Overlapping Genetic and Child-Specific Nonshared Environmental Influences on Listening Comprehension, Reading Motivation, and Reading Comprehension

Thesis

Presented in partial fulfillment of the requirements for the degree Master of Arts in the Graduate School of The Ohio State University

By

Victoria Jewell Schenker, B.A.

Graduate Program in Psychology

The Ohio State University

2015

Thesis Committee:

Stephen A. Petrill, Advisor

John E. Opfer

Vladimir M. Sloutsky

Abstract

This study investigated the genetic and environmental influences on observed associations between listening comprehension, reading motivation, and reading comprehension. Univariate and multivariate quantitative genetic models were conducted in a sample of 284 pairs of twins at a mean age of 9.81 years. Genetic and nonshared environmental factors accounted for statistically significant variance in listening and reading comprehension, and nonshared environmental factors accounted for variance in reading motivation. Furthermore, listening comprehension demonstrated unique genetic and nonshared environmental influences but also had overlapping genetic influences with reading comprehension. Reading motivation and reading comprehension each had unique and overlapping nonshared environmental contributions. Therefore, listening comprehension appears to be related to reading primarily due to genetic factors whereas motivation appears to affect reading via child-specific, nonshared environmental effects.

Keywords: comprehension; reading motivation; reading; quantitative genetics

Acknowledgments

First and foremost, I would like to express my deepest gratitude to my advisor, Dr. Stephen Petrill, for his unceasing support of my research interests and his guidance in my academic and career choices. Under his mentorship, I have had a vast amount of opportunities to present research, collaborate with other researchers in the field, and explore the academic and career options most suitable to my interests and abilities; for all of this and much more, I thank him. I would also like to thank my other committee members, Dr. John Opfer and Dr. Vladimir Sloutsky, for offering feedback on my research and challenging me to grow in my presentation and critical thinking skills.

I would also like to express my gratitude to my undergraduate research advisors and professors and to all of my teachers in elementary through high school. Finally, I would like to thank my family, friends, and labmates for their encouragement and support.

Vita

May 2013…..... B.A. Psychology, University of North Carolina at Chapel Hill

2013-2014…… Graduate Fellow, Department of Psychology, The Ohio State University

2015-present……. Graduate Teaching Associate, Department of Psychology, The Ohio State University

Publications

Schenker, V. J., & Petrill, S. A. (2015). Overlapping genetic and child-specific nonshared environmental influences on listening comprehension, reading motivation, and reading comprehension. *Journal of Communication Disorders, 57*, 94-105.

Fields of Study

Major Field: Psychology

Table of Contents

List of Tables

List of Figures

Introduction

Successful language development is necessary not only for everyday interactions, but also for adequate functioning in a variety of cognitive abilities. This association between language and cognitive functions is particularly true of reading (e.g. Hoover & Gough, 1990). However, language and literacy development are also influenced by other variables, including reading motivation (Wigfield, 1997). Children's motivations to read has been found to impact reading acquisition (Scarborough & Dobrich, 1994b), the amount and breadth of actual reading itself (Guthrie et al., 1999; Wigfield, 1997; Wigfield & Guthrie, 1997), and reading performance (Wigfield, 1997). Thus, it is important to understand the relations between language, motivation, and reading and the influences on these associations; in doing so, we may be able to provide optimal opportunities and environments for children to build and enhance their motivation, language, and reading skills. One approach to understanding these is by examining the genetic and environmental influences that are unique to each and the influences that they share. The current study examines these contributors using a behavioral genetic method.

Simple view of reading

The Simple View of Reading (SVR) posits reading comprehension as the result of decoding and listening comprehension. In other words, reading comprehension is made up of what is shared with listening- that is, comprehension of spoken language- and what is specific to reading- that is, decoding written symbols (Gough, Hoover, & Peterson,

1996; Hoover & Gough, 1990). The processes behind listening comprehension and reading comprehension are more similar than they are different. In both cases, words are presented linearly, word order plays a vital role in parsing, similar grammar is present, and similar background knowledge is necessary (Gough et al., 1996). However, the independence of the two can be found in everyday occurrences, as described by Gough and colleagues (1996), who point out that young children can comprehend language without being able to decode, while adults learning a new language may be able to decode without comprehending. Beyond this anecdotal evidence, there is also evidence from factor analysis data that found listening comprehension and decoding to be distinct factors (Kendeou, Savage, & van den Broek, 2009).

