word Reading and Reading Comprehension

The following section outlines prevailing models of single word reading as well as reading comprehension. Moreover, it will be noted what predictors of such models may be affected by SES (see previous literature review). The single word reading model that was examined in the current study utilizes the cognitive predictors of reading skill that have been best supported by previous research (e.g., Scarborough, 1990). These predictors include phonological awareness, vocabulary and general language skills, rapid serial naming, processing speed, and print knowledge (Caravola et al., 2005; Pennington et al., 2012; Ziegler et al., 2010). Predictors that appear to be more associated with SES (see review above) are phonological awareness, vocabulary and general language skills and print knowledge in

comparison to rapid serial naming and processing speed. The CLRDC and ILTS samples that will be used for the current study do not measure these constructs with the same tests. However, previous research has used these two samples to evaluate the multiple deficit model of dyslexia (Pennington et al., 2012) and demonstrated that the measures for single word reading and its cognitive predictors are highly similar; however, the datasets will be analyzed separately.

The most influential model of reading comprehension has been the Simple View of Reading of Gough and colleagues (e.g., Gough & Tunmer, 1986; Hoover & Gough, 1990), which separates single word reading and oral listening comprehension, as the two key unique components of reading comprehension ability. The Simple View of Reading thus holds that neither decoding nor listening comprehension alone is sufficient for reading comprehension; both are necessary. The Simple View of Reading states that reading ability should be predicted from a measure of listening comprehension as well as a measure of decoding skill (Gough & Tunmer, 1986).

Like virtually all previous studies examining predictors of reading comprehension, the current study faces some measurement limitations. These limitations are difficult to avoid because reading comprehension measures vary in their relative dependence on oral language comprehension as compared to decoding, and this dependence may vary even within the same measure depending on grade level (Keenan, Betjemann, & Olson, 2008). Curtis (1980) found that when young children are learning to read, reading comprehension skill is more dependent on single word reading than on listening comprehension. At later ages, after most children have mastered single word reading skills, the relative importance

between the two predictors of reading comprehension shifts, such that listening comprehension becomes a stronger predictor of reading comprehension than single word reading. Moreover, the extent to which developmental interactions are seen depends on the nature of the reading comprehension test (Keenan et al., 2008). The CLDRC reading comprehension measures (Qualitative Reading Inventory – Recall & Questions and Gray Oral Reading Test – 3rd edition, Comprehension portion) that were used in this study are found by Keenan and colleagues (2008) to not be highly dependent on decoding and instead to emphasize listening comprehension more strongly. One measure identified to load highly on decoding is the Woodcock Johnson-III: Passage Comprehension (Woodcock, McGrew, & Mather, 2001) test, which was the only reading comprehension measures available in the ILTS sample at various time points. The Gates-MacGinitie Reading Comprehension subtest (MacGinitie, MacGinitie, Maria, & Dreyer, 2000) was only collected in 4th Grade. Therefore, this is a limitation that needs to be considered when interpreting results. The rationale for the three main questions of the present study is presented next.

Question 1: Mediation and Moderation of SES

Previous research suggests that cognitive predictors of reading skill may differentially *mediate* SES relations with reading outcomes. The study of Hecht et al. (2000) did not address how the proportions of mediation differed. For Question 1 about predictors, I specifically predicted that rapid serial naming, (working memory and processing speed in the CLDRC sample, and verbal learning memory in the ILTS sample) would be weaker relative mediators of the relation between SES and both single word reading and reading comprehension than phonological awareness and vocabulary (and print knowledge in the ILTS sample). In other

words, I predicted that the size and rank order of mediation effects of predictors on the relation between SES and reading outcomes would differ from their size and rank order of their effects as predictors in a model that did not include SES. For Question 1 of the current study, using mediation modeling to examine direct and indirect effects and testing all mediators at once in the same sample is a novel contribution to the literature. It is unique because although the literature provides evidence that there are mediating effects for a single predictor, little information is known about how the strength of the path coefficients differs from one another, or if certain cognitive predictors have stronger mediating effects than others. In addition, this study included four previously uninvestigated cognitive predictors of reading skill, oral language comprehension, processing speed and working memory (available only in the CLDRC sample), and verbal learning memory (available only in the ILTS sample). These cognitive predictors have been found to influence reading outcomes (Christopher et al., 2012; McGrath et al., 2011; Pennington et al., 2012; Samuelsson et al., 2005).

Another possibility to consider is that SES *moderates* the relation between predictors and reading outcomes. In the moderation models, SES was treated as a moderator variable instead of an independent variable, and the cognitive predictors were independent variables for ease of interpretation (although the results would be similar if the cognitive predictors were treated as moderators). The current analyses examined if the relationship between cognitive predictors and reading outcomes varied at different levels of SES. Thus, two different sets of analyses were necessary to explore effects of parental SES. The

neuroimaging research discussed next suggests such a moderation effect may be found. No previous study has directly tested this potential moderation effect at the behavioral level.

Other evidence that reading development follows a different path as a function of parental SES is provided by behavior genetic and neuroimaging studies. The study of Friend et al. (2008) found that there is a bioecological gene by environment (GxE) interaction such that the heritability of dyslexia was lower as parental SES decreased. This suggests that poor environmental support for reading may often be a stronger cause of low reading performance among children whose parents have less education, while genes may be more important as a cause of the low reading performance among children who fail in reading despite greater environmental support.

Converging results were found in a study that examined if SES modulated the brain-behavior relationship in phonological skills (Noble, Wolmetz, Ochs, Farah, & McCandliss, 2006). Children with equivalent phonological skills, yet diverse SES backgrounds, completed a functional magnetic resonance imaging (fMRI) that examined the relationship between reading-related brain activity (e.g. left perisylvian region involved in phonological processing) and phonological language skills. A phonological awareness (PA) x SES interaction was observed in the left fusiform region. Children in the low-SES group showed evidence of a stronger brain-behavior relationship than the high-SES group. In the low-SES group, PA level was positively predictive of activation in the left fusiform region that supports rapid visual word recognition (Price, Moore, Humphreys, & Wise, 1997; B.A. Shaywitz et al., 2002; S.E. Shaywitz et al., 1998; Temple et al., 2001). In other words, despite an equivalent PA deficit to the high-SES children, the low-SES group showed a more typical brain-behavior

relation. This result suggests that, among children who have adequate literacy and schooling resources and still read poorly, their reading problem reflects atypical brain functioning. In contrast, in children who have a less optimal literacy environment, a reading problem can arise without atypical brain functioning. Both the Friend et al. (2008) and Nobel et al. (2006) studies indicate that factors that are more intrinsic to the child are needed to cause a reading problem in a child who has adequate support for literacy from their environment.

Question 2: SES Moderation of Growth Curves

Considering the aforementioned SES differences in language development, we may expect not only worse reading outcomes with lower parental SES but also a different trajectory of reading development. As previously explained, one early study that found a trajectory difference as a function of parental SES was conducted by Chall et al. (1990). This study tested Chall's model of reading development (1983, 1996), which presents six stages (stage 0 described as pre-reading to stage 5 described as the most mature skilled level of reading). Generally, stages 1 and 2 (typically acquired in 1st Grade, 2nd Grade, and 3rd Grade) can be characterized as the time of *learning to read*. Stages 3 to 5 can be characterized as the *reading to learn* stages, when text becomes more varied, complex, and challenging linguistically and cognitively. Their 'classic study' on the '4th Grade slump' followed 30 children, from grades 2, 4 and 6 for two years. Low-SES status was determined by student's eligibility to participate in the free-lunch program. Chall and colleagues (1990) found, somewhat surprisingly, that the low-income group in their sample achieved as well in literacy and language (i.e. word recognition, word analysis, oral reading, word meaning, reading comprehension and spelling) as a normative population through the third grade. Beginning

with the fourth grade, however, students in the low-SES group exhibited signs of a slump. Word meaning was the first indicator to decrease in comparison to the other indicators (see Table 1). Students in the low-SES group – in 4th to 7th Grade – had the greatest difficulty defining more abstract, academic, literary and less common words as compared to a normative population sample. In 4th Grade, students were about a year behind grade norms. By 7th Grade, they were more than two years behind norms. Next to fall behind were their scores on word recognition and spelling. Oral reading and silent reading comprehension began to fall behind later in 6th Grade and 7th Grade. Therefore, the study by Chall and colleagues (1990) demonstrated that the profile of reading problems varies across SES based on a developmental trajectory.

The study of Chall and colleagues (1990) has several limitations including a small sample size of 30 children. Additionally, further research has documented that deficits in phonological awareness as well as vocabulary and verbal conceptual skills in children from a low-SES background are present since Kindergarten so that would question whether the SES gap in reading only appears late (i.e., the fourth grade slump). Although investigations have found that SES-related differences in reading achievement tend to be more pronounced in higher grades than at the onset of schooling (Applebee, Langer, & Mullis, 1988; Chall et al., 1990), SES-related differences of pre-literacy abilities still can be observed as early as preschool years (McCormick, Signer, & Duncan, 1994). It is possible that their sample size of 30 participants was too small to detect SES effects in earlier school grades, which this study addressed by have two datasets with large sample sizes. Additionally, the results of the study of Chall et al. (1990) may imply that classic dyslexia (i.e. early word

decoding problems) is not more prevalent in children from a low-SES background. However, correlations between SES and individual differences in word reading skills typically fall within the range of 0.3 and 0.7 (White, 1982). Moreover, the analyses in the study of Hecht and colleagues (2000) was more complex than in earlier papers (Bowey, 1995; Chall et al., 1990; Raz & Bryant, 1990) and addressed SES effects on growth of reading skills, after accounting for auto-regressors and time one literacy predictors (phonological awareness, print knowledge, rapid serial naming and vocabulary skills). Finding growth pattern differences prior to fourth grade in the study of Hecht and colleagues (2000) contradicts the ‘fourth grade slump’ documented in the study of Chall et al. (1990). Therefore, there is inconsistent evidence about when in development SES impacts single word reading and reading comprehension: late only, both early and late equally, or starting early and increasing. Clearly, the need to understand the nature of early reading problems in lower SES populations and resolving these inconsistent predictions in the literature motivated the current research project.

Finally, evidence that the profile of poor comprehenders versus poor decoders has considerable developmental stability from preschool to 4th Grade was provided by the study of Elwér, Keenan, Olson, Byrne, and Samuelsson (2013). This study was conducted using participants of the International Longitudinal Twin Study (ILTS), which is one of the samples of the current study. Poor comprehenders and poor decoders were identified in 4th Grade, and predictors of poor comprehending and poor decoding were assessed at the ends of preschool, Kindergarten, 1st Grade, and 2nd Grade. Retrospectively, poor decoders exhibited relative weakness in decoding, phonological awareness, rapid serial naming, and

spelling. On the other hand, poor comprehenders showed lower performance on vocabulary, grammar and morphology, and verbal memory. Group membership (poor decoder or poor comprehender) at fourth grade was prospectively predicted by preschool rapid serial naming and vocabulary skills (77-79% classification). Poor comprehenders had worse preschool vocabulary skills in comparison to poor decoders; in contrast, poor decoders had worse preschool rapid serial naming. The current study extended the work of Elwér and colleagues (2013) by investigating how SES moderates the reading development of single word reading and reading comprehension. It may be possible that language-based skills, such as vocabulary, grammar and morphology, and verbal memory, are more strongly moderated by parental SES than other cognitive predictors. Moreover, the developmental trajectory of reading comprehension may be more strongly moderated by SES than the single word reading trajectory because of the oral listening and language comprehension demands of reading comprehension. Little research is available, however, on how SES affects reading comprehension development longitudinally. Therefore, the analyses of the current study were exploratory in nature.

Question 3: Correlation Differences

Evidence that the profile of reading problems varies as a function of when they appear in reading development is provided by a study conducted by Leach, Scarborough, & Rescorla (2003). When comparing groups of children in the United States, one with early-identified reading problems and one with late-emerging reading problems, Leach and colleagues (2003) found that late-identified children had reading problems equally divided across problems with single word reading and reading comprehension. In the late-emerging

group, 35% had word-level processing deficits and adequate comprehension skills, 32% showed weak comprehension skills and good lower level reading skills, and 32% exhibited both kinds of difficulty. In contrast, the distribution of these three types was more uneven among the children whose reading problems were identified early: 49%, 6%, and 46%, respectively. These differences might be an artifact of how reading comprehension skills were measured or of age. In early schooling, the variance in comprehension skills is mostly all accounted by decoding skills (Curtis, 1980). One limitation of this study (Leach et al., 2003) is that it did not explore if the reading outcomes at different stages in development are more strongly related to parental SES. Therefore, Question 3 of the current study examined if the relation between reading outcomes (single word reading and reading comprehension) and parental SES becomes stronger, more stable, or weaker in later stages of reading development.

In sum, the current research extended previous work in the following ways. First, this study examined for the first time differential mediation and moderation effects of SES in order to answer Question 1 in regards to the cognitive predictors of reading skill. Second, it addressed inconsistent results in the literature about the trajectory of reading development as a function of SES by answering Question 2 about how SES may moderate the development of reading outcomes. Third, Question 3 tested if the relation between reading outcomes and SES became stronger after 4th Grade when readers transitioned to *learning to read*. Fourth, datasets with substantially larger sample sizes than the previous research were used to conduct these analyses. Finally, parental occupation was coded using a novel system,

the International Socioeconomic Index, and it allowed for parental SES to be modeled as a continuous variable.

Aims and Hypotheses

The current study had the following aims and hypotheses:

Question 1: Mediation and moderation of SES. First, I tested whether cognitive predictors of reading skill (phonological awareness, vocabulary and verbal conceptual skills, rapid serial naming and processing speed) differentially *mediated* the relationship between SES and single word reading. In the CLDRC sample, cross-sectional mediation models were conducted in the younger group (ages 8 to 10) and older group (ages 11 to 16). In the ILTS sample, I performed four longitudinal mediation models with mediators measured in preschool and reading outcomes assessed in Kindergarten, 1st Grade, 2nd Grade, and 4th Grade. Specifically, I predicted that rapid serial naming, (processing speed and working memory in the CLDRC sample), and (verbal learning memory in the ILTS sample) would be weaker mediators of the relation between SES and single word reading than phonological awareness and vocabulary (and print knowledge in the ILTS sample). The rankings of the proportion mediated by each predictor were compared to the rankings of the variance explained by predictors of individual differences in these readings models without parental SES as a factor.

I also examined whether the predictors of reading comprehension skill (single word reading and oral listening comprehension) mediated the relationship between SES and reading comprehension. There is inconsistent evidence in the literature regarding which of the predictors of reading comprehension would be a weaker or stronger mediator of the

relationship between SES and reading comprehension (see previous review of Chall et al., 1990; Elwér et al., 2013; Hecht et al., 2000; Snow, 1993; Snow et al., 1991). Therefore, this was a novel exploratory analysis to examine how these predictors mediate relation between SES and reading comprehension.

Moderation models were performed to examine if SES *moderated* the relation between cognitive predictors and reading outcomes at different levels of parental SES. It was predicted that phonological awareness, vocabulary (and print knowledge in the ILTS sample) would be more predictive of reading skill as SES decreases, and rapid serial naming processing speed and working memory in the CLDRC sample), and (verbal learning memory in the ILTS sample) would be less predictive of reading skill as SES decreased. For reading comprehension, this was a novel analysis to explore how SES moderates the relation between reading comprehension and SES.

Question 2: SES moderation of growth curves. I examined whether the growth curves of single word reading and reading comprehension from 1st Grade to 4th Grade varied as a function of SES. Secondary models were conducted to control for initial print knowledge skills in the single word reading model, and initial vocabulary and single word reading skills in the reading comprehension model. I predicted that the starting points would be lower and the slopes would be flatter for children from lower SES backgrounds than higher SES. I also considered the possibility that children from lower SES backgrounds benefit from the equalization of instruction by being in school; therefore, the rate of learning of reading skills might actually be higher (steeper slopes) than those of children from higher SES backgrounds.

Question 3: Correlation differences. Finally, I tested whether the relationship between reading outcomes (i.e., in single word reading versus reading comprehension) and parental SES differed. I predicted that in later stages of reading development, the correlation between SES and reading comprehension would be stronger than the correlation between SES and single word reading. Previous research suggests similar correlations before 4th Grade (e.g. Hecht et al, 2000).

Methods

I conducted analyses in two different samples to answer the three questions pertaining to cognitive predictors, trajectories, and the strength of the relationship between SES and reading outcomes. The reading outcomes examined were single word reading (SWR) and reading comprehension (RC). The first dataset was the cross-sectional Colorado Learning Disability Research Center (CLDRC) sample of school-age twins. The data were split into two age groups to address potential developmental changes caused by the transition from *learning to reading* to *reading to learn* that is argued to occur in 4th Grade (Chall et al., 1990). The second dataset was the International Longitudinal Twin Study (ILTS) population sample of twins from the United States. These subjects were initially tested in preschool and followed up at the end of Kindergarten, 1st Grade, 2nd Grade, and 4th Grade. I performed the analyses for Question 1 and Question 3 in both the CLDRC and ILTS samples. Question 2 was addressed using only the ILTS sample. Table 2 presents the demographic information for each sample.

Participants

Colorado Learning Disability Research Center (CLDRC) sample. The cross-sectional CLDRC study of school-age twins (DeFries et al., 1997) is a sample overselected

for children with dyslexia and Attention Deficit Hyperactivity Disorder (ADHD) between the ages of 8 to 18. All children spoke and read English as their first language. At the time of the current study, the complete CLDRC sample was composed of 4,415 twin pairs and 711 singleton siblings. The sample was reduced by applying the following parameters.

Exclusionary criteria included medical conditions (e.g., seizures), participants older than 16 years old, completing a different version of the reading measures on the day of testing (PIAT versus PIAT-Revised version), and unreported/missing parental occupation and years of education. After applying such criteria, the sample size was $n=1,554$ (twin members= $1,377$, and singleton siblings= 177) (see Table 2). The participants were split into two age groups: the younger group (ages 8 to 10) and the older group (ages 11 to 16). The sample size between RC and SWR analyses differed because the reading comprehension measures only began in the year 2000. The SWR measures, however, were part of the initial testing battery of the sample (Younger group: SWR $n=811$, RC $n=682$; Older group: SWR $n=743$, RC $n=647$).

In the CLDRC sample, twin pairs were assigned to one of two groups based on school history. Group 1 (affected) included twin pairs in which at least one member of the twin pair had a school history of ADHD, dyslexia, or math disability (MD). Group 2 (controls) included only pairs where neither twin had a school history of ADHD, dyslexia, or MD. Although this sample is enriched for children with learning difficulties, the full sample was included. Several of the administered standardized tests have an approximate normal distribution with a mean standard score and standard deviation close to those of the norming sample. The analyses were performed using Mplus 7.0, which allows for statistical

control of familiarity (since both members of twin pairs will be used). Including twin pairs versus selecting on twin member at random increased the power for analyses.

International Longitudinal Twin Study (ILTS) sample. The complete sample for the present study included 489 twin pairs from the Colorado Twin Registry in the United States (see Table 2) (see Byrne et al., 2006, 2007; Olson et al., 2011; Samuelsson et al., 2005). Families of the Colorado Twin Registry were approached by mail or phone and 86% of the 60% who could be contacted agreed to participate. Only participants for whom English was the first language spoken at home were selected. At initial contact and testing, all twins were in their final preschool year, with ages ranging from 54 to 71 months ($M=58.8$) in the United States. Data were collected at 5 time points, at the ends of: Preschool, Kindergarten, 1st Grade, 2nd Grade, and 4th Grade. Exclusionary criteria included unreported/missing parental occupation and years of education. After applying such criteria, the sample size was $n=926$ (463 twin pairs).

The ILTS sample approximates a population sample. The analyses for Question 1 and Question 3 were performed using Mplus 7.0, which allows for statistical control of familiarity (since both members of twin pairs will be used). The analyses for Question 2 were conducted using Hierarchical Linear Modeling, Version 7 (HLM7) software in order to use SES as a continuous variable, and one twin member from each pair was selected at random.

The demographics of the CLDRC and ITLS samples are representative of the state of Colorado in terms of race; however, neither sample is representative of the proportion of individuals of Hispanic/Latino descent, due at least in part to the fact that the samples were restricted to children whose first language was English. The CLDRC is negatively skewed in

favor of more years of parent education compared to the Colorado population. The reading and cognitive predictor measures are not identical across the samples. Therefore, in order to improve the comparisons between the ILTS and CLDRC samples, the CLDRC sample was split into a younger group (ages 8 to 10) and an older group (ages 11 to 16). Further, I conducted the analyses separately for each sample in order to address the fact that the tests administered to measure each construct (e.g., single word reading, rapid serial naming, etc.) were not the same across samples.

Procedure

CLDRC sample. Participants and their families attended a total of four 2.5 hour testing sessions, which typically took place during weekends. Two of the sessions were completed at the University of Colorado, Boulder and the other two at the University of Denver. The University of Denver testing was scheduled approximately 1 month after the University of Colorado, Boulder testing. Examiners at both sites were trained to administer all the measures.