There is a large literature of evidence in support of SVR. One meta-analysis examining 10 studies from 17 different samples found 15 significant positive correlations between decoding and reading, ranging from .33 to .83, and 16 significant positive correlations between listening comprehension and reading, ranging from .37 to .82 (Gough et al., 1996). When pooled, these associations resulted in a significant aggregate correlation for decoding and reading of .55 and a significant aggregate correlation of .56 for listening comprehension and reading. Furthermore, in comparison to a model of reading based on general intelligence measured by verbal ability, Savage (2001) found stronger support for SVR, with listening comprehension as the strongest predictor of reading comprehension.

If SVR is the most accurate model of reading comprehension, it has important implications for reading instruction and intervention. Based on this model, reading instruction should focus on the areas of decoding and listening comprehension, and poor

readers can be classified by their area of struggle so that instruction and intervention can target which areas need the most work (Catts, Adolf, & Weismer, 2006; Gough et al., 1996; Roberts & Scott, 2006; Savage, 2001). Therefore, interventions could be for decoding, for listening comprehension, or for a combination of the two. A further advantage to this system as opposed to a general intelligence-focused intervention is that it may promote less deterministic ideals of fixed potential and can emphasize assessment as a means to guide intervention (Savage, 2001). There is some debate as to whether the multiplicative formula is the best way to combine decoding and comprehension (e.g. Carver, 1998; Dreyer & Katz, 1992; Høien-Tengesdal, 2010; Kirby & Savage, 2008). Some research suggests that the formula is most accurate for the extremes of reader skills (Kirby & Savage, 2008) and that the relation between the two variables changes with age (Francis, Fletcher, Catts, & Tomblin, 2005; Gough et al., 1996). Despite the ambiguities of the multiplicative formula, research generally supports that decoding and comprehension are the vital components of reading comprehension.

However, it is also necessary to consider other influences on reading comprehension in the event that they, too, could be potential targets for improvement. Past research has demonstrated that speed of processing (Joshi & Aaron, 2010), attentional control (Connors, 2008), vocabulary (Tumner & Chapman, 2012), and executive function (Sesma, Mahone, Levine, Eason, & Cutting, 2009) influence reading comprehension in addition to the influences of listening comprehension and decoding. Another possible influence on reading comprehension is children's motivation to read.

Reading motivation

As a model of reading, SVR is meant to reduce the complexities of reading comprehension to make it more understandable, and to allow for empirical prediction. Thus, it is not meant to exhaust all possible influences on reading (Kirby & Savage, 2008), including motivation related to reading. Academic motivation in general refers to certain noncognitive traits related to the learning process. Rather than focusing on skills related to academic outcomes, motivation involves a child's inclinations toward learning and how he/she uses those inclinations to become and stay involved in learning (Tucker-Drob & Harden, 2012b). Reading motivation in particular is a distinct variable, separate from other types of motivation, including motivation in other academic areas (Gottfried, 1990). It is also multidimensional, such that motivation to read can be intrinsic or extrinsic and also involves reading self-efficacy (Wigfield, 1997; Wigfield & Guthrie, 1997). Intrinsic reading motivation involves aspects of reading that are motivating in their own right, including reading for enjoyment or because of curiosity. Extrinsic motivation refers to motivators outside of the reading process, such as being recognized by a teacher for reading or reading for social reasons, to connect with peers. Finally, reading self-efficacy involves a person's self-perceived reading ability.

Research on reading motivation has demonstrated that it is related to reading acquisition (Scarborough & Dobrich, 1994b), the amount and breadth of reading a person does (Guthrie et al., 1999; Wigfield, 1997; Wigfield & Guthrie, 1997), and may also be related to reading performance (Wigfield, 1997). In a review of research on reading motivation and reading acquisition, Scarborough and Dobrich (1994b) found general support for positive attitudes toward reading, interest in reading, and engagement in

reading predicting reading acquisition. In one study on 5-year-olds, for example, preliteracy scores were moderately correlated with children's perceived interests in literacy (Wells, 1985). Past research has also demonstrated that reading motivation is associated with the amount of time spent reading, and amount of time spent reading is related to reading outcomes (see Morgan & Fuchs, 2007 for a review). Morgan and Fuchs (2007) discussed how lack of motivation is a possible underlying cause of reading difficulties due to the association between motivation and reading practice. They also suggested that reading motivation and reading outcomes could be bidirectional, so that poor readers are not motivated to read and thus lag behind their peers in both reading ability and reading motivation.

Reading motivation is an important area for further exploration because educators can use their understanding of reading motivation to improve children's motivation or, if necessary, circumvent low reading motivation and find other ways to improve reading outcomes. If reading motivation is indeed related to reading outcomes, there is good news for educators; research suggests that reading motivation can be facilitated and improved by teachers. In a study on a program designed to promote reading motivation, teachers successfully used hands-on activities to garner student interest, promote students' autonomies, enhance students' intrinsic motivations, and improve students' reading self-efficacies (Wigfield, Guthrie, Tonks, & Perencevich, 2004). However, as Scarborough and Dobrich (1994a) discuss, children low in motivation may need outside goals and motivators for reading. Children who are disinterested in reading may not improve from being encouraged to read. On the contrary, this may lead to decreased enjoyment in reading, a phenomenon the authors term the "broccoli effect." The authors

suggest allowing the reading experience to enable an otherwise unmotivated child to attain a different desirable goal, such as reading recipes for a child who likes cooking. Given their language expertise and the opportunities for one-on-one and small group service provision, speech-language pathologists may be particularly well-positioned to individualize literacy activities according to child interest, and thereby capitalize on motivational resources.

Thus, understanding reading motivation and its relation to reading outcomes is vital to understanding reading-related practices in the home and in schools. The present study examines whether motivation to read is an important component to reading comprehension above and beyond the effects of listening comprehension on reading, and how these three variables are related. This issue is approached by assessing the unique and common genetic and environmental influences on listening comprehension, reading motivation, and reading comprehension.

Behavioral genetic approach

Previous behavioral genetic research suggests that language and reading are heritable and influenced by variance in the environment. In a review of over 100 genetic studies on language, Stromswold (2001) found that genetic factors accounted for much of the variance in language abilities, including listening comprehension. Furthermore, in a paper using the same sample as the present study, Harlaar and colleagues (2010) found that variance in listening comprehension was influenced by genetic factors and the nonshared environment (child-specific environmental influences). Behavioral genetic research on reading suggests that it is also highly heritable. Variance in genetic factors

accounts for 50-80% of the variance in reading outcomes at the end of first grade in Australia, Scandinavia, and in the United States, including in previous work using the current sample (Byrne et al., 2006; Byrne et al., 2007; Petrill, Deater-Deckard, Thompson, DeThorne, & Schatschneider, 2006; Petrill et al., 2007). Furthermore, researchers conducting longitudinal twin studies have found that genetic factors largely account for the stability of reading skills (Byrne et al., 2005; Harlaar, Dale, & Plomin, 2007; Hart et al., 2013; Petrill et al., 2007; Wadsworth, Corley, Hewitt, Plomin, & DeFries, 2002). Keenan, Betjemann, Wadsworth, DeFries, and Olson (2006) examined the genetic and environmental influences on decoding, listening comprehension, and reading comprehension and found support for the SVR. In this study, some twins were selected for reading difficulties while others served as a control. Variability in genetic factors influenced variability in both reading and listening comprehension, and word recognition and listening comprehension accounted for all the genetic influences on reading comprehension. There were no significant shared environmental influences (aspects of the environment that influence twins in the same way) on any of the variables, and all of the nonshared environmental influences were specific to each variable.

However, other studies on the etiology of reading outcomes have found evidence for shared environmental influences on reading in addition to genetic influences. One study demonstrated that at age four, the shared environment accounted for 82% of the variance in reading outcomes for children attending preschool and 62% of the variance in reading outcomes for children not attending preschool (Tucker-Drob, 2012). Another study found that reading was influenced by both genetic factors and by children's socioeconomic status (Rhemtulla & Tucker-Drob, 2012). Together these studies suggest

that reading is heritable but also influenced by shared environmental factors such as preschool attendance and socioeconomic status.