ILTS sample. Parents consented in writing to participate in the study. Testing was performed at home, in preschool, or school. All tests were administered individually to each child during the course of two weeks. For the initial tests, each of the 5 sessions was approximately an hour long. Tests at the end of Kindergarten, 1st Grade and 2nd Grade were administered in one one-hour session. Testing at the end of 4th Grade was conducted in a 1.5- to 2-hours session. Each twin pair was tested at the same time by a different, trained tester.

Measures

Socioeconomic status. SES was determined across the two samples using parental years of education and occupation. Parental occupations were coded using the International Socioeconomic Index (ISEI; Ganzeboom et al., 1992; Ganzeboom & Treiman, 1996), which has a coding system from 10 to 90. Parental years of education and ISEI codes were combined using two-level confirmatory factor analyses, and the resulting SES factor scores were used in subsequent analyses. Two-level models were conducted in order to account for non-independence of the twin data. Table 2 presents the demographic information for each sample.

Cognitive and literacy measures. Single word reading (SWR), reading comprehension (RC), oral listening comprehension (OLC), phonological awareness (PA), vocabulary (VOC), rapid serial naming (RSN), processing speed (PS; only in the CLDRC sample), print knowledge (PK, only in the ILTS sample), verbal learning memory (VLM, only available in the ILTS sample), verbal working memory (WM, only in the CLDRC sample) constructs were composed using the measures outlined below. Tests are listed with the construct they are theorized to measure.

CLDRC sample. The same measures were administered to both the younger age group and older age group, and are from a larger test battery that all participants received. Complete descriptions of each measure have been previously published (Gayán & Olson, 2001; Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005). Hence, a concise description is provided for each test. Reported estimated reliability coefficients of the described measures were obtained from the original citation for the measure. For the

Wechsler Intelligence Scale for Children (WISC) subtests, either the WISC-R (Wechsler, 1974) or WISC-III (Wechsler, 1991) version was administered because in 2006 the larger CLDRC study switched versions.

Phonological awareness. PA is the ability to manipulate a word into the smallest sound units known as phonemes. Four tests were combined to create a PA factor score. Phoneme Deletion 1 & Phoneme Deletion 2 measures (Reliability=.80; Olson, Fosberg, Wise, & Rack, 1994) required participants to isolate and remove a phoneme from a non-word or word and say the resulting word. Pig Latin measure (Reliability=.78; Olson et al., 1989) asked participants to change the word by moving the ending phoneme to the beginning and adding 'ay'. For the Lindamood measure (Reliability=.67; Lindamood & Lindamood, 1979), the participants used colored blocks as representations of phonemes in order to sequence sounds and non-words.

Vocabulary. VOC is the ability to define words, construct sentences, and understand language in order to communicate verbally. VOC was constructed as an observed variable with one single measure. For the WISC Vocabulary subtest (Reliability=.86; Wechsler, 1974, 1991), participants were asked to define words.

Rapid serial naming. RSN is the ability to recognize and name items, which are well known and listed in a serial manner, as quickly and accurately as possible. Four measures were combined to create RSN factor score. Participants were asked to name colors (Reliability=.82), pictures (Reliability=.80), numbers (Reliability=.86), and letters (Reliability=.86) from the Rapid Automatized Naming test (Denckla & Rudel, 1974, 1976).

Processing speed. PS is the ability to process and match visual information, such as symbols (e.g., pictures, letters, shapes). PS factor score was constructed using four measures. Colorado Perceptual Speed Test (Reliability=.81; Decker, 1989; DeFries, Singer, Foch, & Lewitter, 1978) required the participants to identify a string of letters or numbers and letters among three foils. For the Identical Pictures Test (Reliability=.82; French, Ekstrom, & Prince, 1963), participants selected a target picture among an array with four foils. WISC Symbol Search and Coding subtests (Reliability=.74-.85, & .72, respectively; Wechsler, 1974, 1991) asked participants to rapidly match shapes among an array of foils, and copy symbols linked with numbers based on a key, respectively.

Verbal working memory. WM is the ability to hold verbal information and manipulate it in order to provide a response or solve a separate cognitive task. The WM factor score combined three measures. For the WISC Digit Span Backward subtest (Reliability=.78; Wechsler, 1974, 1991), participants had to repeat a string of numbers backwards, with the string increasing in length after each trial. In the Sentence Span Test (Reliability=.65-.71; Kuntsi, Stevenson, Oosterlaan, & Sonuga-Barke, 2001; Siegel & Ryan, 1989) the examiner asked participants to provide the last word for a set of simple sentences. The participants are then asked to recall those words in order after each set. The Counting Span Test (Reliability=.55-.67; Case, Kurland, & Goldberg, 1982; Kuntsi et al., 2001) required participants to count out loud the number of yellow dots on a series of cards with blue and yellow dots. At the end of each set, participants stated in order how many dots appeared on each card for the specific set.

Oral listening comprehension. OLC are skills that support comprehension, such as receptive vocabulary (i.e., understanding of spoken words) and narrative comprehension, in order to understand the meaning of an auditory passage. The OLC factor score was composed of three measures. Participants completed a shortened version of the original Barnes KNOW-IT (Barnes & Dennis, 1996; Barnes, Dennis, Haefele-Kalvaitis, 1996), in which they learned approximately 20 facts about an imaginary planet and listened to 6 episodes describing the adventures of two children who visited it. Then, participants answered 18 comprehension questions. Test-retest reliability is not available for this measure. For the WJ-III Oral Comprehension subtest (Reliability=0.81; Woodcock, McGrew, & Mather, 2001), participants listened to short passages (one to two sentences long) and had to generate the last word of the passage correctly. The Qualitative Reading Inventory 3 (QRI) – Listening Recall & Questions (Reliability=.94-.98; Leslie & Caldwell, 2001) was modified so that participants first answered a question regarding the topic for the passage before listening to it in order to assess domain knowledge. Then, participants listened to one or two passages on audiotape and retold the passage(s) as best they could. In addition, participants answered six additional questions about the passage. Different passages were administered depending on the participant's age and grade. All scores were standardized within level so that comparisons could be conducted across different levels of passages.

Single word reading. SWR is the ability to decode words accurately and the SWR factor score was composed of two measures. For the PIAT Reading Recognition test (Reliability=.89; Dunn & Markwardt, 1970), participants read single words that increased in

difficulty in terms of semantics and phonics; decoding skills were not timed. Time-Limited Word Recognition test (Reliability=.89; Olson, Wise, Conners, Rack, & Fulker, 1989) asked participants to read out loud single words within 2 seconds of their presentation.

Reading comprehension. RC is the ability to comprehend and make inferences about the meaning of a written passage, and the RC factor score combined two measures. For the Gray Oral Reading Test (GORT) – 3rd Edition, Comprehension portion (Reliability=.75; Wiederholt & Bryant, 1992), participants read passages out loud and answered five multiple-choice questions about the passage. The Qualitative Reading Inventory 3 (QRI) (Reliability=.94-.98 Leslie & Caldwell, 2001) is identical in format to the listening comprehension portion of the QRI, which was previously described, except that this format requires participants to read the passages out loud instead of listening to them.

ILTS sample. As previously stated, the ILTS measures were collected at different time points (end of preschool, Kindergarten, 1st Grade, 2nd Grade, and 4th Grade). Constructs of cognitive predictors and reading skills were calculated based on prior factor analyses of these measures (Samuelsson et al., 2005). Complete descriptions of each measure have been previously published (Byrne et al., 2006, 2007; Olson et al., 2011; Samuelsson et al., 2005). Hence, a concise description is provided for each test. Reported estimated reliability coefficients of the described measures were obtained from the original citation for the measure. These measures are from a larger test battery, which all participants received. Definitions for each construct were provided in the CLDRC measure section; therefore, I only defined new constructs in the ILTS measure section (e.g., print knowledge and verbal learning memory).

Preschool phonological awareness. PA factor score combined six measures. In the Comprehension Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 1999), participants were asked to match the target word with one of three words that started or ended with the same sound (Sound Matching subtest; Reliability=.77), to delete a single-syllable word from a compound word and state the new word (Elision subtest; Reliability=.77), and to combine single-syllable words to form compound words (Blending Words subtest; Reliability=.84). Rhyme and Final Sound test asked participants to match words that rhyme and words that end with the same sound (Reliability=.68; Samuelsson et al., 2005). Syllable and Phoneme Blending measure required participants to blend syllables and phonemes to form words (Reliability=.76; Samuelsson et al., 2005). Finally, for the Syllable and Phoneme Elision measure, participants were asked to delete a syllable or a phoneme from a word in order to form a new word (Samuelsson et al., 2005)

Preschool vocabulary. Four measures were combined to create a VOC factor score. Participants were asked to define words (WPPSI-Revised Vocabulary; Test-retest reliability for 4.5 year olds=.83; Wechsler, 1989), to name pictures (The Hundred Picture Naming Test; Reliability=.89; Fisher & Glenister, 1992), to demonstrate grammatical knowledge (Grammatic Closure subtest from the Illinois Test of Psycholinguistic Abilities; Reliability=.84; McCarthy & Kirk, 1961), and to complete sentences in order to assess understanding and application of suffixes (Productive Morphology; Reliability=.88; Samuelsson et al., 2005).

Preschool rapid serial naming. Combining two measures created a RSN factor score. From the CTOPP (Wagner et al., 1999), participants were asked to rapidly and accurately

name objects and colors, which are well known and listed in a serial manner (Rapid Object Naming and Rapid Color Naming subtests; Reliability=.71 for object naming, and .81 for color naming).

Preschool print knowledge. PK is the child's earliest understanding that written language carries meaning, and the PK factor score combined four measures. Participants were asked about their understanding of print conventions (e.g., left to right writing, etc.; Concepts About Print measure; Reliability=.83; Clay, 1975). For the Letter Recognition from Names test and the Letter Recognition from Sounds test, examiners either said a letter's name or sound and the participant had to match it to the printed letter that corresponded to either the name or sound (Reliability=.92 for letter names, and .87 for letter sounds; Samuelsson et al., 2005). The Environmental Print test measured the child's ability to interpret signs with print in a community context, for example, STOP, McDonald's, and EXIT signs (Reliability=.46; Samuelsson et al., 2005).

Preschool verbal learning and memory. VLM is a rather broad concept that refers to memory for verbally presented information. There are a variety of tasks for measuring verbal memory capability, including repeating sounds and sentences, learning of word lists, and story recall. The VLM factor score combined four measures. Participants were asked to repeat pronounceable non-words that increased in syllabic length (Nonword Repetition test; Reliability=.84; Gathercole, Willis, Baddeley, & Emslie, 1994). WPPSI-Revised Sentence Memory subtest (Wechsler, 1989) required participants to repeat sentences that increased in word length (split-half reliability coefficient of .88 for 5-year-old children). From the Wide Range Assessment of Memory and Learning (WRAML; Adams & Sheslow, 1990), examiners

read two stories to the participants and asked them to recall as much information from each story (Story Recall subtest; Reliability=.87), and recall abstract sounds associated with abstract figures, which participants learned over the course of four trials (WRAML Sound Symbol subtest; Reliability=.88).

Kindergarten single word reading. Kindergarten SWR factor score combined four measures. Participants completed the two equivalent versions (Form A and Form B) of the Test of Word Reading Efficiency (TOWRE; Torgesen et al., 1999), which required them to read a list of sight words (Sight Word Efficiency subtest) and a list of non-words (Phonemic Decoding Efficiency subtest) in a period of 45 seconds for each subtest. Test-retest reliability for children ages 6 to 9 is reported in the test manual as .97 for sight word efficiency, and .90 for phonemic decoding efficiency standard scores.

1st Grade single word reading. 1st Grade SWR factor score combined four measures (see description of these four measures in the ‘Kindergarten single word reading’ description; Torgesen et al., 1999).

2nd Grade single word reading. 2nd Grade SWR factor score combined four measures (see description of these four measures in the ‘Kindergarten single word reading’ description; Torgesen et al., 1999).

2nd Grade vocabulary. 2nd Grade VOC was constructed as an observed variable with one single measure. For the ILTS sample, this construct was used as a proxy for oral listening comprehension because it was the only available measure available in 2nd grade. The Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983) required participants to name

pictures of concrete objects, and the pictures increase in difficulty (e.g., from bed to abacus). Test-retest reliability is not available.

1st Grade & 2nd Grade reading comprehension. 1st Grade RC and 2nd Grade RC were constructed as an observed variable with one single measure. The Passage Comprehension subtest from the Woodcock Reading Mastery Test-Revised uses a cloze procedure, which asked participants to verbally provide the missing word, denoted by an underlined space in a sentence (Woodcock, 1987). The missing word needed to be the best fitting word for the one- to two-sentence passage that is read silently. Internal reliability of .88 is reported in the manual for the 5 to 18 years of age group.

4th Grade single word reading. 4th Grade SWR factor score combined four measures. The TOWRE measures administered in Kindergarten, 1st Grade, and 2nd Grade were also completed in 4th Grade, but only the Form A version. In addition, participants completed the untimed measures of Letter-Word Identification (reading out loud words) and Word Attack (reading out loud non-words) from the Woodcock-Johnson III Tests of Achievement (Woodcock et al., 2001). One-year test-retest reliabilities of .85 and .81 are reported in the manual for Letter-Word Identification and Word Attack, respectively, for children ages 8 to 10.

4th Grade reading comprehension. 4th Grade RC was created with combining two measures. The Woodcock Passage Comprehension test administered in 2nd Grade was also completed in 4th Grade (Woodcock, 1987). In addition, participants were also asked to read a series of passages silently. Then, they answered four multiple-choice questions per passage to

assess their comprehension while the passage was still visible (Gates-MacGinitie Reading Comprehension subtest; Reliability=.88; MacGinitie et al., 2000).

Data Cleaning

For both the CLDRC and ILTS samples, raw scores from the previously described measures were corrected for possible linear and nonlinear effects of age by regressing the raw scores on to age and age squared. Standardized residuals were saved for further analysis (McGrath et al., 2011). After controlling for age effects, outliers falling 3 standard deviations (SD) beyond the mean for the entire samples were Winsorized to 3 SDs. The variables were checked for skewness and kurtosis using the general recommendations of Kline (2005), with values between -1.2 to 1.2 across all variables. Variables with extreme violations of normality (Kline, 2005) were log transformed. Pig Latin test (CLDRC older group), Phoneme Deletion 2 test (CLDRC older group), Barnes test (CLDRC older group), Rapid Object Naming and Rapid Color Naming subtests (ILTS preschool), and Sound Matching test (ILTS preschool) were noted to have non-normal distributions. Qualitative Reading Inventory 3 (QRI) for Reading Comprehension and Listening Comprehension were corrected for age effects within each grade.

Variables administered at each time point for each construct (described above) were combined into a single score for that time point using two-level confirmatory factor analyses, and the resulting factor scores were used in subsequent analyses. Two-level models were used in order to account for non-independence of the twin data. Factor loadings for all latent variables were statistically significant and the model fit for each confirmatory factor analysis was evaluated by applying the robust CFI and the robust RMSEA as model fit

statistics. The robust CFI provides a measure of the fit of the hypothesized model relative to the independence model (values range from .00 to 1.00). CFI values greater than .90 suggest an adequate fitting model. The robust RMSEA provides a measure of model fit relative to the population covariance matrix when the complexity of the model is also taken into account. Values less than .06 indicate a good fit, values from .06 to .08 a reasonable fit, values from .08 to .10 a mediocre fit, and values greater than .10 a poor fit (Byrne, 2001). All fit indexes were good for each model and improvement of model fit was conducted by including correlations between variables. When only one measure was obtained for a given construct, that measure was referred to as an observed variable. Bivariate correlations among factor scores and observed variables for both samples are presented in Tables 3, 4, and 5. Bivariate scatterplots with SES or cognitive predictors on the x-axis and RC or SWR on y-axis were inspected and found to exhibit bivariate normality. For missing data, Mplus 7.0 used full information maximum likelihood (FIML) to account for missing data.

Main Analyses

The main analyses answered three questions pertaining to cognitive predictors, trajectories, and the strength of the relationship between SES and reading outcomes (SWR and RC). Question 1 asked how cognitive predictors mediated the relationship between SES and reading outcomes, and if SES moderated the relationship between each cognitive predictor and reading outcomes. Question 2 examined if SES moderated the developmental trajectory of reading outcomes at the starting point (intercept) and growth (slope). Question 3 explored if the relation between SES and reading comprehension was stronger than that of SES and single word reading.

Question 1: Mediation analysis. In order to answer Question 1, mediation analyses were conducted to understand the relationships among SES, cognitive predictors, and single word reading, as well as, SES, single word reading, OLC, and reading comprehension (see Figure 3). The proposed mediators for the single word reading and SES relationship were PA, VOC, RSN, (and PK and VLM from the ILTS sample/ and PS and WM from the CLDRC sample). The mediators for the reading comprehension and SES relationship were SWR and OLC. Mediation was examined according to the methods of Baron and Kenny (1986). Relationships between the independent variable (SES) and dependent variable (SWR or RC), between independent variable and mediators, and between dependent variable and mediators were first established in order to proceed.

Mediation models were conducted in Mplus 7 in order to control for familiarity. It also permitted all mediators to be included in one single model because the correlations among mediators were included in the model to prevent issues with multicollinearity. The direct effect between independent variable (SES) and dependent variable (SWR or RC) as well as the indirect effects of each mediator were calculated. Ranking the indirect effects to measure the proportion mediated by each cognitive predictor was possible because the indirect effects were computed in one single model.

Full mediation was predicted to be highly unlikely because it implied that the inclusion of the mediators decreased the relationship between SES and SWR or RC to zero. Yet, it was possible that the relationship would decrease to a level that was no longer statistically significant. The most likely result was predicted to be that the relationship between SES and SWR or RC became weaker. Partial mediation maintained that the

mediating predictors accounted for part, but not all, of the relationship between SES and SWR or RC. Partial mediation implied not only a significant relationship between the mediators and single word reading or reading comprehension, but also a direct relationship between SES and SWR or RC. Partial mediation could also imply that SES is a proxy for some risk that is not being adequately captured by the standard cognitive reading predictors. Finally, if the relationship between a mediator (e.g. RSN or PS) and SWR was weaker, the possibility of suppression effects needed to be considered. This would imply that a suppressor variable lead to an increase in magnitude of the relationship between SES and SWR or RC making such relationship stronger.

Question 1: Moderation analysis. In order to address the second part of Question 1, I tested if SES moderated the relationship of reading outcomes and their cognitive predictors. Moderators are variables (such as SES) that can make the relationship between two variables (e.g. PA and reading) either stronger or weaker across different values of the moderator. Moderation was tested by modeling interactions in regression equations. One important distinction to make is that in the mediation analysis, SES was modeled as the independent variable. For the moderation portion of the analyses, SES was treated as the moderator. Moderation analysis explored if the relationship between SWR and each cognitive predictor varied at different values of SES (or, if the relationship between RC and the predictors of the Simple View of Reading model varied at different values of SES). However, the interactions could also be interpreted using SES as the independent variable.

For single word reading (CLDRC sample), five separate regression models with the cognitive predictors (PA, VOC, RSN, PS, WM) were performed in order to prevent issues of

multicollinearity given that the cognitive predictors were significantly correlated with each other. The same method was employed on the ILTS sample with the cognitive predictors (PA, VOC, RSN, PK, and VLM). Omnibus regression models were conducted, which included only the main effects and significant interactions from the single regression models. The interaction terms in these equations tested for moderation effects, so if a significant interaction was found, this result would show that SES moderated that specific predictor (PA, VOC, RSN, or PK and VLM for the ILTS sample, or PS and WM for the CLDRC sample). Such result would suggest that the strength of that predictor varied as a function of SES. Based on the literature reviewed earlier, I predicted opposite moderation effects of SES with RSN and PS vs. SES with the other predictors. Specifically, I expected that as SES decreased, the predictiveness of RSN and PS would decrease, whereas the opposite pattern would be observed for the other predictors.

For reading comprehension, two separate regression models were conducted with the predictors of the Simple View of Reading to test for moderator effects in both the CLDRC and ILTS samples ($RC = SES + SWR + SWR \times SES$ and $RC = SES + OLC + OLC \times SES$). Omnibus regression models were performed in both samples with only the main effects and interaction terms that were significant in the single regression models. The interaction terms in these equations tested for moderation effects, so if there was a significant interaction this result would show that SES is the moderator for that specific predictor (e.g. SWR and OLC). Moderation effects were predicted for both OLC and SWR, with the possibility of SES having a stronger moderating effect on OLC (i.e., the interaction of OLC as a predictor would strengthened as SES decreases) in comparison to the

interaction of SES and SWR. If the $SWR \times SES$ interaction term was found to be significant, follow up analysis were conducted to include PA, VOC, RSN, or (PK and VLM for the ILTS sample, or PS and WM for the CLDRC sample) to specify what predictor of SWR is causing the moderation effect between SWR and SES in the RC moderation model.

Question 2: SES moderation of growth curves. In order to answer Question 2, which examined if SES moderated the intercepts and slopes of single word reading and reading comprehension, I conducted growth curve analyses only in the ILTS sample because of its longitudinal nature. Latent growth curve modeling using Hierarchical Linear Modeling, version 7 (HLM7) was performed in order to include SES as a continuous variable at the intercept and slope level. One twin member from each pair was selected at random, only for the growth curve analyses.

The growth curve model estimates the average intercept (initial starting value) and slope (growth trajectory) of a specific measure over time. For single word reading, the total unadjusted raw score of single word reading efficiency and phonemic decoding efficiency (TOWRE, Form A) at 1st Grade, 2nd Grade, and 4th Grade was modeled, while controlling for single word reading skills in Kindergarten. For reading comprehension, the unadjusted raw scores of the Woodcock Passage Comprehension subtest at 1st Grade, 2nd Grade, and 4th Grade were modeled, while controlling vocabulary skills in preschool and single word reading skills in 1st Grade. By controlling for cognitive predictors of single word reading and reading comprehension, the magnitudes of the estimates of the relations between SES and later reading skills were not influenced by prior levels of reading attainment. Differences in either the single word reading trajectory or the reading comprehension trajectory indicated if

SES moderated the initial starting value and/or growth in either single word reading or reading comprehension.

Question 3: Correlation differences. Differences between correlations were computed in order to address Question 3, which tested if the relationship between SES and reading comprehension was stronger than that of SES and single word reading at different stages of development (CLDRC: younger group versus older group; ILTS: 2nd Grade versus 4th Grade). For the CLDRC sample, correlations were computed (SWR and SES, RC and SES) in the younger age group and in the older age group. The Hotelling/Williams Test (Williams, 1959) examined the difference between dependent correlations of the same sample (younger group or older group).

For the ILTS sample, correlations between single word reading and SES, as well as, reading comprehension and SES were conducted for the end of 2nd Grade and 4th Grade. Differences between these dependent correlations were also examined using Hotelling/Williams Test (Williams, 1959). If differences between two correlations were found, it would indicate the relationship between single word reading and SES or reading comprehension and SES was stronger or weaker at different time points of reading development. I hypothesized that the relationship between SES and reading comprehension would be stronger than that of SES and single word reading because reading comprehension relies more heavily upon language-based knowledge.

Power

Power estimates for the F-test multiple regression models of the interaction terms were based on Cohen (1988). In order to obtain significant power at 80%, provided the

interaction term in the models has a small effect size (.07), 320 participants are needed in the sample. In order to have significant power at 80% with an effect size of .12 (larger, but still small effect size) for an interaction term, 190 participants are needed (estimates calculated using G*Power 3.1.2 version). As of September of 2012, the ILTS sample had 489 twin pairs and the CLDRC sample had 2,213 twin pairs. Thus, even with a small effect size (.07), the samples should provide adequate power to detect interactions and main effects.

Results

Question 1: Mediation and Moderation of SES

The first question was concerned with whether cognitive predictors of single word reading (SWR) and reading comprehension (RC) *mediate* the relation between SES and these two reading outcomes and whether SES *moderates* the relation between cognitive predictors and these two reading outcomes. In other words, Question 1 investigated whether SES adds anything to well-established cognitive models of reading outcomes. If not, those models are equivalent across SES levels.

For single word reading, I first tested whether cognitive predictors of reading skill (PA, VOC, RSN, PS, PK, VLM, and WM) *mediated* the relationship between SES and single word reading and hypothesized that RSN, WM, VLM, and PS would be weaker mediators of the relation between SES and single word reading in comparison to PA, VOC, and PK (see Figure 3). For reading comprehension, I examined whether the predictors of the Simple View of Reading Model (OLC and SWR) *mediated* the relation between SES and reading comprehension, which was a novel exploratory analysis.

The second set of analyses for Question 1 included regression models to test if SES *moderated* the relation between SWR and each cognitive predictor. I predicted that VOC, PA,

and PK might be more predictive of reading skill as SES decreased, and RSN, PS, WM, and VLM might be less predictive of reading skill as SES decreased. Similar moderation analyses were conducted for reading comprehension and the predictors of the Simple View of Reading Model, which again was a novel exploratory analysis.

In the CLDRC sample, cross-sectional mediation and moderation models were conducted separately in the younger group and older group. Longitudinal mediation and moderation models were performed in the ILTS sample.

CLDRC sample. Mediation and moderation results for single word reading and reading comprehension are first presented for the younger group then for the older group. Mediators for the single word reading model were phonological awareness (PA), vocabulary (VOC), rapid serial naming (RSN), processing speed (PS), and verbal working memory (WM). In accordance to the methodology of mediation, I first conducted individual regression models in order to establish statistically significant relationships between the independent variable (SES) and dependent variables (SWR or RC), between independent variable and mediators, and between dependent variables and mediators (Baron & Kenny, 1986). All single regression models were significant. See Tables 3 and 4 for the correlations among predictors, reading skill, and SES.

Younger group: Single word reading. Total effects (direct and indirect) in the mediation model of single word reading and SES were estimated at .29 ($p < .001$), with a direct effect path between SES and single word reading of .07 ($p < .001$) (see Table 6). Cognitive predictors (PA, VOC, RSN, and PS) partially mediated the relationship between SES and single word reading in the younger group (total indirect effects = .22, $p < .001$).

Working memory (WM) did not contribute any indirect effects. When comparing the proportion of mediation among cognitive predictors, the rank order was PA (45%), VOC (27%), RSN (14%), and PS (9%), which does not differ from the ranking of variance explained in a regression model where SES was not included ($SWR = PA + VOC + RSN + PS + WM$). Therefore, including SES in the model did not alter the order of variance explained by each cognitive predictor.

I next examined if SES moderated the relationship between SWR and each cognitive predictor performing individual regression models ($SWR = Cognitive\ Predictor + SES + Interaction$). Three significant interactions were identified ($PA \times SES$, $RSN \times SES$, and $PS \times SES$, see Figures 4, 5, and 6, respectively; regression equation located in the 'Note' section). The interactions indicated that PA was a better predictor of single word reading as SES increased, and RSN and PS were better predictors of single word reading as SES decreased, which were the opposite moderating effects I predicted. In an omnibus regression model with SES, cognitive predictors, and the 3 significant interactions, only the interaction of PA and SES ($\beta = .08$, $p < .001$, effect size = .01; see Figure 7) was significant and in the same direction as in the single regression model. These results indicated that single word reading skills at a young age (ages 8 to 10) may not be identical across SES levels because the relationship between single word reading and PA varies as a function of SES.

Younger group: Reading comprehension. Indirect effects of oral listening comprehension and single word reading skills decreased the direct effect path between SES and reading comprehension to non-significance (see Table 7), indicating full mediation (total effects = .29, $p < .001$, total direct effects = .02, $p > .05$, total indirect effects = .28, $p < .001$).

When comparing the proportion of mediation, the rank order was oral listening comprehension (54%) and single word reading (46%), which differed from the ranking of variance explained in a regression model where SES was not included ($RC = OLC + SWR$). In the regression model without SES, the standardized Beta for single word reading (SWR $\beta=.48, p<.001$) was higher than the standardized Beta for oral listening comprehension (OLC $\beta=.45, p<.001$). These findings suggested that language-based skills, such as oral listening comprehension, might be more susceptible to SES effects.

In the moderation models, which tested if SES moderated the relationships between oral listening comprehension/single word reading and reading comprehension, none of the interaction terms were significant. Results indicated that the profile of reading comprehension skills at a younger age (ages 8 to 10) functions in the same manner across different levels of SES.

Older group: Single word reading. Total effects (direct and indirect) in the mediation model of single word reading and SES in the older group were estimated at .27 ($p<.001$), with a non-significant, direct effect path between SES and single word reading of .02 ($p>.05$) (see Table 6). Cognitive predictors (PA, VOC, RSN, and PS) fully mediated the relationship between SES and single word reading (total indirect effects=.26, $p<.001$). Working memory (WM) did not contribute any indirect effects. When comparing the proportion of mediation among cognitive predictors, the rank order was VOC (46%), PA (38%), RSN (8%), and PS (4%). This ranking of cognitive predictors differed from the ranking of variance explained in a regression model without SES as an independent variable, which yielded the order of PA, VOC, RSN, PS, and WM based on the standardized Betas

(PA $\beta=.48$, $p<.001$; VOC $\beta=.33$, $p<.001$; RSN $\beta=.11$, $p<.001$; PS $\beta=.09$, $p<.001$; WM $\beta=.07$, $p<.001$). These results supported the hypothesis that PA and VOC are stronger mediators of the relation between single word reading and SES, especially VOC. In the moderation models, none of the interaction terms were significant, indicating that the profile of single word reading skills in the older group (ages 11 to 16) does not vary as a function of SES.

Older group: Reading comprehension. Oral listening comprehension and single word reading skills partially mediated the relation between SES and reading comprehension (indirect effects $=.28$, $p<.001$). Total effects (direct and indirect) in the mediation model of reading comprehension and SES in the older group were estimated at $.35$ ($p<.001$), with a significant, direct effect path between SES and reading comprehension of $.07$ ($p>.001$) (see Table 7). The proportion of mediation contributed by oral listening comprehension (75%) was substantially higher than that of single word reading (25%), which suggests that language-based skills may be more susceptible to SES effects, which does not differ from the ranking of variance explained in a regression model where SES was not included ($RC = OLC + SWR$). Therefore, including SES in the model did not alter the order of variance explained by each cognitive predictor.

In the moderation models, which tested if SES moderated the relationships between reading comprehension and oral listening comprehension/single word reading, none of the interaction terms were significant. Results indicated that the profile of reading comprehension skills at an older age (ages 11 to 16) functions in the same manner across different levels of SES.

As part of an exploratory set of analyses, I conducted the mediation and moderation models substituting SES with parental years of education or parental occupation. Parental years of education and occupation were significantly correlated (younger group $r=.50$, $p<.001$; older group $r=.52$, $p<.001$) and theory suggests that both constructs have both shared and unique variance, which they contribute when computing an SES factor. Hence, the variable of parental years of education was controlled for parental occupation, and vice-versa. Parental years of education (corrected for parental occupation) yielded similar results to that of the SES moderation and mediation models. In contrast, parental occupation (corrected for parental education) was not significantly correlated with single word reading or reading comprehension; therefore, analyses were not performed.

In summary, results supported developmental changes in reading development and its relation to SES. In the younger group (ages 8 to 10), the total effects of SES on single word reading was partially mediated by the cognitive predictors via indirect effects, yet the direct effect between SES and single word reading continued to be significant. In contrast, the direct effect between SES and reading comprehension decreased to non-significance due to the indirect effects of oral listening comprehension and single word reading. The opposite pattern was found in the older group (ages 11 to 16), in which the direct effect between SES and single word reading decreased to non-significance and the direct effect between SES and reading comprehension remained statistically significant. The profile of single word reading skills at a younger age (ages 8 to 10) may not be identical across SES levels because the relationship between single word reading and PA varies as a function of SES. The profile of single word reading skills at an older age (ages 11 to 16), as well as, the profile of reading

comprehension at both sets of ages (ages 8 to 10, and ages 11 to 16) function in the same manner across different levels of SES.

ILTS sample. First, longitudinal mediation models for single word reading and reading comprehension models are presented. I tested if cognitive predictors of reading skill during preschool mediated the relation between SES and single word reading skills in Kindergarten, 1st Grade, 2nd Grade, and 4th Grade. For reading comprehension, mediators (oral listening comprehension and single word reading) were measured in 2nd Grade, and reading comprehension skills were assessed in 2nd Grade and 4th Grade. Models were performed separately for each grade (see Table 8). Mediators for the single word reading model were phonological awareness (PA), vocabulary (VOC), rapid serial naming (RSN), print knowledge (PK), and verbal learning memory (VLM). Second, moderation models are summarized, which tested if SES moderated the relationship between SES and each cognitive predictor of reading skill at different grades.

In accordance to the methodology of mediation, I first conducted individual regression models in order to establish statistically significant relationships between the independent variable (SES) and dependent variables (single word reading or reading comprehension), between independent variable and mediators, and between dependent variables and mediators (Baron & Kenny, 1986). All single regression models were significant. See Table 5 for the correlations among predictors, reading skill, and SES.

Mediation models for single word reading. Cognitive predictors (PA, VOC, and PK) in preschool fully mediated the relationship between SES and Kindergarten single word reading skills (total effects=.19, $p < .001$, total direct effects=.01, $p > .05$, total indirect

effects=.18, $p < .001$). Rapid serial naming and verbal learning memory did not provide significant indirect mediating effects (See Table 8). Rank order of the proportion mediated for each cognitive predictor was PK (44%), PA (32%), and VOC (13%). This ranking of cognitive predictors differed from the ranking of variance explained in a regression model without SES as an independent variable, which yielded the order of PK, PA, RSN, VOC, and VLM based on the standardized Betas (PK $\beta = .33$, $p < .001$; PA $\beta = .31$, $p < .001$; RSN $\beta = .14$, $p < .001$; VOC $\beta = .09$, $p < .05$; VLM $\beta = .05$, $p = .18$). These results supported the hypothesis that PA, PK, and VOC are stronger mediators of the relation between single word reading and SES than RSN and VLM.

In the later grades (1st Grade, 2nd Grade, and 4th Grade), cognitive predictors in preschool partially mediated the direct effect path between SES and single word reading but the direct effect path for each grade remained significant (1st Grade direct effect=.10, $p < .001$; 2nd Grade direct effect=.12, $p < .001$; 4th Grade direct effect=.11, $p < .001$; see Table 8). In 1st Grade, all cognitive predictors contributed significant mediating indirect effects (total indirect effects=.12, $p < .001$; see Table 8), with the rank order of proportion mediated as PK (34%), PA (24%), VOC (21%), VLM (13%), and RSN (8%). This ranking of cognitive predictors differed from the ranking of variance explained in a regression model without SES as an independent variable, which yielded the order of PK, RSN, PA, VLM, and VOC based on the standardized Betas (PK $\beta = .25$, $p < .001$; RSN $\beta = .20$, $p < .001$; PA $\beta = .18$, $p < .001$; VLM $\beta = .08$, $p = .06$; VOC $\beta = .08$, $p = .10$).

In 2nd Grade, PA, PK, RSN, and VLM significantly mediated the relationship between SES and single word reading (total indirect effects=.10, $p < .001$; see Table 8).

Vocabulary did not provide significant indirect mediating effects. Each cognitive predictor mediated the following proportions: PA (31%), PK (23%), VLM (19%), and RSN (12%), which differed from the ranking of variance explained in a regression model without SES as an independent variable. Based on the standardized Betas, the ranking order was RSN, PA, PK, VLM, and VOC (RSN $\beta=.24$, $p<.001$; PA $\beta=.17$, $p<.001$; PK $\beta=.13$, $p<.001$; VLM $\beta=.09$, $p<.05$; VOC $\beta=.03$, $p=.59$).

Finally, results of the 4th Grade mediation model were similar to those of 2nd Grade. PA, RAN, RSN, and VLM significantly mediated the direct effect path between SES and single word reading via indirect effects (total indirect effects=.09, $p<.001$; see Table 8). The indirect effect path of vocabulary was not significant. The proportion mediated by each cognitive predictor was PA (25%), VLM (21%), PK (21%), and RSN (14%). This ranking of cognitive predictors differed from the ranking of variance explained in a regression model without SES as an independent variable, which yielded the order of RSN, PA, PK, VLM, and VOC based on the standardized Betas (RSN $\beta=.26$, $p<.001$; PA $\beta=.13$, $p<.001$; PK $\beta=.12$, $p<.001$; VLM $\beta=.09$, $p<.05$; VOC $\beta=.04$, $p=.47$).

Overall, across all grades, PA and PK, on average, had higher indirect effects than RSN and VLM, which is not the same pattern expected by the ranking of variance explained in regression models without SES as an independent variable. These findings appear to support the hypothesis that PA and PK are stronger mediators in comparison to VLM and RSN; results did not support that VOC had higher indirect effects. However, including all cognitive predictors in a regression model might produce multicollinearity issues given that they are all significantly correlated with each other. An alternative option was to rank the

correlations of the cognitive predictors with single word reading at each grade (see Table 5 that presents all the correlations). The ranking of Kindergarten correlations (Kindergarten single word reading and each cognitive predictor) did not differ in order; however, the rankings of correlations for all other grades (1st Grade, 2nd Grade, and 4th Grade) differed.

Mediation models for reading comprehension. In 2nd Grade, vocabulary (proxy for oral listening comprehension) and single word reading skills partially mediated the relation between SES and reading comprehension (indirect effects=.22, $p < .001$). Total effects (direct and indirect) in the mediation model of reading comprehension and SES were estimated at .26 ($p < .001$), with a significant, direct effect path between SES and reading comprehension of .05 ($p > .01$) (see Table 9). The proportion of mediation contributed by single word reading (64%) was substantially higher than that of vocabulary (36%), which suggests that decoding skills in 2nd grade may be more susceptible to SES effects, which does not differ from the ranking of variance explained in a regression model where SES was not included ($RC = VOC + SWR$). Therefore, including SES in the model did not alter the order of variance explained by each cognitive predictor.

In 4th Grade, vocabulary and single word reading skills partially mediated the effects of SES on reading comprehension (total effects=.32, $p < .001$; total direct effects=.09, $p < .001$; total indirect effects=.23, $p < .001$; see Table 9). Vocabulary and single word reading skills mediated approximately the same proportion, 48% and 52%, respectively, which does not differ from the ranking of variance explained in a regression model where SES was not included ($RC = VOC + SWR$). Therefore, including SES in the model did not alter the order of variance explained by each cognitive predictor. In sum, in both 2nd Grade and 4th Grade,

predictors of the Simple View of Reading model partially mediated the effects of SES and reading comprehension, and the direct effect path between SES and reading comprehension remained significant.

Moderation models for single word reading. I examined if SES moderated the association of single word reading and cognitive predictors (PA, VOC, PK, RSN, and VLM) at each time point (Kindergarten, 1st Grade, 2nd Grade, and 4th Grade). Cognitive predictors were measured in preschool. Of the 20 moderation models ($SWR = Cognitive\ Predictor + SES + Interaction$), none of the interaction terms were significant. Results indicated that the profile of single word reading in Kindergarten, 1st Grade, 2nd Grade, and 4th Grade functions in the same manner across different levels of SES.

Moderation models for reading comprehension. SES did not moderate the relationship among reading comprehension and the predictors of the Simple View of Reading Model (vocabulary and single word reading). None of the interaction terms were significant ($RC = VOC + SWR + SES + VOC \times SES + SWR \times SES$), which suggested that the profile of reading comprehension skills in 2nd Grade and 4th does not differ as a function of SES.

As part of an exploratory set of analyses, I conducted the mediation and moderation models substituting SES with parental years of education or parental occupation. The variable of parental years of education was controlled for parental occupation effects, and vice-versa ($r=.51, p<.001$). Similarly to the results found in the CLDRC sample, parental years of education (corrected for parental occupation) yielded similar results to that of the SES moderation and mediation models. Parental occupation (corrected for parental years of

education) was not significantly correlated with single word reading or reading comprehension; therefore, analyses were not performed.

Question 2: SES Moderation of Growth Curves

The second question examined if SES moderated the starting values (intercepts) and growth (slopes) of single word reading and reading comprehension. Growth curve models were estimated for single word reading using the raw scores of the TOWRE Form A: Sight Word Efficiency and Phonemic Decoding Efficiency. Growth curve models were estimated for reading comprehension using the raw scores of the Woodcock Passage Comprehension subtest. Time points for each growth curve were: 1st Grade, 2nd Grade, and 4th Grade. The moderator, parental SES, was modeled as a continuous variable. Comparison of no-growth, linear, and quadratic models suggested that developmental changes in both variables were best described by both linear and quadratic rates of change.

Children's single word reading skills were best described by a quadratic curve that specified a significant age-related linear increase (linear slope=25.15, $p < .001$) that decelerated in magnitude over time (quadratic slope=-2.05, $p < .001$; see Table 10: Model 2) from 1st Grade through 4th Grade. SES moderated the starting values of single word reading skills in 1st Grade, in which for every one point increase of SES, the average participant showed a 7.16 point increase in SWR skills. SES did not moderate the linear or quadratic rate of change (see Figure 8; Table 10: Model 4). When controlling for single word reading scores in Kindergarten, moderating effects of SES on the intercept and linear or quadratic slopes were not significant (see Table 10: Model 5).

I conducted an additional set of growth curve analyses to explore the trajectory from Kindergarten to 4th Grade in order to examine the growth increase from Kindergarten to 1st Grade and how SES moderates such increase and its starting values (see Table 11). It was possible that the moderating effects of SES would be more significant from Kindergarten to 1st Grade considering the environmental variability of reading environments prior to academic schooling. From Kindergarten through 4th Grade, children's single word reading skills were also best described by a quadratic curve that specified a significant age-related increase (linear slope=40.27, $p < .001$), which decelerated in magnitude over time (quadratic slope=-3.51, $p < .001$; see Table 11: Model 2). The value of the initial starting value (intercept) is -9.64 because there were several participants with an unadjusted raw score of 0, which produced a floor effect; therefore, when fitting a best-fit equation to model the data, the intercept was modeled as negative. SES did not moderate the initial starting values of single word reading but moderated the linear and quadratic rates of change. For every one-point increase in SES, the rate of linear change in single word reading over age increased (became steeper) by 5.15 points for the average participant, which decelerated in magnitude (inverse U-shape curve) by -0.79 points (quadratic slope; see Figure 9; Table 11: Model 4). When controlling for print knowledge skills in preschool, moderating effects of SES on the linear and quadratic slopes were non-significant. SES appeared to moderate the intercept, but considering its negative value of -4.51, implies an autocorrective artifact due to the strong correlation between print knowledge and single word reading skills in Kindergarten (see Table 11: Model 5).