There is little previous research specifically on the etiology of reading motivation. One study using the current sample examined the behavioral genetic aspects of reading motivation related to independent reading (i.e. reading self-efficacy and willingness to take on difficult reading material; Harlaar, Deater-Deckard, Thompson, DeThorne, & Petrill, 2011); but little consideration has been taken of the genetic and environmental influences on reading motivation as a whole. However, several studies have examined the etiology of other types of academic motivation. Aspects of academic motivation, such as enjoyment and self-perceived ability, have been found to be largely explained by genetic factors and child-specific environmental influences (Spinath, Spinath, & Plomin, 2008). Furthermore, two studies conducted by Tucker-Drob and Harden (2012a, 2012b) found evidence for both additive genetic and nonshared environmental influences on academic motivation. In a study on 4-year-old children, the researchers found evidence that variance in motivation was accounted for by both genetic factors and the nonshared environment, and that the amount of variance explained by each varied by socioeconomic status. The link between motivation and mathematic achievement in this study was accounted for by genetic influences. In a study on teenagers, the researchers found that academic achievement and intellectual interest were influenced by genetic factors, shared environment, and nonshared environment, but that again these influences varied by socioeconomic status, such that achievement scores were more greatly influenced by genetic factors for children higher in socioeconomic status. These studies point to possible associations between genetic and environmental influences on academic

motivation, such that children genetically influenced to be more motivated learners may seek out or evoke environmental experiences that further promote academic achievement.

Another study examined enjoyment of learning and self-perceived ability in various academic areas in a large sample of twins across six countries, including twins from the current sample (Kovas et al., 2015). Participants ranged in age from 9 to 16. The researchers found that the two aspects of academic motivation (enjoyment of learning and self-perceived ability) were heritable and influenced by the nonshared environment. Variance in enjoyment of learning at age 9, for example, was influenced by genetic factors (38% for Math and English in the United Kingdom, 30% for Science in the United Kingdom, 36% for Math in Germany, and 4% for German in Germany). Estimates of shared environmental influences were close to zero for most academic subjects. Finally, variance in enjoyment of learning was largely influenced by the nonshared environment (62% for Math in the United Kingdom, 59% for English in the United Kingdom, 67% for Science in the United Kingdom, 62% for Math in Germany, and 69% for German in Germany).

Therefore, aspects of academic motivation for several different academic areas have been found to be largely influenced by genetic factors and child-specific nonshared environments. The present study uses a behavioral genetic approach to examine reading motivation specifically and to consider its association with reading ability. It was examined how reading motivation may explain variance related to reading comprehension above and beyond influences of listening comprehension on reading comprehension.

Current study

The main objective of the current study was to examine the genetic and environmental impacts on listening comprehension, reading motivation, and reading comprehension. Each variable was assessed for unique genetic and environmental influences and whether any of the variables had overlapping genetic and environmental influences. Specifically, it was examined whether reading motivation impacts reading comprehension above and beyond the influences of listening comprehension, and whether genetic factors or environmental factors influence this relationship. Therefore, the first research question asked what influences the association between listening comprehension and reading comprehension. Because of the high heritability of listening comprehension and reading comprehension and the similarity in processing for both (e.g. Petrill et al., 2007; Stromswold, 2001) it was hypothesized that listening and reading comprehension would have overlapping genetic influences. The second question asked if and how reading motivation predicts reading comprehension above and beyond the influences of listening comprehension. It was expected that reading motivation and reading comprehension would have overlapping influences. Previous literature on academic motivation suggests that it may be influenced by genetic factors and the nonshared environment, and that academic motivation has overlapping genetic influences with academic outcomes. Thus, the current study examined whether these influences are important for reading motivation specifically and investigated whether genetic factors, environmental influences, or both are most important for reading outcomes.

Methods

Participants

A total of 284 families with same-sex twin siblings (57% female) participated. They were drawn from the Western Reserve Reading and Math Projects (WRRMP), an ongoing longitudinal twin study of reading and related variables. Of the 284 twin pairs, 116 were monozygotic twins (41%), and 168 were dizygotic twins (59%). Zygosity was determined mainly by using polymorphic DNA markers obtained from buccal swabs, but for the families who did not consent to DNA testing, it was determined using a measure of twin physical similarity that is 95% accurate when compared to DNA data (Price et al., 2000). The mean age of participants was 9.81 years (*SD* = .99), and the mean grade level was third grade (*range from 1st grade to 7th grade*). Although WRRMP is a longitudinal data set beginning at the mean age of 6.07 (*SD = .68)*, this visit was the first to include measures of listening comprehension and reading motivation, granting the first opportunity to consider concurrent relations between outcomes on those measures and outcomes on reading measures. Families were from Ohio, particularly the Cleveland, Columbus, and Cincinnati areas. Reported races of the twins were 91.4% White, 5.2% African American, and 1.4% Asian. The median level of parental education was completion of a 4-year college, making up 35% of the parents. About .5% did not graduate from high school, 10% graduated high school, 15.7% completed some college,

7.5% graduated from a 2-year college, 5.5% completed some graduate or professional school, and 20.71% graduated from gradate or professional school.