When comparing the moderating effects of SES in both single word reading models, results indicated that SES moderated the growth (slope) from Kindergarten through 4th Grade, but moderated the starting values (intercepts) from 1st Grade through 4th Grade. This pattern suggested that learning to read from Kindergarten to 1st Grade happens at a faster pace as SES increases. In addition, when print knowledge was controlled, the moderating effects of SES were accounted for in preschool print knowledge skills, which is a cognitive predictor that is less heritable and more environmentally driven than the other predictors (Byrne et al., 2002).

For reading comprehension skills, children's abilities were best described by a quadratic curve with an age-related increase (linear slope=8.46, $p<.001$) that decelerates in magnitude over time (quadratic slope=-0.72, $p<.001$) from 1st Grade through 4th Grade (see Table 12: Model 2). SES moderated the starting values of reading comprehension skills in 1st Grade, in which for every one point increase of SES, the average participant showed a 2.56 points increase in reading comprehension skills. SES did not moderate the linear or quadratic rate of change (see Figure 10, Table 12: Model 4). After controlling for vocabulary skills in preschool and single word reading skills in 1st Grade, the moderating effect of SES on the starting values of reading comprehension skills in 1st Grade was not significant (see Table 12: Model 5).

Question 3: Correlation Differences

The third question tested if the relationship between SES and reading comprehension was stronger than that of SES and single word reading at different stages of development (CLDRC: younger group versus older group; ILTS: 2nd Grade versus 4th

Grade). I hypothesized that the correlation between SES and reading comprehension would be significantly stronger because reading comprehension relies not only on decoding skills, but also oral listening comprehension skills (e.g., vocabulary). Correlations computed to address Question 1 were used for this set of analyses (see Tables 4, 5, and 13).

CLDRC sample. In the younger group (ages 8 to 10), Pearson correlations between SES and SWR and SES and RC were both the same (SWR and SES $r=.29$, $p<.01$; RC and SES $r=.29$, $p<.01$). The relationships between SES and SWR and SES and RC were not significantly different in the younger group (Hotelling/Williams Test $t[679]=0.0$, $p>.05$, $n=682$). In the older group (ages 11 to 16), Pearson correlations between SES and SWR ($r=.27$, $p<.01$) and SES and RC ($r=.35$, $p<.01$) were significantly different (Hotelling/Williams Test $t[740]=2.54$, $p<.01$, $n=743$). A stronger relationship between SES and RC in comparison to that of SES and SWR suggested that in the reading to learn stage, SES was more strongly correlated with RC than SWR.

ILTS sample. In 2nd Grade, the difference between the correlation of SES and SWR ($r=.22$, $p<.01$) and the correlation of SES and RC ($r=.26$, $p<.01$) was significant (Hotelling/Williams Test $t[923]=1.65$, $p<.05$, $n=926$), with the relationship between SES and RC being stronger than that of SES and SWR. I found the same pattern of results in 4th Grade (SES & 4th Grade RC $r=.32$, $p<.01$; SES & 4th Grade SWR $r=.20$, $p<.01$; Hotelling/Williams Test $t[923]=4.47$, $p<.001$, $n=926$). Although the correlations were significantly different in 2nd Grade, the pattern of results was quite similar to that of the CLDRC sample with the difference between correlations increasing over time as children transition from *learning to read* to *reading to learn* (see Table 13).

To further examine these correlation differences, I performed additional analyses to explore the distribution of reading outcomes in the tail ends of the distribution. Children with good reading outcomes were identified to have scores above 1 standard deviation from the mean, and children with poor reading outcomes were identified to have scores below 1 standard deviation from the mean. Three groups were created for each end of the distribution: 1) children with good (or poor) single word reading only, children with good (or poor) reading comprehension only, and children with both good (or poor) single word reading and reading comprehension. The parental SES variable was dichotomized using a median split to create a high-SES group and a low SES-group. For each sample (CLDRC older group, and ILTS 4th Grade), separate 2 x 3 (SES [high and low] x reading performance [RC only, SWR only, and Both SWR and RC]) chi-square analyses were conducted to compare the distribution of reading performance in the high end of the distribution and in the low end of the reading outcome distribution as a function of parental SES. SPSS (Version 21) was used to perform the analyses and one twin was selected at random.

For the CLDRC older group, both analyses were significant (High Reading Performance: $\chi^2[265]=16.19$, $df=3$, $p<.001$; Low Reading Performance: $\chi^2[265]=10.75$, $df=3$, $p<.05$). Across the three high reading outcome groups, the proportion of children from the low-SES group was significantly smaller than the proportion from the high-SES group (see Table 14). In the low reading performance chi-square, the proportions of children from the low-SES group with poor RC or poor RC and SWR were significantly larger than the proportion of children from the high-SES group. There were not proportion differences in terms of SWR deficits.

For the ILTS 4th Grade group, both analyses were also significant (High Reading Performance: $\chi^2[444]=16.81$, $df=3$, $p<.001$; Low Reading Performance: $\chi^2[444]=15.89$, $df=3$, $p<.001$). In the high reading performance chi-square, the proportions of children from the low-SES group with good RC or good RC and SWR were significantly smaller than the proportion of children from the high-SES group. No proportion differences were found in terms of good SWR skills (see Table 14). In the low reading performance chi-square, the proportions of children from the low-SES group with poor RC or poor RC and SWR were significantly larger than the proportion of children from the high-SES group. There were no proportion differences in terms of SWR deficits.

In sum, across both samples (CLDRC older group and ILTS 4th Grade), the proportions of children with poor RC or poor RC and SWR in the low end of the distribution was higher for children from lower SES backgrounds. In contrast, the proportion of children with good RC or good RC and SWR appeared to be lower for children from lower SES backgrounds.

Discussion

Overall Summary of Findings

It is well known that higher parental socioeconomic status (SES) predicts better child reading outcomes, but little work has been done to unpack this finding. Parental SES is an umbrella variable under which there are many possible factors that might influence a child's reading development, and reading is a multifaceted construct. The main overall questions addressed by this project were, 1) whether cognitive models of the two main reading outcomes, single word reading and reading comprehension, performed similarly across levels of parental SES, and 2) whether these two main reading outcomes, were equally influenced by parental SES. The current study predicted a differential relation between parental SES and both predictors and outcomes because of the known large relation between parental SES and child oral language development. A secondary question was what aspects of parental SES are most important for reading outcomes.

To summarize the results briefly (see Table 15), the relationship between parental SES and both reading predictors and outcomes was not completely uniform. In terms of outcomes, SES had a stronger relation to reading comprehension (RC) than to single word reading (SWR), especially at later ages. In terms of predictors, the relation between SES and

SWR was disproportionately mediated by two language skills, vocabulary (VOC) and phonological awareness (PA). With regard to the second question, not all aspects of SES are equally important for a child's reading outcomes; parental education accounts for nearly all of the SES effect and parental occupation contributes little if anything. These findings have implications for interventions aimed at improving reading outcomes in children from lower SES families, which will be discussed later.

First, I will summarize the results in more detail in relation to the three questions that motivated this study. The first broad question concerned whether cognitive predictors of single word reading and reading comprehension *mediated* the relation between SES and these two reading outcomes and whether SES *moderated* the relation between cognitive predictors and these two reading outcomes. The second question examined if SES *moderated* the starting values (intercepts) and growth (slopes) of single word reading and reading comprehension development, and whether any such moderation remained after controlling for early precursors of later reading skills. Finally, the third question tested if the relationship between SES and reading comprehension was stronger than that between SES and single word reading at later stages of reading development.

The Colorado Learning Disability Research Center (CLDRC) sample and the International Longitudinal Twin Study (ILTS) sample were employed to conduct these analyses. Parental occupation was coded using the International Socioeconomic Index coding system, which was a unique method for this study. SES was computed using a two-level factor analysis of parental occupation and years of education.

With regard to the first question, this study found that cognitive predictors only partially mediated the relationship between SES and the two reading outcomes, specifically single word reading in the CLRDC younger group and reading comprehension in the CLDRC older group. In the ILTS sample, cognitive predictors only partially mediated the direct effect path between SES and single word reading in 1st Grade, 2nd Grade, and 4th Grade, as well as, the direct effect path between SES and reading comprehension in 2nd Grade and 4th Grade. This partial mediation suggested that there are other factors aside from the cognitive predictors of reading skill that account for the relationship between SES and reading outcomes and demonstrates that there is not complete model equivalence across levels of parental SES. This finding of lack of complete model equivalence across SES contrasts with previous evidence for model equivalence for these two well-established models of reading outcomes across languages and countries. Moreover, the ranking of proportion mediated by each predictor differed from the ranking of variance explained by the predictors in these well-established models. Since the direct effect between SES and reading outcomes was not fully accounted for by the cognitive predictors of reading skills, we must ask what else about SES could be influencing reading outcomes.

Turning to the second aspect of the first question addressed by this study, *moderation*, there were only a few significant results and these were contrary to what was predicted. SES only moderated the relationship between phonological awareness (PA)/rapid serial naming (RSN)/processing speed (PS) and single word reading in the CLDRC younger group. No other interactions were statistically significant in the CLDRC older group or ILTS sample. The interaction terms, PA x SES, RSN x PS, and PS x SES, were in the opposite direction of

what was predicted. The interactions indicated that PA was a better predictor of single word reading as SES increased, and RSN and PS were better predictors of single word reading as SES decreased.

A possible explanation for the opposite findings was that the strength of the relationship between the cognitive predictor and single word reading differed as a function of level of reading development, with lower SES children being at an earlier stage of reading development. In order to test this alternative explanation for these results, I conducted a median split of age for the CLDRC younger group and compared the correlations between cognitive predictors and single word reading in each age subgroup. For this alternative explanation to be supported, the correlation between phonological awareness and single word reading should be greater in the older than younger subgroup, whereas the correlations between single word reading and rapid serial naming and processing speed, respectively, should exhibit an opposite pattern. However, this explanation was only supported for rapid serial naming; the correlations for phonological awareness and processing speed were not significantly different by age subgroup (see Table 16). Hence, the reason for the unpredicted patterns of moderation for phonological awareness and processing speed remain unexplained.

For the mediation and moderation models, analyses were also conducted substituting parental years of education (corrected for parental occupation) and then parental occupation (corrected for parental years of education) for SES, in order to address the secondary question of what aspect of parental SES was most important for child literacy outcomes. These residual parent education and occupation were justified by the fact that the raw

correlation between these two components of SES was only about .50, meaning that there was considerable non-overlapping variance in each component of SES. These analyses produced the novel result that parental years of education (corrected for parental occupation) yielded similar results to that of the SES moderation and mediation models, but that parental occupation (corrected for parental years of education) did not.

This finding suggests that parental education could act environmentally in the home to enhance the child's language and literacy development, whereas parent occupational status and consequent economic resources alone matter less for the child's and language and literacy development. Carrying the argument further, one could argue from these results that parental stimulation of language and literacy development matter more than more expensive neighborhoods and the better schools that go with such neighborhoods. But, since the parental education effect is confounded with genetic similarities between parents and children, evidence from genetically sensitive designs is needed. Adoption studies have found that adoptive parental SES accounts for roughly 5% of the variance in child reading outcomes (Petrill, Deater-Deckard, Schatschneider, & Davis, 2005; Wadsworth, Corley, Hewitt, & DeFries, 2001).

For Question 2 concerning growth curves, SES moderated the starting values (intercept) and growth (slopes) for single word reading and reading comprehension development. However, when controlling for early reading attainment skills (e.g., print knowledge, vocabulary, decoding skills), the SES effect was fully accounted by these early literacy skills. Regardless, the intercepts and slopes for the lower SES group were, on average, lower than those of the higher SES group indicating a main effect of SES, which is

well-documented in the literature (Bowey, 1995; Chall & Jacobs, 2003; Nation's Report Card, 2011; Raz & Bryant, 1990; Share et al., 1983). Exploratory analyses identified a pattern that suggested that learning to read from Kindergarten to 1st Grade happens at a faster pace as SES increases. However, when controlling for print knowledge skills in preschool, the moderating SES effects were completely accounted for by print knowledge. Print knowledge is a cognitive predictor that tends to be less heritable and more environmentally driven than the other cognitive predictors (Byrne et al., 2002).

In regards to Question 3 testing whether parental SES mattered more for reading comprehension than single word reading, especially at the *reading to learn* stage, I found that the relationship between SES and reading comprehension was stronger than that of SES and single word reading both in the CLDRC older group, and in the 2nd Grade and 4th Grade of the ILTS group. These results supported the hypothesis that reading comprehension, which is more dependent on broad language skills than single word reading, would be more influenced by parental SES than single word reading would be, especially in the *reading to learn* stage of reading development. The increase in strength of this relationship warrants further research in order to inform not only to better understand the SES effect, but also how to reduce such effects with remediation or preventative interventions in the earlier years of schooling.

Recent Literature

The current results supported previous findings that SES effects appear early on in reading development (Hecht et al., 2000) and not just as part of the '4th Grade slump' (Chall, et al., 1990). However, from 1st Grade through 4th Grade, the study of Hecht et al., (2000)

did not find differences between the relationships of reading comprehension or and parental SES. Correlations ranged from .40 to .44 for both reading outcomes. The current findings supported a similar pattern in the CLDRC younger group. However, the same pattern was not found for the CLDRC older group and the 4th Grade ILTS group. In these groups, the relationship between SES and reading comprehension was stronger than that between SES and single word reading. As children grow older and are *reading to learn*, language-based skills, such as vocabulary and oral listening comprehension, play a greater role in reading comprehension and hence the influence of parental SES increases. If this trend continues, the SES gap in reading comprehension should be greatest at the end of high school.

The relation between parental SES and child reading outcomes found in this study is similar to that found in extensive previous research. On average, the correlation between SES and academic achievement ranges from 0.299 (SD = .169, k = 207; Siring, 2005) to 0.343 (SD= .204, k= 219³; White, 1982), similar to the correlations in the current study for both reading outcomes. Even though the SES effect is robust with a medium effect size, it only accounts for roughly between 9 and 12 percent of the variance in child reading outcomes. Therefore, the SES effect is not as large as the heritabilities of single word reading and reading comprehension, which are between .70 and .80, indicating that genetic differences account for more than half of the variance in reading outcomes (Byrne et al., 2009; Byrne et al., 2007; Keenan, Betjemann, Wadsworth, DeFries, & Olson, 2006; Olson et al., 2001; Samuelsson et al., 2008). Of course this contrast makes the likely erroneous assumption and that the parental SES effect on reading outcomes is entirely environmental

³ Number of studies.

(a shared environmental effect), instead of being at least partly genetic. So, we next turn to this and other issues concerning how and when parental SES influences child reading development.

If a relation is found between adoptive parental SES and child reading outcomes in an adoption study, then we know that the SES effect is environmental because parents and their adopted children are genetically unrelated. Adoption studies have found that adoptive parental SES accounts for roughly 5% of the variance in child reading outcomes (Petrill et al., 2005; Wadsworth et al., 2001). This value is roughly half of what is found in non-adoptive families, as just discussed. So, about half the parental SES effects appear to be genuinely environmental.

The study of Petrill and colleagues (2005) clearly indicated that shared environmental influences decrease with increasing age in development. Heritability of individual differences in reading outcomes varies approximately from .48 to .80 across studies and increases with age. Shared environmental influences in reading outcomes range from zero to .25 (Byrne et al., 2009; Byrne et al., 2007; Hayiou-Thomas, Harlaar, Dale, & Plomin, 2010; Keenan, Betjemann, Wadsworth, DeFries, & Olson, 2006; Logan et al., 2013; Olson et al., 2001; Samuelsson et al., 2008). If a median value for shared environmental influences were to be .10, then the environmental portion of the SES effect of .05 from the adoption studies (Petrill et al., 2005; Wadsworth et al., 2001) would indicate that parental SES only accounts for half of shared environmental influences. The other half could be both bioenvironmental (e.g., prenatal factors) and sociocultural (e.g., parent and school effects not captured by SES). This is to say that if we could manage to make parental SES equivalent across all children,

there would be large heritable individual differences in reading outcomes and there would still be other unknown environmental influences accounting for roughly 5% of the variance. Although a small percentage, it would be valuable to identify what those other unknown environmental influences are. Then, if we somehow also manage to make those equal across all children, then heritable individual differences in reading outcomes would account for all the variance, with heritability approaching 1.0. The environments would be equal among all children.

Interpretation of Findings

How might parental SES, acting environmentally, influence child reading development? One logical possibility is that SES only strongly contributes to the children's environment *before* they enter school and that its effect disappears once they are ensconced in a more homogeneous literacy environment. If this were the case, we would not find mediating effects of parental SES after Kindergarten, which is clearly not the case. Another less extreme related logical possibility is that the SES effect decreases as children progress through formal education, again because of the homogenizing effects of public education. Again, the current results do not support this possibility. Instead, the current study found that SES effects on reading development are present before schooling begins, are only somewhat diminished in Kindergarten, persist through high school for single word reading, and actually increase for reading comprehension. Since SES's effects are present all throughout a child's reading development, we need to try to identify which correlates of parental SES are most important for these effects on child literacy.

Knowing that parental SES combines multiple factors, it is then natural to ask, which of these factors affect reading development. I found that in terms of reading development, parental education can be used as a proxy of SES because it yields more similar results to SES than occupation alone. The social capital part of parental SES seems to matter more than the economic component. Perhaps a house in the right neighborhood matters less than a house with the right books.

To tease apart the effects of parental education, I conducted an exploratory analysis in both samples to see if there were differences in the strength of the correlations between father's and mother's education and child reading outcomes. If one assumes that mothers spend more time with their child than fathers, maternal education would be more highly correlated to reading outcomes than paternal education. In contrast, similar correlations would suggest the same contributions of genetic and environmental factors from each parent. Results from the exploratory analyses were partially supportive of a greater maternal effect. Mother's years of education (controlled for father's years of education and parental occupations) and father's years of education (controlled for mother's years of education and parental occupations) were computed for both samples. From the correlations between RC or SWR and father's or mother's years of education in the CLDRC younger group and older group (Younger Group n=530: Father's years of education RC $r=.13$, $p<.01$ & SWR $r=.15$, $p<.01$; Mother's years of education RC $r=.19$, $p<.01$ & SWR $r=.17$, $p<.01$; Older Group n=468: Father's years of education RC $r=.17$, $p<.01$ & SWR $r=.11$, $p<.05$; Mother's years of education RC $r=.14$, $p<.01$; SWR $r=.13$, $p<.01$), only the reading comprehension correlations in the younger group were statistically different (Hotelling/Williams Test

$t[527]=1.75$ $p<.05$, $n=530$). In the ILTS sample, correlations for both reading outcomes in 4th Grade (4th Grade ILTS $n=791$: Mother's years of education RC $r=.13$, $p<.05$, & SWR $r=.10$, $p<.05$; Father's years of education RC $r=.14$, $p<.05$, & SWR $r=.09$, $p>.05$) were not statistically different. Therefore, further research is necessary to unpack what aspects of parental education as part of the SES effect influences reading development.

Future Research and Limitations

From the results of this study and the previous discussion, we can conclude that maternal education partly acts environmentally to influence child reading outcomes, a finding that should guide intervention efforts aimed at trying to close the achievement gap between higher and lower SES backgrounds. These results suggest that targeting vocabulary skills, listening comprehension, and phonological awareness early on might lead to better outcomes in reading development. Therefore, interventions in early years of schooling should not only teach decoding skills with well-established phonics curriculum, but also enrich their vocabularies and develop comprehension skills using methods such as the one developed by Anne Brown and colleagues (Baker & Brown, 1984; Brown, 1980). These methods actively engage children's comprehension by asking them questions about the text and asking them to summarize the story. Since the current research found that the relation between SES and single word reading were disproportionately mediated by two language skills, vocabulary and phonological awareness, as the Common Core is implemented the needs of students from lower SES backgrounds cannot be pushed aside so that the curriculum can align more closely with the needs of students from higher SES backgrounds.

The current research used some of the largest and most comprehensive current datasets to address the questions of interest, but there were limitations nonetheless. The measures of the two samples (CLDRC and ILTS) were not completely equivalent, but similar constructs were measured in each sample. The age range for the CLDRC sample was wider than that of the ILTS sample. Modifications to account for these measure differences included creating factor scores of the constructs (e.g., PA, SWR, RSN, etc.) instead of computing averages or composite scores. Theoretical models and previous research conducted in each of the samples supported the measures that were combined for each factor score. The CLDRC sample was split into two groups (younger group: ages 8 to 10, and older group: ages 11 to 16) in order to better resemble the ILTS sample. The CLDRC sample is overselected for children with dyslexia and Attention Deficit Hyperactivity Disorder (ADHD), which is a limitation. However, several standardized tests administered in this sample have an approximate normal distribution with a mean standard score and standard deviation close to those of the norming sample. In addition, the current research demonstrated similar results in the ILTS sample, which is not overselected for neurodevelopmental disabilities.

Another limitation is that some of reading comprehension measures was highly dependent on decoding instead of emphasizing listening comprehension skills, especially the Passage Comprehension subtest from the Woodcock Reading Mastery Test-Revised (Woodcock, 1987). For reading comprehension measures, the ILTS sample ranged from 1st Grade through 4th Grade, which limits the results of reading comprehension development to children younger than 11 years of age. It is possible that SES might moderate the trajectory

of reading comprehension in later stages of reading development. Therefore, future research needs to address these limitations in order to better understand reading comprehension in middle school and high school, and how it relates to SES and other environmental factors.

A future reading comprehension study should combine both more accurate assessment measures and a longitudinal sample with a wider age range. This research design would assess if SES moderates the trajectory (intercepts and slopes) of reading comprehension development from 4th Grade through middle school and high school. Do children from lower SES backgrounds fall further behind in later grades? In later grades, high-order language-based skills (e.g., complex vocabulary, inferential reasoning, etc.) tend to become even more important than single word decoding skills.

Perhaps the biggest limitation of the current study was the inability to examine all the correlates of parental SES that might be relevant for a child's reading development. An ideal study would directly measure pre-school language and literacy stimulation in the homes of both biological and adoptive families, and test the relations between that stimulation and child literacy outcomes. Other future research needs to examine if other factors of SES, such as nutrition, access to healthcare, and neighborhoods, mediate the relationship between SES and reading outcomes. Therefore, it is important to continue to disentangle SES in order to further our understanding of the achievement gap so as to improve the outcome of future readers.

References

- Adams, W., & Sheslow, D. (1990). WRAML manual. *Wilmington, DE: Jastak Associates.*
- Allison, C., Robinson, E., Hennington, H. & Bettagere, R. (2011). Performance of low income African American boys and girls on the PPVT-4: A comparison of receptive vocabulary. *Contemporary Issues in Communication Science and Disorders, 38*, 20-25.
- American Psychiatric Association (2000). *Diagnostic and statistical manual of mental Disorders, 4th ed.-TR.* Washington (DC): American Psychiatric Association.
- Appel, K., & Thomas-Tate, S. (2009). Morphological awareness skills of fourth-grade African American students. *Language, Speech, and Hearing Services in Schools, 40*, 312-324.
- Applebee, A. N., Langer, J. A., & Mullis, I. V. (1988). Who reads best. *Factors related to reading achievement in grades, 3*(7), 11.
- August, D. E., & Shanahan, T. (2006). *Developing literacy in second language learners: Report of the National Literacy Panel on Language-Minority Children and Youth.* Mahwah, NJ: Erlbaum.
- Baker, L., & Brown, A. L. (1984). Metacognitive skills and reading. *Handbook of reading research, 1*, 353-394.

- Barnes, M.A., & Dennis, M. (1996). Reading comprehension deficits arise from diverse source: Evidence from readers with and without developmental brain pathology. In C. Cornoldi and J. Oakhill (Eds.), *Reading Comprehension Difficulties: Processes and Intervention* (pp. 251-278.). Mahwah, NJ: Erlbaum.
- Barnes, M.A., Dennis, M., & Haefele-Kalvaitis, J. (1996). The effects of knowledge availability and knowledge accessibility on coherence and elaborative inferencing in children from six to fifteen years of age. *Journal of Experimental Child Psychology*, *61*, 216-241.
- Barnett, W. S. (1995). Long-term effects of early childhood programs on cognitive and school outcomes. In *The Future of Children*, *5*(3), (pp. 25–50). Los Altos, CA: The David and Lucile Packard Foundation.
- Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of personality and social psychology*, *51*(6), 1173.
- Boetsch, E. A., Green, P. A., & Pennington, B. F. (1996). Psychosocial correlates of dyslexia across the life span. *Development and Psychopathology*, *8*, 539-562.
- Bornstein, M. H., & Bradley, R. H. (2003). *Socioeconomic status, parenting, and child development*. Psychology Press.
- Bowey, J. A. (1995). Socioeconomic status differences in preschool phonological sensitivity and first-grade reading achievement. *Journal of Educational Psychology*, *87*(3), 476.
- Brooks-Gunn, J., Duncan, G. J., & Aber, J. L. (Eds.). (1997). *Neighborhood poverty: Context and consequences for children* (Vol. 1). Russell Sage Foundation Publications.

- Brown, A. L. (1980). Metacognitive development and reading. *Theoretical issues in reading comprehension*, 453-481.
- Bus, A., Van Ijzendoorn, M., & Pelligrini, A. (1995). Joint book reading makes for success in learning to read: A meta-analysis on intergenerational transmission of literacy. *Review of Educational Research*, 65, 1–21.
- Byrne, B., Coventry, W. L., Olson, R. K., Hulslander, J., Wadsworth, S., DeFries, J. C., et al. (2008). A behavior-genetic analysis of orthographic learning, spelling, and decoding. *Journal of Research in Reading*, 31, 8-21.
- Byrne, B., Coventry, W. L., Olson, R. K., Samuelsson, S., Corley, R., Willcutt, E. G., ... & DeFries, J. C. (2009). Genetic and environmental influences on aspects of literacy and language in early childhood: Continuity and change from preschool to Grade 2. *Journal of Neurolinguistics*, 22(3), 219-236.
- Byrne, B., Delaland, C., Fielding-Barnsley, R., Quain, P., Samuelsson, S., Høien, T., ... & Olson, R. K. (2002). Longitudinal twin study of early reading development in three countries: Preliminary results. *Annals of dyslexia*, 52(1), 47-73.
- Byrne, B., Olson, R. K., Samuelsson, S., Wadsworth, S., Corley, R., DeFries, J. C., & Willcutt, E. (2006). Genetic and environmental influences on early literacy. *Journal of Research in Reading*, 29(1), 33-49.
- Byrne, B., Samuelsson, S., Wadsworth, S., Hulslander, J., Corley, R., DeFries, J. C., ... & Olson, R. K. (2007). Longitudinal twin study of early literacy development: Preschool through Grade 1. *Reading and Writing*, 20(1-2), 77-102.

- Caldas, S. J., & Bankston, C. (1997). Effect of school population socioeconomic status on Individual academic achievement. *The Journal of Educational Research*, 90(5), 269-277.
- Capps, R., Fix, M., Murray, J., Ost, J. Passel, J. S., & Herwanto, S. (2005). *The new demography of America's schools: Immigration and the No Child Left Behind Act* (Research report). Washington, DC: Urban Institute.
- Caravolas, M., Volin, J., & Hulme, C. (2005). Phoneme awareness is a key component of alphabetic literacy skills in consistent and inconsistent orthographies: Evidence from Czech and English children. *Journal of Experimental Child Psychology*, 92, 107-139.
- Cardoso-Martins, C., Peterson, R., Olson, R., & Pennington, B. (2009). Component reading skills in Down syndrome. *Reading and writing*, 22(3), 277-292.
- Case, R., Kurland, D. M., & Goldberg, J. (1982). Operational efficiency and the growth of short-term memory span. *Journal of experimental child psychology*, 33(3), 386-404.
- Catts, H., Fey, M., Zhang, X., & Tomblin, J.B. (1999). Language basis of reading and reading disabilities: Evidence from a longitudinal study. *Scientific Studies of Reading*, 3, 331-361.
- Chall, J. S. (1983). Literacy: Trends and explanations. *Educational Researcher*, 3-8.
- Chall, J. S., & Jacobs, V. A. (2003). The classic study on poor children's fourth-grade slump. *American Educator*, 27. Retrieved from <http://www.aft.org/newspubs/periodicals/ae/spring2003/hirschsclassic.cfm>.
- Chall, J. S., Jacobs, V., & Baldwin, L. (1990). *The reading crisis: Why poor children fall behind*. Cambridge, MA: Harvard University Press.
- Clay, M. (1975). *The early detection of reading difficulties: A diagnostic survey*. Auckland, New Zealand: Heinemann.

- Clotfelter, C., Ladd, H. F., Vigdor, J., & Wheeler, J. (2007). High poverty schools and the distribution of teachers and principals. *North Carolina Law Review*, 85, 1345–1379.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Condron, D. J., & Roscigno, V. J. (2003). Disparities within: Unequal spending and achievement in an urban school district. *Sociology of Education*, 76, 18–36.
- Cosentino de Cohen, C., Deterding, N., & Chu Clewell, B. (2005). *Who's left behind? Immigrant children in high and low LEP schools* (Policy Report). Washington, DC: Urban Institute.
- Craig, H. K., Zhang, L., Hensel, S. L., & Quinn, E. J. (2009). African American English-speaking students: An examination of the relationship between dialect shifting and reading outcomes. *Journal of Speech, Language, and Hearing Research*, 52, 839-855.
- ^aChristopher, M. E., Hulslander, J., Byrne, B., Samuelsson, S., Keenan, J. M., Pennington, B., ... & Olson, R. K. (2013). Modeling the etiology of individual differences in early reading development: Evidence for strong genetic influences. *Scientific Studies of Reading*, 17(5), 350-368.
- ^bChristopher, M. E., Hulslander, J., Byrne, B., Samuelsson, S., Keenan, J. M., Pennington, B., ... & Olson, R. K. (2013). The genetic and environmental etiologies of individual differences in early reading growth in Australia, the United States, and Scandinavia. *Journal of experimental child psychology*, 115(3), 453-467.

- Christopher, M. E., Miyake, A., Keenan, J. M., Pennington, B., DeFries, J. C., Wadsworth, S. J., ... & Olson, R. K. (2012). Predicting word reading and comprehension with executive function and speed measures across development: A latent variable analysis. *Journal of Experimental Psychology: General*, *141*(3), 470.
- Curtis, M.E. (1980). Development of components of reading skill. *Journal of Educational Psychology*, *72*, 656-669.
- Decker, S. N. (1989). Cognitive processing rates among disabled and normal reading young adults: A nine year follow-up study. *Reading and Writing*, *1*(2), 123-134.
- DeFries, J. C., Filipek, P. A., Fulker, D. W., Olson, R. K., Pennington, B. F., Smith, S. D., & Wise, B. W. (1997). Colorado Learning Disabilities Research Center. *Learning Disabilities: A Multidisciplinary Journal*, *8*, 7-19.
- DeFries, J. C., Singer, S. M., Foch, T. T., & Lewitter, F. I. (1978). Familial nature of reading disability. *British Journal of Psychiatry*, *132*, 361-367.
- Dehaene, S., Pegado, F., Braga, L. W., Ventura, P., Filho, G. N., Jobert, A.,...Cohen, L. (2010). How learning to read changes the cortical Networks for vision and language. *Science*, *330*, 1359-1364.
- Denckla, M. B., & Rudel, R. G. (1974). Rapid "automatized" naming of pictured objects, colors, letters and numbers by normal children. *Cortex*, *10*(2), 186-202.
- Denckla, M. B., & Rudel, R. G. (1976). Rapid 'automatized' naming (RAN): Dyslexia differentiated from other learning disabilities. *Neuropsychologia*, *14*(4), 471-479.
- Dickinson, D.K., & Tabors, P.O. (Eds.). (2001). *Building literacy with language: Young children learning at home and school*. Baltimore, MD: Brookes.

- Dohrenwend, B. P., Levay, I., Shrout, P. E., Schwartz, S., Naveh, G., Link, B. G., ... & Stueve, A. (1992). Socioeconomic status and psychiatric disorders: the causation-selection issue. *Science*, *255*(5047), 946-952.
- Duncan, G., Brooks-Gunn, J., & Klebanov, E. (1994). Economic deprivation and early childhood development. *Child Development*, *65*, 296-318.
- Duncan, O. D., Featherman, D. L., & Duncan, B. (1972). Socioeconomic background and achievement. New York: Seminar Press.
- Dunn, L.M., & Dunn, M. (1997). *Peabody Picture Vocabulary Test-III*. Circle Pines: MN: American Guidance Service.
- Dunn, L. M., & Dunn, D. M. (2007). *Peabody Picture Vocabulary Test, Fourth Edition*. Minneapolis, MN: NCS Pearson.
- Dunn, L. M., & Markwardt, F. C. (1970). Peabody individual achievement test. Circle Pines, MN: American Guidance Service.
- Elliott, J. G., & Gibbs, S. (2008). Does dyslexia exist? *Journal of Philosophy of Education*, *42*, 475-495.
- Elwér, Å., Keenan, J. M., Olson, R. K., Byrne, B., & Samuelsson, S. (2013). Longitudinal stability and predictors of poor oral comprehenders and poor decoders. *Journal of experimental child psychology*.
- Fisher, J. P., & Glennister, J. M. (1992). *The hundred pictures naming test*. Hawthorn, Australia: Australian Council for Educational Research.
- Ekstrom, R. B., French, J. W., & Prince, L. A. (1963). Kit of reference tests for cognitive factors. *Educational Testing Services, Princeton*.

- Friend, A., DeFries, J. C., & Olson, R. K. (2008). Parental education moderates genetic influences on reading disability. *Psychological Science, 19*(11), 1124-1130.
- Friend, A., DeFries, J. C., Olson, R. K., Pennington, B., Haarlar, N., Byrne, B.,... Keenan, J. M. (2009). Heritability of high reading ability and its interaction with parental education. *Behavior Genetics, 39*, 427-436.
- Ganzeboom, H. B., De Graaf, P. M., & Treiman, D. J. (1992). A standard international socio-economic index of occupational status. *Social science research, 21*(1), 1-56.
- Ganzeboom, H. B., & Treiman, D. J. (1996). Internationally comparable measures of occupational status for the 1988 International Standard Classification of Occupations. *Social science research, 25*(3), 201-239.
- Gathercole, S. E., Willis, C. S., Baddeley, A. D., & Emslie, H. (1994). The children's test of nonword repetition: A test of phonological working memory. *Memory, 2*(2), 103-127.
- Gayán, J., & Olson, R. K. (2001). Genetic and environmental influences on orthographic and phonological skills in children with reading disabilities. *Developmental Neuropsychology, 20*(2), 483-507.
- Gilger, J., Pennington, B., & DeFries, J. (1991). Risk for reading disability as a function of family history in three family studies. *Reading and Writing: An Interdisciplinary Journal, 3*, 205-217.
- Golden, C. J. (1978). *Stroop color and word test: A manual for clinical and experimental uses*. Chicago, IL: Skoelting.
- Gordon, M. T. (1976). A different view of the IQ-Achievement gap. *Sociology of Education, 49*, 4- 11.

- Goswami, U., Wang, H. L. S., Cruz, A., Fosker, T., Mead, N., & Huss, M. (2011). Language-universal sensory deficits in developmental dyslexia: English, Spanish, and Chinese. *Journal of Cognitive Neuroscience, 23*, 325–37.
- Gottfried, A. W. (1985). Measures of socioeconomic status in child development research: Data and recommendations. *Merrill-Palmer Quarterly (1982-), 85-92*.
- Gough, P. B., & Tunmer, W. E. (1986). Decoding, reading, and reading disability. *Remedial and Special Education, 7*, 6–10.
- Green, L. J. (2002). *African American English: A linguistic introduction*. Cambridge, England: Cambridge University Press.
- Hanley, J R. (2005). Learning to read in Chinese . In M. J. Snowling & C. Hulme (Eds.), *The science of reading: a handbook* (316–35). Oxford: Blackwell Publishing.
- Hart, B., & Risley, T. R. (1995). *Meaningful differences in the everyday experience of young American children*. Baltimore: P. H. Brookes.
- Hart, S. A., Petrill, S. A., DeThorne, L. S., Deater-Deckard, K., Thompson, L. A., Schatschneider, C., & Cutting, L. E. (2009). Environmental influences on the longitudinal covariance of expressive vocabulary: measuring the home literacy environment in a genetically sensitive design. *Journal of Child Psychology and Psychiatry, 50*(8), 911-919.
- Hauser, R. M. (1994). Measuring socioeconomic status in studies of child development. *Child Development, 65*, 1541–1545.
- Haycock, K., & Hanushek, E. A. (2010). An effective teacher in every classroom. *Education Next, 10*, 46–52.

- Hayiou-Thomas, M. E., Harlaar, N., Dale, P. S., & Plomin, R. (2010). Preschool speech, language skills, and reading at 7, 9, and 10 years: Etiology of the relationship. *Journal of Speech, Language, and Hearing Research, 53*(2), 311-332.
- Hecht, S. A., Burgess, S. R., Torgesen, J. K., Wagner, R. K., & Rashotte, C. A. (2000). Explaining social class differences in growth of reading skills from beginning kindergarten through fourth-grade: The role of phonological awareness, rate of access, and print knowledge. *Reading and Writing: An Interdisciplinary Journal, 12*, 99–127.
- Hess, R., & Holloway, S. (1984). Family and school as educational institutions. In R. D. Parke (Ed.), *Review of child development research: Vol. 7* (pp. 179–222.). Chicago: University of Chicago Press.
- Hoff, E. (2003). The specificity of environmental influence: Socioeconomic status affects early vocabulary development via maternal speech. *Child Development, 74*, 1368–1378.
- Hollingshead, A. B. (1975). Four factor index of social status.
- Hoover, W. A., & Gough, P. B. (1990). The simple view of reading. *Reading & Writing: An Interdisciplinary Journal, 2*, 127–160.
- Hu, W., Ling, Lee H., Zhang, Q., Liu, T., Bo Geng, L., Seghier, M.L., ... Price, C. J. (2010). Developmental dyslexia in Chinese and English populations: dissociating the effect of dyslexia from language differences. *Brain, 133*, 1694–1706.
- Jensen, A. R. (1969). How much can we boost IQ and scholastic achievement? *Harvard Educational Review, 39*, 1–12

- Kagan, S. L., Moore, E., & Bredekamp, S. (1995). *Reconsidering children's early development and learning: Toward common views and vocabulary*. Washington, DC: National Education Goals Panel.
- Kaplan, E., Goodglass, H., & Weintraub, S. (1983). *Boston Naming Test*. Philadelphia: Lea and Febiger.
- Keating, P. A., & Manis, F. *The keating-manis phoneme deletion test*.
- Keenan, J. M., Betjemann, R. S., & Olson, R.K. (2008). Reading comprehension tests vary in the skills they assess: Differential dependence on decoding and oral comprehension. *Scientific Studies of Reading, 12*, 281 – 300.
- Keenan, J. M., Betjemann, R. S., Wadsworth, S. J., DeFries, J. C., & Olson, R. K. (2006). Genetic and environmental influences on reading and listening comprehension. *Journal of Research in Reading, 29*(1), 75-91.
- Kieffer, M.J. (2008). Catching poverty, up or falling behind? Initial English proficiency, concentrated and the reading growth of language minority learners in the United States. *Journal of Educational Psychology, 100*(4), 851–868.
- Kieffer, M. J. (2012). Before and after third grade: Longitudinal evidence for the shifting role of socioeconomic status in reading growth. *Reading and Writing, 25*, 1725–1746.
- Kline, R. B. (2005). *Principles and practice of structural equation modeling*. New York: Guilford Press.
- Klingner, J. K., Artiles, A. J., & Mendez Barletta, L. (2006). English Language Learners who struggle with reading: Language acquisition or LD? *Journal of Learning Disabilities, 39*, 108-128.

- Krasowicz-Kupis, G., Borkowska, A. R., & Pietras, I. (2009). Rapid automatized naming, phonology and dyslexia in Polish children. *Medical Science Monitor, 15*, CR460–CR9.
- Kohn, R., Dohrenwend, B. P., & Mirotznik, J. (1998). Epidemiological Findings on Selected Psychiatric Disorders in the. *Adversity, stress, and psychopathology*, 235.
- Korat, O., Klein, P., & Drori-Segal, O. (2007). Maternal mediation in book reading, home literacy environment, and children's emergent literacy: A comparison between two social groups. *Reading and Writing: An International Journal, 20*, 361–398.
- Kuntsi, J., Stevenson, J., Oosterlaan, J., & Sonuga-Barke, E. J. (2001). Test-retest reliability of a new delay aversion task and executive function measures. *British Journal of Developmental Psychology, 19*(3), 339-348.
- Landerl, K., & Wimmer, H. (2008). Development of word reading fluency and spelling in a consistent orthography: An 8-year follow-up. *Journal of Educational Psychology, 100*, 150–161.
- Landerl, K., Wimmer, H., & Frith, U. (1997). The impact of orthographic consistency on dyslexia: A German-English comparison. *Cognition, 63*, 315–334.
- Lauren, L., & Caldwell, J. (2001). *Qualitative Reading Inventory - 3*. New York: Addison Wesley Longman, Inc.
- Leach, J. M., Scarborough, H. S., & Rescorla, L. (2003). Late-emerging reading disabilities. *Journal of Educational Psychology, 95*, 211-224.