Procedure

Data collection occurred in participants' homes. Parental consent and children's assents were obtained before administration of assessments. Parents and children completed questionnaires and assessments evaluating reading and related variables. Children were assessed individually in different rooms of the home by separate examiners, and the entire visit took approximately three hours. Families each received $100 to say "thank you" for participation.

Measures

Listening comprehension. Two measures were employed to assess listening comprehension: The Understanding Spoken Paragraphs subtest of the Clinical Evaluation of Language Fundamentals- Fourth Edition (CELF; Semel, Wiig, & Secord, 2003) and the Narrative Comprehension subtest of the Test of Narrative Language (TNL; Gillam & Pearson, 2004). The CELF Understanding Spoken Paragraphs subtest involves the tester reading paragraphs aloud and requires the participant to answer questions about the content of the paragraphs. It measures the participant's ability to understand oral narrative and to think critically to give the correct answers, which are critical skills in a classroom or other learning context as students must be able to listen to instructions and information in order to learn as expected. The published internal consistency reliability of the CELF Understanding Spoken Paragraphs at age nine is .74. The TNL Narrative Comprehension subtest requires the participant to listen to a story and measures the

participant's ability to recall and understand information as well as to make inferences in order to answer questions about the story. Participants are asked both literal and inferential questions about the information in order to assess listening and language skills, including knowledge of word meanings and sentence structures and recognition of relationships between words and ideas. The published reliability for the TNL Narrative Comprehension at age nine is .71.

Reading Motivation. Children participating in the study completed the Motivation for Reading Questionnaire (MRQ; Wigfield et al., 1996), which contains 54 items assessing eleven aspects of reading motivation. The MRQ is provided in Appendix A. Wigfield and colleagues published the MRQ as a means of measuring the reading motivation of children in elementary and middle school, particularly in grades 3 to 6. The researchers intended it to be used to understand the ways in which children are motivated to read, such as by tracking children's motivation over the course of a school year, developing profiles for individual students, and comparing the reading motivation of various groups, such as boys and girls. They also suggested measurement outcomes should be related to reading frequency and reading performance.

The MRQ uses a 4-point scale ranging from 1 = Almost Never to 4 = Almost every day. It assesses various aspects of reading motivation including intrinsic motivation, such as willingness to take on challenging reading material and reading curiosity, extrinsic motivation, including reading for recognition and reading for grades, and reading self-efficacy. Items measuring willingness to take on challenging reading material, for example, included "If a book is interesting, I don't care how hard it is to read." Items measuring reading for recognition included "I like having the teacher say I

read well." Reading self-efficacy was measured by items such as "I know that I will do well in reading next year." The total composite score of the MRQ was used to measure the twins' reading motivations in order to best understand how all aspects of reading motivation are related to language and reading outcomes. The internal reliability of the total motivation score calculated within this sample is .91.

Reading Comprehension. Reading comprehension was also assessed using two measures: The Passage Comprehension subtest of the Woodcock Reading Mastery Test-Revised (WRMT-R; Woodcock, 1987) and the Reading Comprehension subtest of the Peabody Individual Achievement Test- Revised (PIAT-R; Markwartdt, 1989). Both tests measure the participants' ability to understand what they have read to themselves. The Passage Comprehension subset of the WRMT-R requires the participant to read sentences or passages and to provide a word to fill in a blank. It has a published reliability of .92 for third graders. The Reading Comprehension subtest of the PIAT-R requires the participant to read a sentence and choose one picture out of four that best corresponds with the sentence. The published split-half reliability of this subtest for third graders is .93.

Results

Descriptive and correlation analyses

Descriptive statistics and correlations were assessed using SPSS 22 and SAS 9.3. Descriptive statistics for raw scores on listening comprehension, reading motivation, and reading comprehension measures can be found in Table 1. For the CELF Understanding Spoken Paragraphs subtest, each of the three paragraphs had five associated questions worth one point each. Therefore, the possible range of scores is 0 to 15. The present sample had a range of 1 to 15, suggesting the sample was representative of the full range of ability. The mean score of 10.2 (*SD* = 3.04) indicates that the participants were typically on the higher end of the scale, with data being skewed left.

For the TNL Narrative Comprehension subtest, questions associated with each of the three stories had maximum total scores of 11 through 15. The raw sum score for the three stories could range from 0 to 40. With a mean of 31.42 (*SD* = 3.84), the participants performed on the higher end of the scale. However, the scores ranged from 12 to 39, indicating that ceiling effects were not an issue. The distribution of scores was fairly normal.

The total score of the Motivation for Reading Questionnaire was used, which is a sum of the scores of 50 of its 54 items, excluding those related to avoiding reading work. Participants gave each item a score of 1 to 4, resulting in a possible total score range of

50 to 200. Participants answered the MRQ with scores ranging from 60 to 197, suggesting that they represented almost the full range of reading motivation as measured by the MRQ. The mean score was 143.24 (*SD* = 24.17), indicating the scores were centered on the higher end of the measure with a fairly normal spread. The internal reliability was .91.

The WRMT-R Passage Comprehension subtest is made up of 68 items, each of which is worth 1 point. Therefore, total raw scores can have a possible range from 0 to 68. Participants in the present study ranged in total raw score from 1 to 57, suggesting a fairly wide representation of the total possible range. The mean of the raw scores was 38.49 (*SD* = 7.66).

The PIAT-R Reading Comprehension subtest contains 82 items, but raw scores begin with Item 19, resulting in a possible range of scores of 19 to 100. Participants ranged in total raw score from 22 to 97, indicating a wide representation of possible outcomes on this subtest. Participants had a mean score of 64.56 (*SD = 13.13*), and the outcomes are represented by a fairly normal curve. All measures were residualized for age and sex, then z-scored for use in all subsequent analyses.

Correlations between all listening comprehension, reading motivation, and reading comprehension measures are presented in Table 2. The two listening comprehension measures were moderately correlated ($r = .47$, $p < .01$). A factor score of the two measures, hence called Listening Comprehension, was created for use in further analyses as the listening comprehension variable. The eigenvalue for the factor

score was 1.47, explaining 73.53% of the variance. The two measures had factor loadings of .86.

Similarly, the two measures of reading comprehension were highly correlated ($r = .70$, $p < .01$). A factor score was created for the two measures, hence called Reading Comprehension, for use as the reading comprehension variable in further analyses. The eigenvalue was 1.70, accounting for 84.91% of the variance. The measures had factor loadings of .92.

Listening Comprehension and Reading Comprehension were moderately correlated ($r = .60$, $p < .01$). Although the two factor scores correlated more strongly than the two listening comprehension variables, it is important to note that the factor scores do not include measurement error. Reading motivation and Reading Comprehension were also modestly correlated ($r = .21$, $p<.01$). Reading motivation and Listening Comprehension were not significantly correlated based on a significance value of $p = .01$ but were modestly correlated based on a significance value of $p = .05$ ($r = .12$, $p = .01$).

Behavioral genetic analyses

Univariate behavioral genetic analyses. Structural equation modeling in Mx (Neale, 1997) was used to examine the genetic, shared environment, and nonshared environmental influences on listening comprehension, reading motivation, and reading comprehension. Monozygotic (MZ) twins inherit 100% of the same segregating genes, whereas dizygotic (DZ) twins on average inherit 50% of the same genes. Therefore, additive genetic influences are estimated when MZ twins are more similar on a measure

than are DZ twins. Shared environment, or environmental variables that influence the measures of both twins, are estimated when MZ correlations are less than two times as similar as DZ correlations. Finally, differences between MZ twins are due to nonshared environmental influences, which also include the measurement error. Using factor scores for Listening Comprehension and Reading Comprehension remove measurement error because they include only common variance. Although true latent factors done in the same analysis in the model would be error-free, it was not possible to create these factors due to having only one measure of reading motivation. Mean scores of MZ twins were not significantly different than mean scores of DZ twins for Listening Comprehension ($t = 1.33$, $p = .80$), reading motivation ($t = 1.11$, $p = .75$), or Reading Comprehension ($t = .93$, $p = .26$). Intraclass correlations for MZ twins and DZ twins are presented in Table 3, which show that MZ twin correlations generally exceed DZ twin correlations, suggesting genetic influences, and MZ correlations are less than one, suggesting nonshared environmental influences.