- Lesaux, N. K. (with Koda, K., Siegel, L. S., & Shanahan, T.). (2006). Development of literacy. In D. August & T. Shanahan (Eds.), *Developing literacy in second-language learners: Report of the National Literacy Panel on Language-Minority Children and Youth* (pp. 75–122). Mahwah, NJ: Erlbaum.
- Leslie, L., & Caldwell, J. S. (2001). Qualitative Reading Inventory (QRI).
- Lindamood, C. H., & Lindamood, P. C. (1979). *Lindamood test of auditory conceptualization*: Pearson.
- Logan, J. A., Hart, S. A., Cutting, L., Deater-Deckard, K., Schatschneider, C., & Petrill, S. (2013). Reading development in young children: Genetic and environmental influences. *Child development, 84*(6), 2131-2144.
- MacGinitie, W., MacGinitie, R., Maria, K., & Dreyer, L. (2002). *Gates-MacGinitie Reading Tests, 4th Edition Technical Report*. Itasca, IL: Riverside.
- Markwardt, F. C., Jr. (1989). *Peabody Individual Achievement Test—Revised*. Circle Pines, MN: American Guidance Service.
- McCarthy, J. J., & Kirk, S. A. (1961). *The Illinois test of psycholinguistic abilities*. Urbana, IL: University of Illinois Press.
- McCormick, C. E., Signer, S. B., & Duncan, S. (1994). Kindergarten predictors of first-grade reading achievement: A regular classroom sample. *Psychological reports, 74*(2), 403-407.
- McGrath, L. M., Pennington, B. F., Shanahan, M. A., Santerre–Lemmon, L. E., Barnard, H. D., Willcutt, E. G., & Olson, R. K. (2011). A multiple deficit model of reading disability and attention deficit/hyperactivity disorder: Searching for shared cognitive deficits. *Journal of Child Psychology and Psychiatry, 52*, 547–557.

- Nation, K. (1999). Reading skills in hyperlexia: a developmental perspective. *Psychological bulletin*, 125(3), 338.
- Nation, K., & Norbury, C. F. (2005). Why reading comprehension fails: Insights from developmental disorders. *Topics in Language Disorders*, 25(1), 21-32.
- Nation's Report Card (2011). *Reading 2011: National assessment of educational progress at grades 4 and 8* (NCES 2012-457). U.S. Department of Education.
- National Institute for Literacy (1997). *Facts sheet: Family literacy*. Washington, DC: Author.
- National Research Council. (1998). *Preventing reading difficulties in young children*. Washington, DC: National Academy Press.
- Newcomer, P. (1999). *Standardized reading inventory, second edition (SRI-2)*. Austin, TX: Pro-Ed.
- Nisbett, R. E. (2009). *Intelligence and how to get it: Why schools and cultures matter*. New York: W. W. Norton & Company, Inc.
- Noble, K. G., Farah, M. J., & McCandliss, B. D. (2006). Socioeconomic background modulates cognition–achievement relationships in reading. *Cognitive Development*, 21(3), 349-368.
- Noble, K., Wolmetz, M., Ochs, L., Farah, M., & McCandliss, B. (2006). Brain–behavior relationships in reading acquisition are modulated by socioeconomic factors. *Developmental Science*, 9, 642–654.
- Olson, R., Forsberg, H., Wise, B., & Rack, J. (1994). Measurement of word recognition, orthographic, and phonological skills. In G.R. Lyon (Ed.) *Frames of reference for the assessment of learning disabilities: New views on measurement issues* (pp. 243-277). Baltimore: Paul H. Brookes Publishing Co.

- Olson, R. K., Keenan, J. M., Byrne, B., Samuelsson, S., Coventry, W. L., Corley, R., ... & Hulslander, J. (2011). Genetic and environmental influences on vocabulary and reading development. *Scientific Studies of Reading, 15*(1), 26-46.
- Olson, R., Wise, B., Conners, F., Rack, J., & Fulker, D. (1989). Specific deficits in component reading and language skills Genetic and environmental influences. *Journal of learning disabilities, 22*(6), 339-348.
- Papadopoulos, T. C., Georgiou, G.K., & Kendeou, P. (2009). Investigating the double-deficit hypothesis in Greek: findings from a longitudinal study. *Journal of Learning Disabilities, 42*, 528–47.
- Paulesu, E., Demonet, J.F., Fazio, F., McCrory, E., Chanoine, V., Brunswick, N., Cappa, S.F., Cossu, G., Habib, M., Frith, C.D., & Frith, U. (2001). Dyslexia; cultural diversity and biological unity. *Science, 291*, 2165–2167.
- Pennington, B. F., Santerre-Lemmon, L., Rosenberg, J., MacDonald, B., Boada, R., Friend, A., ... & Olson, R. K. (2012). Individual prediction of dyslexia by single versus multiple deficit models. *Journal of abnormal psychology, 121*(1), 212-224.
- Peterson, R. L., & Pennington, B. F. (2012). Seminar: Developmental dyslexia. *The Lancet, 379*, 1997-2007.
- Petrill, S. A., Deater-Deckard, K., Schatschneider, C., & Davis, C. (2005). Measured environmental influences on early reading: Evidence from an adoption study. *Scientific Studies of Reading, 9*(3), 237-259.

- Petrill, S. A., Hart, S. A., Harlaar, N., Logan, J., Justice, L. M., Schatschneider, C., ... & Cutting, L. (2010). Genetic and environmental influences on the growth of early reading skills. *Journal of Child Psychology and Psychiatry*, 51(6), 660-667.
- Price, C.J., Moore, C.J., Humphreys, G.W., & Wise, R.J.S. (1997). Segregating semantic from phonological processes during reading. *Journal of Cognitive Neuroscience*, 9 (6), 727-733.
- Rack, J. P., Snowling, M. J., & Olson, R. K. (1992). The nonword reading deficit in developmental dyslexia: A review. *Reading Research Quarterly*, 29-53.
- Ramseyer, G. C. (1979). Testing the difference between dependent correlations using the Fisher Z. *The Journal of Experimental Educational*, 307-310.
- Raz, I. S., & Bryant, P. E. (1990). Social background, phonological awareness, and children's reading. *British Journal of Developmental Psychology*, 8, 209-225.
- Reardon, S. F. (2011). The widening academic achievement gap between the rich and the poor: New evidence and possible explanations. *Whither opportunity*, 91-116.
- Reitan, R. M. (1971). Trail making test results for normal and brain-damaged children. *Perceptual and Motor Skills*, 33(575-581).
- Rickford, J. R. (1999). *African American vernacular English: Features, evolution, educational implications*. Malden, MA: Blackwell.
- Roberts, G., Mohammed, S. S., & Vaughn, S. (2010). Reading achievement across three language groups: Growth estimates for overall reading and reading subskills obtained with the early childhood longitudinal survey. *Journal of Educational Psychology*, 102, 668-686.

- Rothstein, R. (2004). *Class and Schools: Using Social, Economic, and Educational Reform to Close the Achievement Gap*. Washington, DC: Economy Policy Institute.
- Roza, M., & Hill, P. T. (2004). How within-district spending inequities help some schools to fail. *Brookings Paper on Education Policy*, 7, 201–227.
- Rumberger, R. W., & Palardy, G. J. (2005). Does segregation still matter? The impact of student composition on academic achievement in high school. *Teachers College Record*, 107, 1999–2045.
- Sameroff, A. J., Seifer, R., & Bartko, W. T. (1997). Environmental perspectives on adaptation during childhood and adolescence. In S. Luther, J. Burack, D. Cicchetti, & J. Wiesz (Eds.), *Developmental psychopathology: Perspectives on adjustment, risk, and disorder* (pp. 507–526). New York: Cambridge University Press.
- Samuelsson, S., Byrne, B., Olson, R. K., Hulslander, J., Wadsworth, S., Corley, R., ... & DeFries, J. C. (2008). Response to early literacy instruction in the United States, Australia, and Scandinavia: A behavioral-genetic analysis. *Learning and individual differences*, 18(3), 289-295.
- Samuelsson, S., Byrne, B., Quain, P., Wadsworth, S., Corley, R., DeFries, J. C., ... & Olson, R. (2005). Environmental and genetic influences on prereading skills in Australia, Scandinavia, and the United States. *Journal of Educational Psychology*, 97(4), 705-722.
- Samuelsson, S., Olson, R., Wadsworth, S., Corley, R., DeFries, J. C., Willcutt, E., ... & Byrne, B. (2007). Genetic and environmental influences on prereading skills and early reading and spelling development in the United States, Australia, and Scandinavia. *Reading and Writing*, 20(1-2), 51-75.

- Sattler, J. M., & Ron. Dumont. (2008). *Assessment of children*. Jerome M. Sattler, Publisher.
- Scarborough, H.S. (1990). Very early language deficits in dyslexic children. *Child Development*, *61*, 1728– 1743.
- Scarborough, H. S., & Dobrich, W. (1994). On the efficacy of reading to preschoolers. *Developmental review*, *14*(3), 245-302.
- Schatschneider, C., Carlson, C. D., Francis, D. J., Foorman, B., & Fletcher, J. (2002). Relationships of rapid automatized naming and phonological awareness in early reading development: Implications for the double deficit hypothesis. *Journal of Learning Disabilities*, *35*, 245–256.
- Share, D. L., Jorm, A. F., Maclean, R., Matthews, R., & Waterman, B. (1983). Early reading achievement, oral language ability, and a child's home background. *Australian Psychologist*, *18*(1), 75-87.
- Shaywitz, B.A., Shaywitz, S.E., Pugh, K., Mencl, W.E., Fulbright, R.K., Skudlarski, P., Constable, R.T., Marchione, K.E., Fletcher, J.M., Lyon, G.R., & Gore, J.C. (2002). Disruption of posterior brain systems for reading in children with developmental dyslexia. *Biological Psychiatry*, *52*, 101–110.
- Shaywitz, S.E (2003). *Overcoming dyslexia: A new and complete science-based program for reading problems at any level*. New York: Random House.
- Shaywitz, S. E., & Shaywitz, B. A. (2005). Dyslexia (specific reading disability). *Biological Psychiatry*, *57*, 1301-1309.

- Shaywitz, S.E., Shaywitz, B.A., Pugh, K.R., Fulbright, R.K., Constable, R.T., Mencl, W.E., Shenkweiler, D.P., Liberman, A.M., Skudlarski, P., Fletcher, J.M., Katz, L., Marchione, K.E., Lacadie, C., Gatenby, C., & Gore, J.C. (1998). Functional disruption in the organization of the brain for reading in dyslexia. *Proceedings of the National Academy of Sciences, USA*, **95**, 2636–2641.
- Sirin, S. R. (2005). Socioeconomic status and academic achievement: A meta-analytic review of research. *Review of educational research*, *75*(3), 417-453.
- Siegel, L. S., & Ryan, E. B. (1989). The development of working memory in normally achieving and subtypes of learning disabled children. *Child development*, 973-980.
- Smith, J., Brooks-Gunn, J., & Klebanov, P. (1997). Consequences of living in poverty for young children's cognitive and verbal ability and early school achievement. In G. Duncan & J. Brooks-Gunn (Eds.), *Consequences of growing up poor* (pp. 132-189). New York: Russell Sage Foundation.
- Snow, C. E. (1993). Age differences in second language acquisition: Research findings and folk psychology. In K. Bailey, M. Long, & S. Peck (Eds.), *Second language acquisition studies* (pp. 141–150). Rowley, MA: Newbury House.
- Snow, C., Baines, W., Chandler, J., Goodman, I., & Hemphill, L. (1991). *Unfulfilled expectations: Home and school influences on literacy*. Cambridge, MA: Harvard University Press.
- Snow, C. E., Burns, M. S., & Griffin, P. (Eds.). (1998). *Preventing reading difficulties in young children*. Washington, DC: National Academy Press.

- Snowling, M.J., Gallagher, A., & Frith, U. (2003). Family risk of dyslexia is continuous: Individual differences in the precursors of reading skill. *Child Development, 74*, 358–373.
- Storch, S. A., & Whitehurst, G. J. (2002). Oral language and code-related precursors to reading: Evidence from a longitudinal structural model. *Developmental Psychology, 38*, 934–947.
- Tabors, P. O., & Snow, C.E. (2001). Young bilingual children and early literacy development. In S.B. Neuman & D.K. Dickinson (Eds.) *Handbook of early literacy research* (pp. 159–178). New York, NY: The Guilford Press.
- Tan, L. H., & Perfetti, C. A. (1998). Phonological codes as early sources of constraint in Chinese word identification: A review of current discoveries and theoretical accounts. *Reading and Writing, 10*, 165–200.
- Tanaka, H., Black, J. M., Hulme, C., Stanley, L. M., Kesler, S. R., Whitfield-Gabrieli, S.,... Hoeft, F. (2011). The brain basis of the phonological deficit in dyslexia is independent of IQ. *Psychological Science, 22*, 1442-1451.
- Temple, E., Poldrack, R.A., Salidis, J., Deutsch, G.K., Tallal, P., Merzenich, M., & Gabrieli, J.D.E. (2001). Disrupted neural responses to phonological and orthographic processing in dyslexic children: an fMRI study. *NeuroReport, 12* (2), 299–307.
- Thomas-Tate, S., Washington, J., & Edwards, J. (2004). Standardized assessment of phonological awareness skills in low-income African American first graders. *American Journal of Speech-Language Pathology, 13*, 182-190.

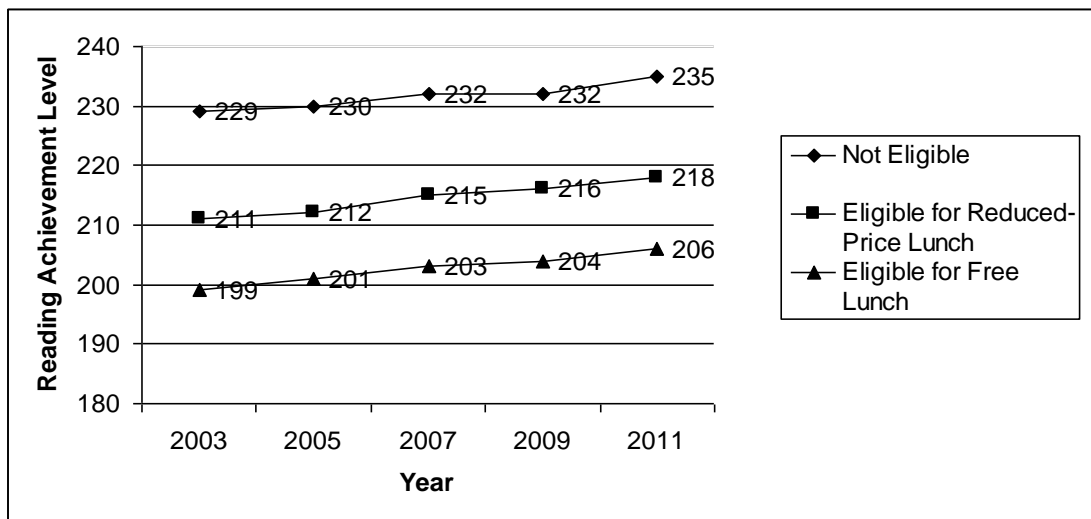
- Torgesen, J. K., Wagner, R. K., & Rashotte, C. A. (1999). *A test of word reading efficiency (TOWRE)*. Austin, TX: Pro-ED.
- Wadsworth, S. J., Corley, R. P., Hewitt, J. K., & DeFries, J. C. (2001). Stability of genetic and environmental influences on reading performance at 7, 12, and 16 years of age in the Colorado Adoption Project. *Behavior Genetics*, *31*(4), 353-359.
- Wagner, R. K., Torgesen, J. K., & Rashotte, C. A. (1999). *CTOPP: Comprehensive test of phonological processing*. Austin, TX: PRO-ED.
- Wallach, M. A., & Wallach, L. (1976). *Teaching all children to read*. Chicago: The University of Chicago Press.
- Wechsler, D. (1974). *Manual for the Wechsler intelligence scale for children, revised*. Psychological Corporation.
- Wechsler, D. (1989). *Manual for the Wechsler Preschool and Primary Scale of Intelligence—Revised*. New York: Psychological Corporation.
- Wechsler, D. (1991). *Wechsler intelligence scale for children--third edition*. San Antonio, TX: The Psychological Corporation.
- Wechsler, D. (2002). *Wechsler preschool and primary scale of intelligence - third edition*. San Antonio, TX: Pearson.
- Wechsler, D. (2003). *Examiners' manual: Wechsler Intelligence Scale for Children-Fourth Edition*. San Antonio, TX: The Psychological Corporation.

- Willcutt, E. G., Pennington, B. F., Olson, R. K., Chhabildas, N., & Hulslander, J. (2005). Neuropsychological analyses of comorbidity between reading disability and attention deficit hyperactivity disorder: In search of the common deficit. *Developmental neuropsychology*, 27(1), 35-78.
- Williams, E. J. (1959). The comparison of regression variables. *Journal of the Royal Statistical Society. Series B (Methodological)*, 396-399.
- White, K. R. (1982). The relation between socioeconomic status and academic achievement. *Psychological Bulletin*, 91(3), 461.
- Whitehurst, G. J., & Lonigan, C. J. (1998). Child development and emergent literacy. *Child Development*, 69, 848–872.
- Wiederholt,, L., & Bryant, B. (1992). *Examiner's manual: Gray Oral Reading Test - 3*. Austin, TX: Pro-Ed.
- Wolf, M., Bowers, P. G. (1999). The double-deficit hypothesis for the developmental dyslexias. *Journal of Educational Psychology*, 91, 415–38.
- Wolf, M., & Denckla, M. (2005). *The rapid automatized naming and rapid alternating stimulus tests*. Austin, TX: Pro-Ed.
- Woodcock, R. W. (1987). *Woodcock Reading Mastery Tests—Revised*. Circle Pines, MN: American Guidance Service.
- Woodcock, R. W., McGrew, K. S., & Mather, N. (2001). *Woodcock-Johnson III*. Itasca, IL: Riverside Publishing.

- Yoshikawa, H. (1995). Long-term effects of early childhood programs on social outcomes and delinquency. In *The Future of Children*, 5(3), 51–75. Los Altos, CA: The David and Lucile Packard Foundation.
- Ziegler, J. C., Bertrand, D., Toth, D., Csepe, V., Reis, A., Faisca, L., Saine, N., Lyytinen, H., Vaessen, A., & Blomert, L. (2010). Orthographic depth and its impact on universal predictors of reading: a cross-language investigation. *Psychological Science*, 21, 551–559.
- Zill, N., Moore, K., Smith, E., Stief, T., & Coiro, M. (1995). The life circumstances and development of children in welfare families: A profile based on national survey data. In P. L. Chase-Lansdale & J. Brooks-Gunn (Eds.), *Escape from poverty: What makes a difference for children?* (pp. 38-59). New York: Cambridge University Press.

Appendix

Figure 1. *Trend in 4th Grade NAEP Reading Average Scores, by Eligibility for Free or Reduced-Price School Lunch*

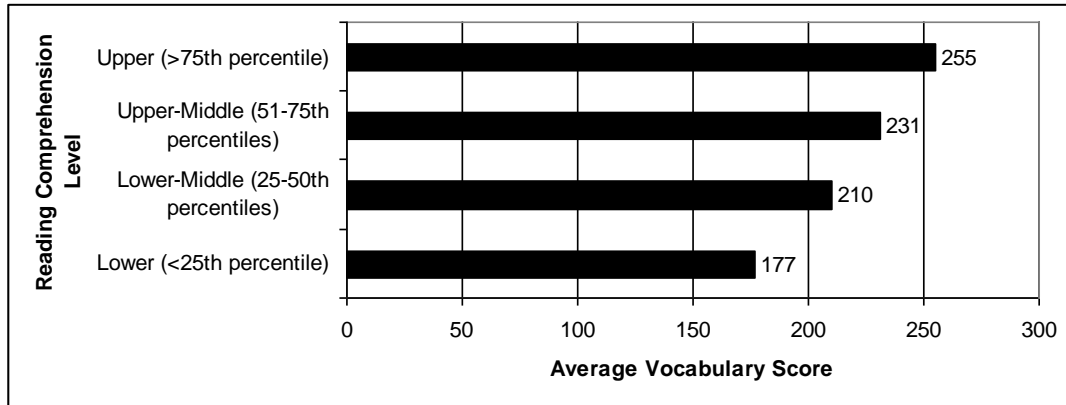


Note. NAEP=National Assessment of Educational Progress.

The Reading Achievement Level mean score in 2011 for fourth-graders was 221 points (SD=35).

Source of data Nation's Report Card, 2011.

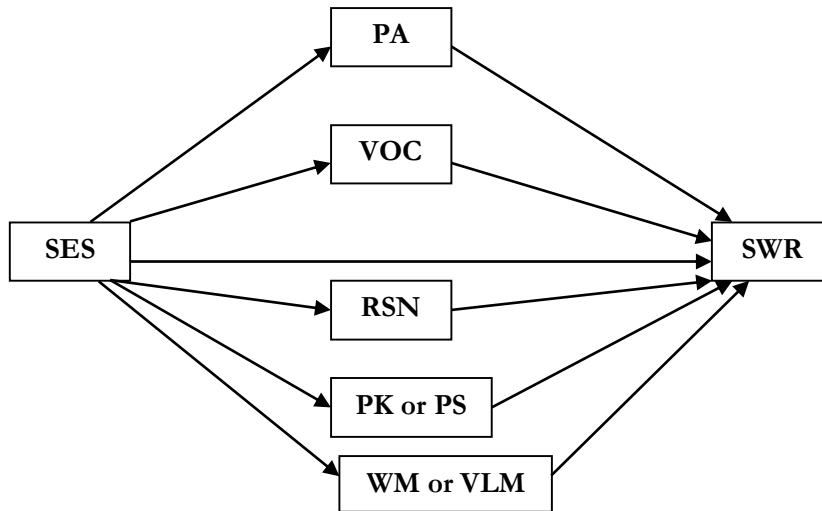
Figure 2. Average Scores in NAEP Vocabulary at 4th Grade by Reading Comprehension Level in 2011



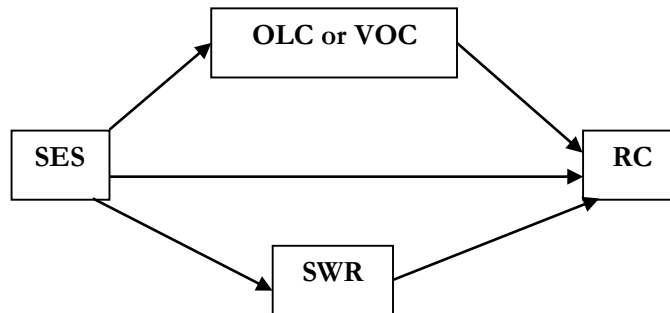
Note. NAEP=National Assessment of Educational Progress. The Vocabulary mean score in 2011 for fourth-graders was 220 points (SD=36). Source of data Nation's Report Card, 2011.

Figure 3. Mediation Models for Single Word Reading and Reading Comprehension

SWR Mediation Model

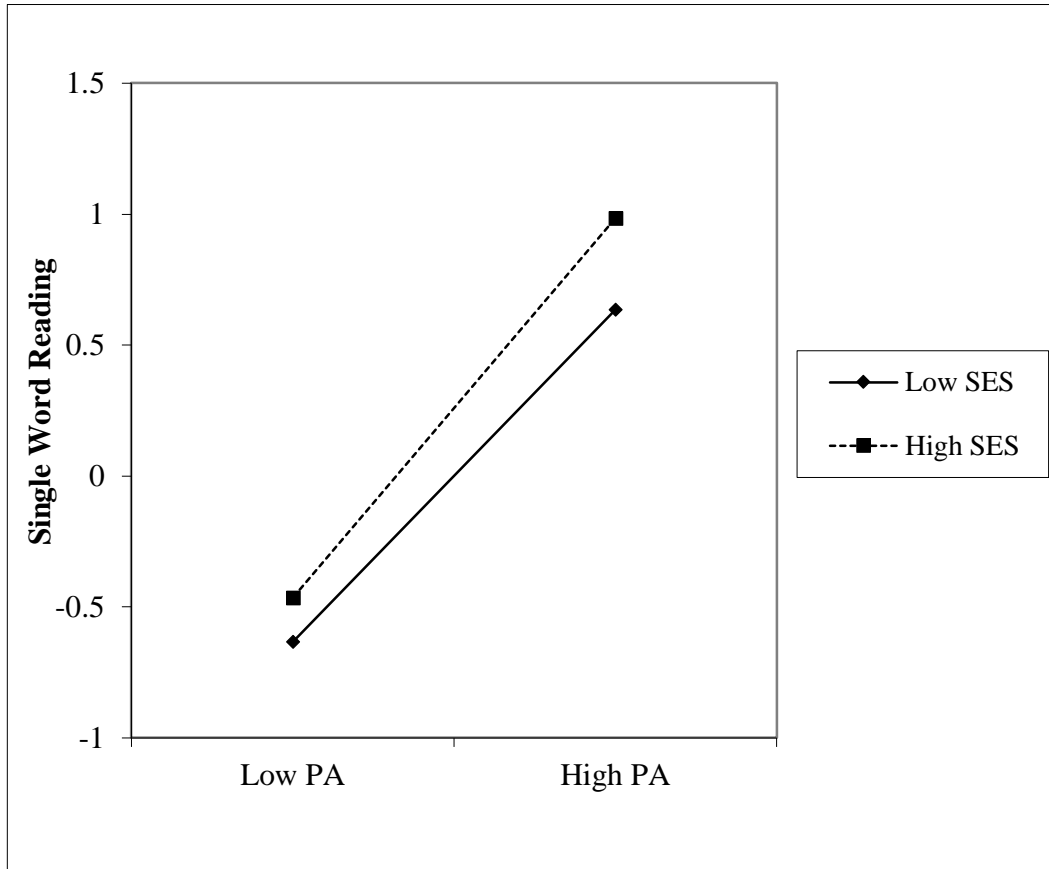


RC Mediation Model



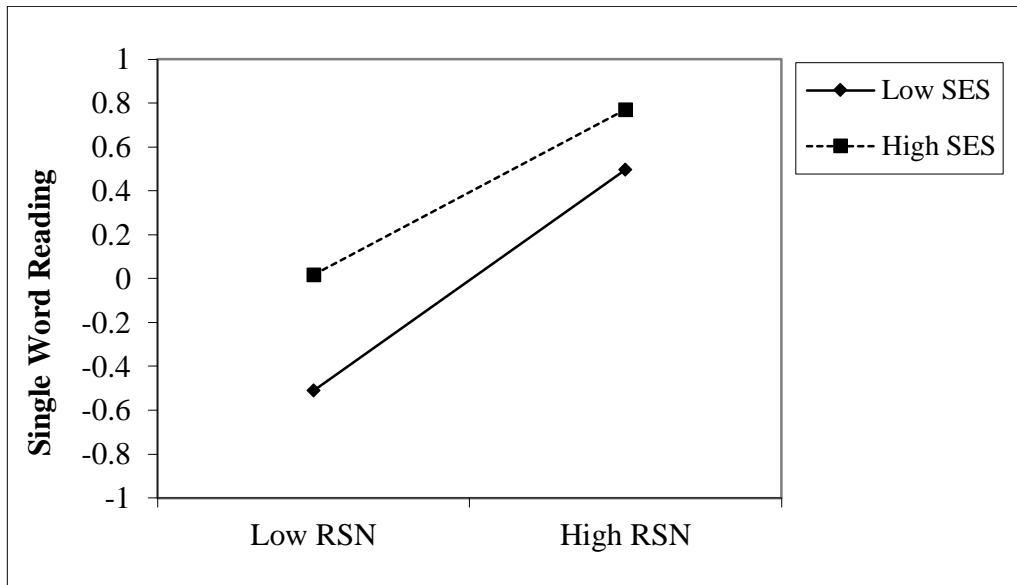
Note. SES=socioeconomic status; PA=phonological awareness; VOC=vocabulary and general language skills; RSN=rapid serial naming; PK=print knowledge; PS=processing speed; WM=Working Memory; VLM=Verbal Learning and Memory; SWR=single word reading; OLC=oral listening comprehension; RC=reading comprehension.

Figure 4. CLDRC PA \times SES Interaction: Single Moderation Model for Single Word Reading (Younger Group)



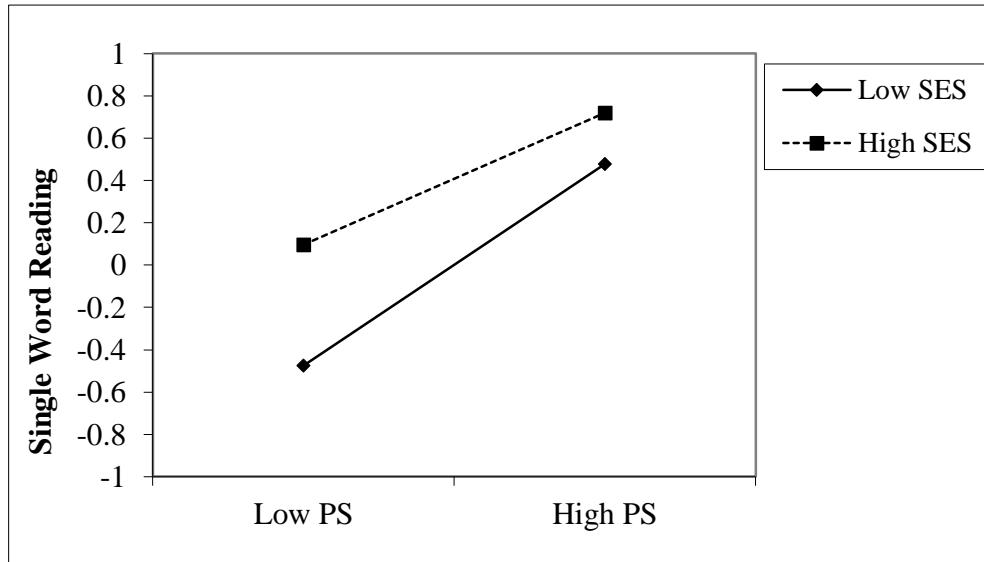
Note. Adjusted $R^2=.70$; PA $\beta=.52$, $p<.001$, effect size=.52; SES $\beta=.14$, $p<.001$, effect size=.01; PA \times SES $\beta=.05$, $p<.05$, effect size=.01. SES in the analysis was modeled as a continuous variable and dichotomized for the purposes of this graph. SES=socioeconomic status; PA=phonological awareness; CLDRC=Colorado Learning Disability Research Center.

Figure 5. CLDRC RSN \times SES Interaction: Single Moderation Model for Single Word Reading (Younger Group)



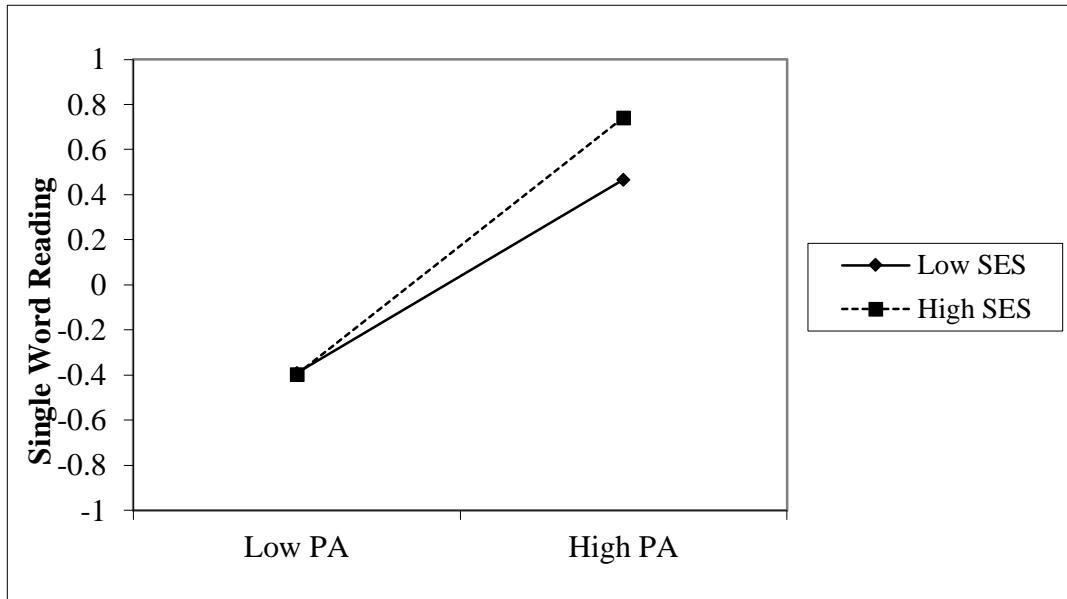
Note. Adjusted $R^2=.33$; RSN $\beta=.50$, $p<.001$, effect size=.24; SES $\beta=.22$, $p<.001$, effect size=.05; RSN \times SES $\beta=-.07$, $p<.05$, effect size=.01. SES in the analysis was modeled as a continuous variable and dichotomized for the purposes of this graph. SES=socioeconomic status; RSN=rapid serial naming; CLDRC=Colorado Learning Disability Research Center.

Figure 6. CLDRC PS \times SES Interaction: Single Moderation Model for Single Word Reading (Younger Group)



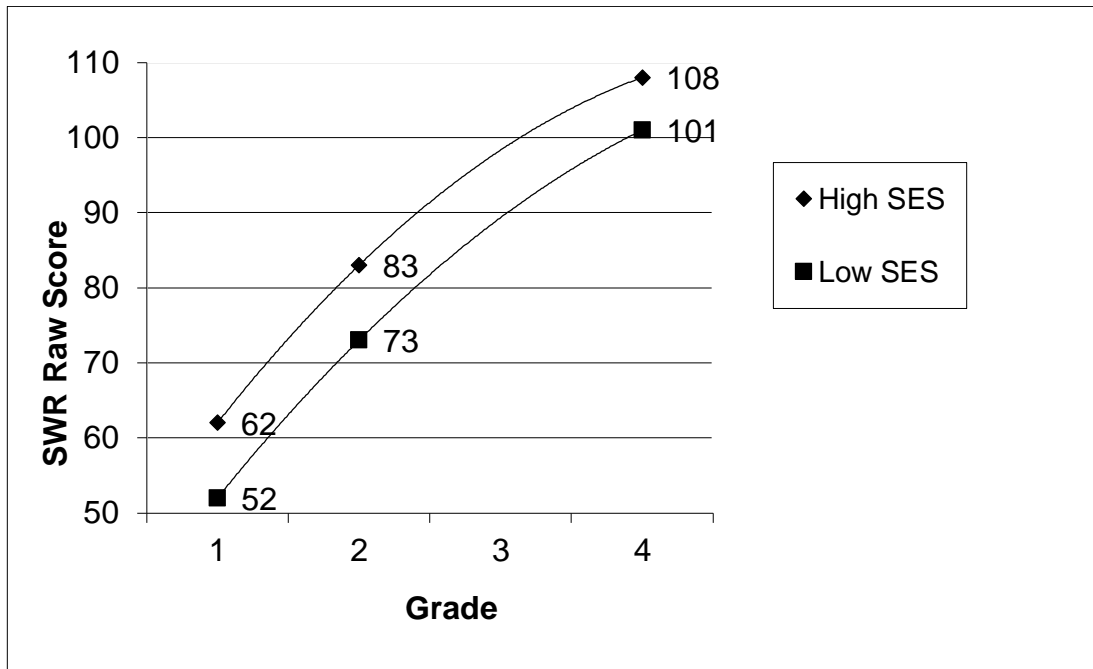
Note. Adjusted $R^2=.25$; PS $\beta=.42$, $p<.001$, effect size=.22; SES $\beta=.22$, $p<.001$, effect size=.05; PS \times SES $\beta=-.09$, $p<.01$, effect size=.01. SES in the analysis was modeled as a continuous variable and dichotomized for the purposes of this graph. SES=socioeconomic status; PS=processing speed; CLDRC=Colorado Learning Disability Research Center.

Figure 7. CLDRC PA \times SES Interaction: Omnibus Moderation Model for Single Word Reading (Younger Group)



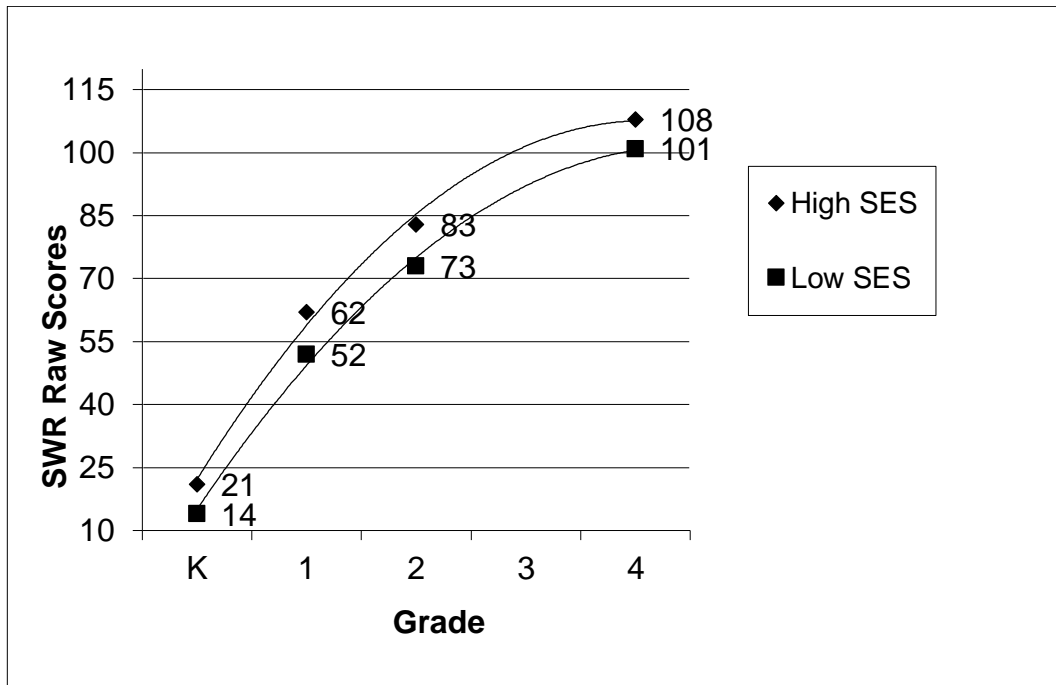
Note. Adjusted $R^2=.70$; PA $\beta=.54$, $p<.001$, effect size=.17; VOC $\beta=.22$, $p<.001$, effect size=.04; RSN $\beta=.16$, $p<.001$, effect size=.02; PS $\beta=.10$, $p<.001$, effect size=.01; WM $\beta=.03$, $p=.35$, effect size=.00; SES $\beta=.07$, $p<.01$, effect size=.01; PA \times SES $\beta=.08$, $p<.01$, effect size=.01; RSN \times SES $\beta=-.01$, $p=.75$, effect size=.00; PS \times SES $\beta=-.04$, $p=.12$, effect size=.00. SES in the analysis was modeled as a continuous variable and dichotomized for the purposes of this graph. PA=phonological awareness; VOC=vocabulary; RSN=rapid serial naming; PS=processing speed; WM=working memory; SES=socioeconomic status; CLDRC=Colorado Learning Disability Research Center.

Figure 8. *ILTS Growth Curve Model for Single Word Reading from 1st Grade through 4th Grade*



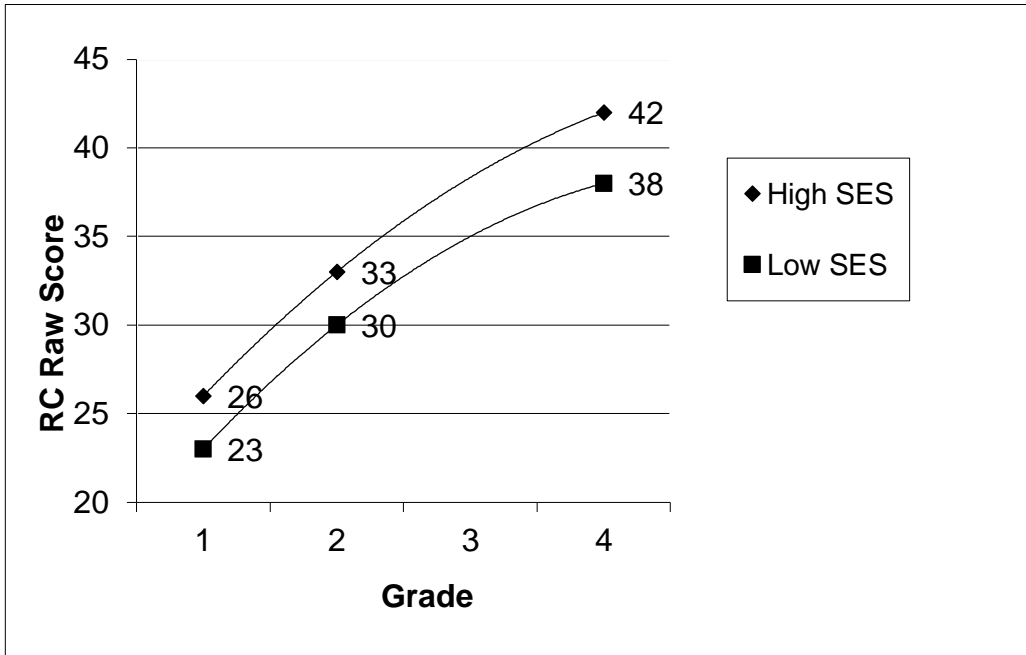
Note. SWR raw score is the total of words and non-words correctly read on the Test of Word Reading Efficiency (Form A). SES in the analysis was modeled as a continuous variable and dichotomized for the purposes of this graph. SWR=single word reading; SES=socioeconomic status; ILTS=International Longitudinal Twin Study.