The univariate model decomposes the observed phenotypic variance of Listening Comprehension, reading motivation, and Reading Comprehension into additive genetics (A), shared environment (C), and nonshared environment (E). Additive genetic variance (a^2) of each variable was found by summing the squared additive genetic path estimates of that variable; shared environment variance (c^2) was found by summing the squared shared environment path estimates; and nonshared environmental variance (e^2) was found by summing the squared nonshared environment path estimates.

Estimated genetic, shared environmental, and nonshared environmental influences for each measure are presented in Table 4. An estimated 67% of the variance in

Listening Comprehension was associated with variance in genetic factors and 33% was due to variance in nonshared environment. Variance in reading motivation was only significantly influenced by variance in nonshared environment (76%), including error. The intraclass correlations suggest that reading motivation may also be influenced by genetic factors, with an MZ correlation of .30 as compared to a DZ correlation of .00. The resulting genetic influence on reading motivation was estimated as 24%; however, this value was not significant. For Reading Comprehension, 75% of variance was due to variance in genetic factors and 28% was due to variance in nonshared environment, including error.

Multivariate behavioral genetic analyses. Trivariate Cholesky decomposition models were conducted to estimate the genetic, shared environmental, and nonshared environmental pathways influencing Listening Comprehension, reading motivation, and Reading Comprehension. By using this model, the overlapping and independent sources of influence on these measures can be examined. Listening Comprehension was entered into the model first, reading motivation was entered second, and Reading Comprehension was entered third (Figure 1). Variables were entered in this order because it provided a way to examine how reading motivation relates to reading comprehension above and beyond the influences of listening comprehension as well as an examination of how other influences may impact reading comprehension other than those two constructs. Therefore, A1, C1, and E1 estimated the overlapping additive genetic, shared environmental, and nonshared environmental variance between Listening Comprehension, reading motivation, and Reading Comprehension. A2, C2, and E2 estimated the overlapping additive genetic, shared environmental, and nonshared

environmental variance for reading motivation and Reading Comprehension. Finally, A3, C3, and E3 estimated any unique additive genetic, shared environmental, and nonshared environmental variance of Reading Comprehension not shared with Listening Comprehension or reading motivation.

Table 5 presents the models of estimated additive genetic, shared environmental, and nonshared environmental overlap between Listening Comprehension, reading motivation, and Reading Comprehension. Listening Comprehension showed significant genetic influences, as demonstrated by the significant additive genetic pathway (.80). There were overlapping genetic influences on Listening Comprehension and Reading Comprehension (pathway of .71). There were no shared environmental influences on any of the variables. Finally, each variable had independent nonshared environmental influences (pathways of .41-.88). Reading motivation and Reading Comprehension had small but significant nonshared environmental overlap above and beyond any influences involved with Listening Comprehension (pathway of .14 or correlation of .02). Thus, the relation between Listening Comprehension and Reading Comprehension was influenced by additive genetic factors, whereas Listening Comprehension also had unique genetic influences. Reading motivation and Reading Comprehension, on the other hand, were related through nonshared environmental influences, and each variable also had unique nonshared environmental influences.

It is important to note that estimates of nonshared environmental influences also included measurement error. However, the relation between reading motivation and Reading Comprehension was more likely to be due to true nonshared environmental effects rather than error for two reasons. First, if the estimate represented error, it would

mean that the error of the MRQ and the error of the Reading Comprehension measures were related rather than reading motivation and reading comprehension being related. In other words, this would only reflect error if the measures had errors that covaried with one another. Second, using MZ twins, an MZ-difference analysis (Plomin, DeFries, Knopik, & Neiderhiser, 2013) was conducted, where the twin differences in motivation were compared to differences in Reading Comprehension. Because MZ twins share both genetics and the common environment, a significant correlation between twin differences in motivation and differences in reading are assumed to be due to differences in the nonshared environment. Twin 1's Reading Comprehension score was residualized with twin 2's Reading Comprehension score, and twin 1's reading motivation score was residualized with twin 2's reading motivation score. The correlation between these two difference scores was $r = .16$ ($p < .05$), which is very similar to the nonshared environmental overlap between reading motivation and Reading Comprehension obtained by model fitting. This demonstrates that even when accounting for the scores of their MZ co-twin, reading motivation and Reading Comprehension were correlated, again suggesting that there may be true child-specific influences on the association between reading motivation and reading comprehension above and beyond any genetic and shared environmental similarities.