Figure 9. *Growth Curve Model for Single Word Reading from Kindergarten through 4th Grade*



Note. SWR raw score is the total of words and non-words correctly read on the Test of Word Reading Efficiency (Form A). SES in the analysis was modeled as a continuous variable and dichotomized for the purposes of this graph. K=Kindergarten; SWR=single word reading; SES=socioeconomic status; ILTS=International Longitudinal Twin Study.

Figure 10. *Growth Curve Model for Reading Comprehension from 1st Grade through 4th Grade*



Note. RC raw score is the total score on the Passage Comprehension subtest from the Woodcock Reading Mastery Test-Revised. SES in the analysis was modeled as a continuous variable and dichotomized for the purposes of this graph. RC=reading comprehension; SES=socioeconomic status; ILTS=International Longitudinal Twin Study.

Table 1. Mean Test Scores and Differences from Norms on Reading Battery, Total Population Tested at End of Grades, 2, 3, 4, 5, 6, and 7

Reading Battery n=30					
Grade	Word recognition	Oral Reading	Silent Reading	Spelling	Word Meaning
Grade 2	2.7	3.5	2.9	2.9	3.1
Difference from 2.8 ^a	(-0.1)	(+0.7)	(+0.1)	(+0.1)	(+0.3)
Grade 3	4.3	5.2	4.8	3.7	3.9
Difference from 3.8 ^a	(+0.5)	(+1.4)	(+1.0)	(-0.1)	(+0.1)
Grade 4	4.5	4.9	5.5	4.6	4.3
Difference from 4.8 ^a	(-0.3)	(+0.1)	(+0.7)	(-0.2)	(-0.5)
Grade 5	6.9	6.8	7.0	5.5	4.8
Difference from 5.8 ^a	(+1.1)	(+1.0)	(+1.2)	(-0.3)	(-1.0)
Grade 6	6.1	6.7	6.6	6.1	4.4
Difference from 6.8 ^a	(-0.7)	(-0.1)	(-0.2)	(-0.7)	(-2.4)
Grade 7	7.3	8.1	7.1	6.7	5.0
Difference from 7.8 ^a	(-0.5)	(+0.3)	(-0.7)	(-1.1)	(-2.8)

Note. ^a Expected grade equivalents, or norms, from May of the school year. No standard scores were reported in the study. Data source: Chall, Jacobson, & Baldwin, 1999.

Table 2. *Demographics*

	Samples			
	CLDRC Younger Group Ages 8 to 10 n=811	CLDRC Older Group Ages 11 to 16 n=743	ILTS n=926	Colorado Demographics
Age	9.3 (0.89) ^a	13.3 (1.65) ^a	4.9 (0.19) ^b	--
Sex	51.4% male	48.2% male	49.2% male	--
Child Race*	89% Caucasian ^c 2% African American	91% Caucasian ^c 1% African American	87% Caucasian ^c 3% African American	72.0% Caucasian; 4% African American
Child Hispanic Ethnicity*	5% Hispanic	5% Hispanic	7% Hispanic	19.0% Hispanic
Parental Years of Education	15.8 (2.1)	15.8 (2.4)	15.3 (1.9)	87.6% high school degree or more years of education. (30.9% 4 yr. College Degree or more). Approximately 14 years of education
Parental Occupation ^d	55.7 (12.5)	56.9 (12.9)	56.3 (12.9)	--

Note. Standard deviations presented in parentheses

CLDRC=Colorado Learning Disability Research Center; ILTS=International Longitudinal Twins Study.

*Ethnicity and race information for: CLDRC Younger Group n=477, CLDRC Older Group n=338, ILTS n=926.

^a Child's age in years at the initial testing session

^b Child's age in years at the end of preschool, which was the initial time of testing. Follow-up data was collected at the end of Kindergarten, 1st Grade, 2nd Grade and 4th Grade.

^c Participants who identified as 'Other: Hispanic' were coded as Caucasian.

^d Parental occupation coding based on International Socioeconomic Index, range from 10 to 90.

Table 3. CLDRC Correlations of the Single Word Reading Constructs for the Younger Group (Ages 8 to 10) & Older Group (Ages 11 to 16)

CLDRC Younger Group (n=811)							
Construct	1	2	3	4	5	6	7
1. SES	1.0						
2. SWR	.29**	1.0					
3. PA	.20**	.77**	1.0				
4. VOC	.29**	.56**	.45**	1.0			
5. RSN	.17**	.53**	.46**	.27**	1.0		
6. PS	.20**	.45**	.37**	.25**	.54**	1.0	
7. WM	.22**	.54**	.57**	.41**	.43**	.40**	1.0

CLDRC Older Group (n=743)							
Construct	1	2	3	4	5	6	7
1. SES	1.0						
2. SWR	.27**	1.0					
3. PA	.20**	.76**	1.0				
4. VOC	.33**	.67**	.50**	1.0			
5. RSN	.18**	.39**	.37**	.24**	1.0		
6. PS	.25**	.40**	.34**	.34**	.55**	1.0	
7. WM	.25**	.52**	.56**	.44**	.35**	.38**	1.0

Note. *p<.05; **p<.01, ***p<.001. SES=socioeconomic status; PA=phonological awareness; VOC=vocabulary and general language skills; RSN=rapid serial naming; PS=processing speed; WM=Working Memory; SWR=single word reading; CLDRC=Colorado Learning Disability Research Center.

Table 4. *CLDRC Correlations of the Reading Comprehension Constructs for the Younger Group (Ages 8 to 10) & Older Group (Ages 11 to 16)*

Construct	CLDRC Younger Group (n=682)				CLDRC Older Group (n=647)			
	1	2	3	4	1	2	3	4
1. SES	1.0				1.0			
2. RC	.29**	1.0			.35**	1.0		
3. SWR	.29**	.67**	1.0		.27**	.58**	1.0	
4. OLC	.31**	.66**	.45**	1.0	.35**	.75**	.47**	1.0

Note. *p<.05; **p<.01, ***p<.001. SES=socioeconomic status; SWR=single word reading; OLC=oral listening comprehension; RC=reading comprehension; CLDRC=Colorado Learning Disability Research Center.

Table 5. *ILTS Correlations of Single Word Reading and Reading Comprehension Constructs from Preschool through 4th Grade (n=926)*

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1. SES	1.0												
2. Preschool PA	.25**	1.0											
3. Preschool VOC	.36**	.65**	1.0										
4. Preschool PK	.34**	.63**	.61**	1.0									
5. Preschool RSN	.07*	.29**	.28**	.37**	1.0								
6. Preschool VLM	.27**	.58**	.65**	.51**	.30**	1.0							
7. Kindergarten SWR	.19**	.53**	.38**	.54**	.34**	.38**	1.0						
8. 1 st Grade SWR	.21**	.38**	.28**	.42**	.34**	.31**	.68**	1.0					
9. 2 nd Grade VOC	.31**	.50**	.68**	.50**	.24**	.46**	.39**	.32**	1.0				
10. 2 nd Grade SWR	.22**	.36**	.29**	.36**	.36**	.31**	.60**	.87**	.32**	1.0			
11. 2 nd Grade RC	.26**	.47**	.44**	.45**	.34**	.40**	.53**	.64**	.47**	.71**	1.0		
12. 4 th Grade SWR	.20**	.32**	.26**	.33**	.36**	.29**	.50**	.77**	.30**	.87**	.65**	1.0	
13. 4 th Grade RC	.32**	.53**	.57**	.51**	.33**	.49**	.48**	.58**	.58**	.64**	.75**	.63**	1.0

Note. *p<.05; **p<.01, ***p<.001. SES=socioeconomic status; PA=phonological awareness; VOC=vocabulary and general language skills; RSN=rapid serial naming; PK=print knowledge; VLM=Verbal Learning and Memory; SWR=single word reading; RC=reading comprehension; ILTS=International Longitudinal Twin Study.

Table 6. CLDRC Single Word Reading Mediation Models

Paths	Path Coefficients	
	Younger Group (n=811)	Older Group (n=743)
SES – PA	.20***	.20***
SES – VOC	.29***	.33***
SES – RSN	.16***	.18***
SES – PS	.20***	.25***
SES – WM	.22***	.25***
SES – SWR	.07***	.02 (ns)
PA – SWR	.53***	.52***
VOC – SWR	.22***	.36***
RSN – SWR	.15***	.08***
PS – SWR	.09***	.05*
WM – SWR	.03 (ns)	.03 (ns)
Total Effects	.29***	.27***
Direct Effects: SES – SWR	.07***	.02 (ns)
Indirect Effects:	.22***	.26***
SES – PA – SWR	.10***	.10***
SES – VOC – SWR	.06***	.12***
SES – RSN – SWR	.03***	.02**
SES – PS – SWR	.02***	.01*
SES – WM – SWR	.01 (ns)	.01 (ns)

Note. * $p < .05$; ** $p < .01$, *** $p < .001$. ns=not significant;
SES=socioeconomic status; PA=phonological awareness;
VOC=vocabulary and general language skills; RSN=rapid serial
naming; PS=processing speed; WM=Working Memory;
SWR=single word reading; CLDRC=Colorado Learning
Disability Research Center.

Table 7. CLDRC Reading Comprehension Mediation Models

Paths	Path Coefficients	
	Younger Group (n=682)	Older Group (n=647)
SES – OLC	.31***	.35***
SES – SWR	.29***	.27***
SES – RC	.02 (ns)	.07**
OLC – RC	.45***	.60***
SWR – RC	.46***	.28***
Total Effects	.29***	.35***
Direct Effects: SES – RC	.02 (ns)	0.07**
Indirect Effects:	.28***	.28***
SES – OLC – RC	.15***	.21***
SES – SWR – RC	.13***	.07***

Note. *p<.05; **p<.01, ***p<.001. ns=not significant;
SES=socioeconomic status; SWR=single word reading; OLC=oral
listening comprehension; RC=reading comprehension;
CLDRC=Colorado Learning Disability Research Center.

Table 8. *ILTS Single Word Reading Mediation Models (n=926)*

Paths	Path Coefficients			
	Kindergarten	1 st Grade	2 nd Grade	4 th Grade
SES – PA	.25**	.25**	.25**	.25**
SES – VOC	.36**	.36**	.36**	.36**
SES – RSN	.07*	.07*	.07*	.07*
SES – PK	.34**	.34**	.34**	.34**
SES – VLM	.27**	.27**	.27**	.27**
SES – SWR	.01 (ns)	.10**	0.12**	0.11**
PA – SWR	.32**	.19**	.18**	.14**
VOC – SWR	-.09*	-.11*	-.06 (ns)	-.07 (ns)
RSN – SWR	.14**	.20**	.25**	.27**
PK – SWR	.323**	.20**	.10*	.09*
VLM – SWR	.07 (ns)	.10*	.11**	.11**
Total Effects	.19**	.21**	.22**	.20**
Direct Effect: SES – SWR	.01 (ns)	.10**	.12**	.11**
Indirect Effects:	.18**	.12**	.10**	.09**
SES – PA – SWR	.08**	.05**	.05**	.04**
SES – VOC – SWR	-.03*	-.04*	-.02 (ns)	-.03 (ns)
SES – RSN – SWR	.01 (ns)	.02*	.02*	.02*
SES – PK – SWR	.11**	.07**	.03*	.03*
SES – VLM – SWR	.02 (ns)	.03*	.03**	.03**

Note. *p<.05; **p<.01, ***p<.001. ns=not significant; SES=socioeconomic status; PA=phonological awareness; VOC=vocabulary and general language skills; RSN=rapid serial naming; PK=print knowledge; VLM=Verbal Learning and Memory; SWR=single word reading; ILTS=International Longitudinal Twin Study.

Table 9. *ILTS Reading Comprehension Mediation Models (n=926)*

Paths	Path Coefficients	
	2 nd Grade	4 th Grade
SES – VOC	.31***	.31***
SES – SWR	.22***	.22***
SES – RC	.05*	.09***
VOC – RC	.26**	.39**
SWR – RC	.62**	.48**
Total Effects	.26***	.32***
Direct Effect: SES – RC	.05*	.09***
Indirect Effects:	.22***	.23***
SES – VOC – RC	.08***	.12***
SES – SWR – RC	.14***	.11***

Note. *p<.05; **p<.01, ***p<.001. SWR and VOC were measured in 2nd Grade. SES=socioeconomic status; SWR=single word reading; VOC=vocabulary; RC=reading comprehension; ILTS=International Longitudinal Twin Study.

Table 10. *ILTS Single Word Reading Growth Curve Model from 1st Grade to 4th Grade (n=434)*

Model	Unconditional Intercept Model 1	Unconditional Growth Curve Model 2	Intercept on SES Model 3	Intercept & Slope on SES Model 4	Intercept & Slope on SES with Controls Model 5 ^a
Fixed part					
Intercept, β_{00}	79.62***	37.48***	37.48***	37.45***	24.62***
Linear rate of change, β_{10}		25.15***	25.13***	25.14***	24.75***
Quadratic rate of change, β_{20}		-2.05***	-2.04***	-2.05***	-1.99***
SES β_{01}			7.16***	7.59**	3.49
Lin. Rate * SES, β_{11}				2.04	2.12
Sqr. Rate * SES, β_{21}				-0.54	-0.56
Intercept & Linear Slope Correlation		-0.50	-0.52	-0.53	-0.37
Random part					
σ^2_e	25.51	7.75	7.79	7.75	7.75
σ^2_{u0}	16.57***	28.46***	28.00***	28.10***	19.52***
σ^2_{u1}		10.23***	10.06**	10.21***	10.29***
σ^2_{u2}		1.51**	1.47***	1.49**	1.53***
Deviance	12484.6	10717.1	10698.0	10692.4	10535.9
# of parameters	3	10	11	13	14
$\Delta\chi^2$		2131.5***	19.1***	5.6	156.5***
Degrees of Freedom		7	1	2	1

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. ^aSingle word reading skills in Kindergarten was the control variable in Model 5. ILTS=International Longitudinal Twin Study; SES=socioeconomic status.

Table 11. *ILTS Single Word Reading Growth Curve Model from Kindergarten to 1st Grade (n=434)*

Model	Unconditional Intercept Model 1	Unconditional Growth Curve Model 2	Intercept on SES Model 3	Intercept & Slope on SES Model 4	Intercept & Slope on SES with Controls Model 5 ^a
Fixed part					
Intercept, β_{00}	64.15***	-9.64***	-9.63***	-9.65***	-9.30***
Linear rate of change, β_{10}		40.27***	40.26***	40.27***	39.92***
Quadratic rate of change, β_{20}		-3.51***	-3.50***	-3.50***	-3.45***
SES β_{01}			4.62***	1.33	-4.51*
Lin. Rate * SES, β_{11}				5.15***	5.19***
Sqr. Rate * SES, β_{21}				-0.79***	-0.79***
Intercept & Linear Slope Correlation		-0.27	-0.30	-0.29	-0.40
Random part					
σ^2_e	38.24	8.98	9.00	8.98	8.97
σ^2_{u0}	4.83	18.05***	18.08***	18.04***	14.25***
σ^2_{u1}		14.88***	14.82**	14.55***	14.88***
σ^2_{u2}		2.14***	2.12***	2.08***	2.15***
Deviance	17605.1	14343.2	14330.8	14320.0	14160.3
# of parameters	3	10	11	13	14
$\Delta\chi^2$		3261.9***	12.4***	10.8**	159.7***
Degrees of Freedom		7	1	2	1

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. ^aPrint knowledge skills in preschool was the control variable in Model 5. ILTS=International Longitudinal Twin Study; SES=socioeconomic status.

Table 12. *ILTS Reading Comprehension Growth Curve Model from 1st Grade to 4th Grade (n=434)*

Model	Unconditional Intercept Model 1	Unconditional Growth Curve Model 2	Intercept on SES Model 3	Intercept & Slope on SES Model 4	Intercept & Slope on SES with Controls Model 5 ^a
Fixed part					
Intercept, β_{00}	32.03***	18.07***	18.00***	18.01***	18.86***
Liner rate of change, β_{10}		8.46***	8.51***	8.51***	7.75***
Quadratic rate of change, β_{20}		-0.72***	-0.73***	-0.73***	-0.61***
SES β_{01}			3.84***	2.56**	0.17
Lin. Rate * SES, β_{11}				0.49	0.22
Sqr. Rate * SES, β_{21}				-0.02	0.03
Intercept & Linear Slope Correlation		-0.77	-0.82	-0.82	-0.51
Random part					
σ^2_e	8.67	3.44	3.44	3.44	3.46
σ^2_{u0}	4.16***	8.82***	8.80***	8.76***	3.69***
σ^2_{u1}		2.81	2.85	2.83	3.00
σ^2_{u2}		0.32	0.33	0.33	0.43
Deviance	9523.6	8158.4	8101.1	8095.0	7660.4
# of parameters	3	10	11	13	15
$\Delta\chi^2$		1365.2***	57.3***	6.1*	434.6***
Degrees of Freedom		7	1	2	2

Note. *p<.05, **p<.01, ***p<.001. ^a1st Grade single word reading and preschool vocabulary skills were the control variables in Model 5. ILTS=International Longitudinal Twin Study; SES=socioeconomic status.

Table 13. *CLDRC & ILTS Correlations among SES and Reading Outcomes*

	CLDRC		ILTS	
	Younger Group (n=682)	Older Group (n=743)	2 nd Grade (n=926)	4 th Grade (n=926)
SWR & SES	.29**	.27**	.22**	.20**
RC & SES	.29**	.35**	.26**	.32**
SWR & RC	.67**	.58**	.71**	.63**

Note. **p<.01. CLDRC=Colorado Learning Disability Research Center; ILTS=International Longitudinal Twin Study; SWR=single word reading; RC=reading comprehension; SES=socioeconomic status.

Table 14. *Distribution of Reading Outcomes by SES Level*

	Low Reading Skills ^a				High Reading Skills ^b			
	SWR only	RC only	Both (RC & SWR)	None	SWR only	RC only	Both (RC & SWR)	None
CLDRC Older Group (n=268)								
High SES	17	9	4	110	23	23	11	83
Low SES	16	14	15	83	9	14	2	103
ILTS 4th Grade (n=447)								
High SES	18	6	13	186	22	30	24	147
Low SES	17	23	25	159	18	13	10	183

Note. ^aLow Reading Skills group was defined by 1SD below the mean, ^bHigh Reading Skills group was defined by 1SD above the mean. SES=socioeconomic status; SWR=single word reading; RC=reading comprehension; CLDRC=Colorado Learning Disability Research Center; ILTS=International Longitudinal Twins Study.

Table 15. *CLDRC & ILTS Summary of Results*

	CLDRC Younger Group	CLDRC Older Group	ILTS
Question 1			
1. Cognitive predictors mediate the relationship between SES and SWR.	Partial Mediation [.07] ^a	Full Mediation	Full Mediation (Kindergarten). Partial Mediation: 1 st Grade [.10] ^a , 2 nd Grade [.12] ^a , 4 th Grade [.11] ^a
2. Cognitive predictors mediate the relationship between SES and RC.	Full Mediation	Partial Mediation [.07] ^a	Partial Mediation: 2 nd Grade [.05] ^a , 4 th Grade [.09] ^a
3. SES moderates the relationship between SWR and cognitive predictors.	Significant PA x SES Interaction	No significant interactions	No significant interactions (Kindergarten, 1 st Grade, 2 nd Grade, and 4 th Grade)
4. SES moderates the relationship between RC and cognitive predictors.	No significant interactions	No significant interactions	No significant interactions (2 nd Grade and 4 th Grade)
Question 2			
5. SES moderates the starting values (intercept) of SWR.	—	—	Yes, but SES effect is fully accounted by Kindergarten SWR.
6. SES moderates the growth (slope) of SWR.	—	—	Yes, but SES effect is fully accounted by Preschool PK.
7. SES moderates the starting values (intercept) of RC.	—	—	Yes, but SES effect is fully accounted by preschool VOC and 1 st Grade SWR.
8. SES moderates the growth (slope) of RC.	—	—	No
Question 3			
9. Relationship of SES and RC is stronger than that of SES and SWR.	No	Yes	Yes (2 nd Grade and 4 th Grade)

Note. ^aPath coefficients for the direct effects are listed in the brackets. CLDRC=Colorado Learning Disability Research Center; ILTS=International Longitudinal Twin Study; SES=socioeconomic status; SWR=single word reading; RC=reading comprehension; PK=print knowledge; VOC=vocabulary.

Table 16. *CLDRC Younger Group: Correlations between SWR and Cognitive Predictors using Median Split of Age*

	Young Subgroup ^a (M=8.52 years; SD=0.33; n=406)	Old Subgroup ^b (M=10.03 years; SD=0.57; n=405)
SWR & PA	.77**	.77**
SWR & RSN	.60**	.46**
SWR & PS	.49**	.41**

Note. ** $p < .01$. ^a Young Subgroup is the younger group using median split of age. ^b Old Subgroup is the older group using median split. M=mean; SD=standard deviation; SWR=single word reading; CLDRC=Colorado Learning Disability Research Center; PA=phonological awareness; RSN=rapid serial naming; PS=processing speed.