Because MZ correlations were greater than two times the DZ correlations in some cases, additional analyses were conducted using a model that allows for dominance genetic effects (D) rather than shared environmental effects. Dominance effects are the result of interactions between alleles at the different loci (Plomin et al., 2013). Whereas shared environment (C in the ACE model) is estimated when the correlations between

MZ twins are less than two times as similar than the correlations between DZ twins, dominance (D in the ADE model) can be estimated when correlations between MZ twins are more than twice as large as correlations between DZ twins. Analyses using the ADE can be found in Table 6. These analyses resulted in no significant additive genetic nor dominance influences on any of the variables or on overlap between any of the variables. Estimates of genetic influences using the ADE model were lower than the estimates using the ACE model. There were significant nonshared environmental independent influences on Listening Comprehension, reading motivation, and Reading Comprehension (pathways of .50-.83) as well as significant nonshared environmental influences on the relation between reading motivation and Reading Comprehension (pathway of .14). The nonshared environmental influences demonstrated in the ADE model were consistent with those found in the ACE mode. However, analyses using the ADE model did not provide any improvement in model fit above an AE model parameterizing additive genetics and nonshared environment ($x^2_{cha} = 2.38$, $df_{cha} = 6$; Table 7). Therefore, results from the ACE model are used in our discussion.

Discussion

The primary goal of this study was to examine whether reading motivation was associated with genetic or environmental influences on reading comprehension above and beyond listening comprehension. Listening and reading comprehension were largely heritable and also influenced by variance in nonshared environment, whereas reading motivation was only significantly influenced by variance in nonshared environment. Furthermore, although listening comprehension demonstrated unique genetic influences, it also showed overlapping genetic influences with reading comprehension. These overlapping genetic factors support past literature on the similarities between and common processes of language and reading. Reading motivation showed both unique nonshared environmental influences and overlapping nonshared environmental influences with reading comprehension. This finding supports the hypothesis that reading motivation relates to reading comprehension above and beyond the contributions of listening comprehension, and demonstrates that this association stems from overlapping child-specific aspects of the environment.

These child-specific environmental influences could be anything nongenetic that works at the individual, rather than the familial, level. A single life experience may have a drastic impact on an individual child's outcomes, such as an illness that affects a child's school attendance and in turn influences his motivation and academic outcomes. However, there are also more subtle ways the environment can impact individual children

differently. Teachers and family members may treat children differently based on a child's personal characteristics and interests; for example, a parent may take a child who shows interest in reading to the library more often, which in turn could amplify the child's motivation to read even more. These effects could be due to gene-environmental correlation (Plomin et al., 2013), but may also stem from nonshared environmental influences. Finally, even the same environmental influences may be perceived or interpreted by children differently. Two children may grow up in the same home and attend the same school but perceive their experiences differently and therefore be influenced by their environments in different ways.

Due to the overlapping child-specific environmental influences on reading motivation and reading outcomes, reading motivation may be an important area to target for intervention. Working to improve a child's motivation to read by customizing her learning environment to her own unique interests and learning style could be an important key to improving her reading comprehension. Past literature suggests that this could be accomplished in several ways (Chirkov & Ryan, 2001; Ryan & Deci, 2000; Scarborough & Dobrich, 1994a). Parents, teachers, and clinicians can promote student's autonomies by allowing them to choose reading materials that relate to their own interest. They can provide feedback on a child's reading, particularly feedback that is focused on the individual child and not as a comparison to their peers in order to improve the child's reading self-efficacy. They should also accomplish these goals while using a caring attitude and providing appropriate levels of challenge for the student. Past work on motivation in relation to mathematics in the presence of anxiety suggests that materials for intrinsically motivated students should be challenging enough to garner students'

interests but not overly challenging, so that students still feel as though hard work will help them accomplish their goals (Wang et al., in press). This may very well be true of reading motivation and reading outcomes as well and as such should be taken into consideration when working to improve reading skills through motivation. Given that literacy is within the scope of practice for speech-language pathologists (ASHA, 2001), the individualized support of speech-language pathologists offers a unique opportunity to tailor to children's unique interests and motivations. This could be as simple as letting children pick out the books they prefer or working on literacy within a different activity, such as reading the pop-up instructions within a video game.

Taken together, the present study supports phenotypic literature on the connections between listening comprehension and reading comprehension as well as the association between reading motivation and reading outcomes. Therefore, support was found for views of SVR researchers who emphasize focused interventions on specific reading needs, including decoding and listening comprehension. Due to overlapping nonshared environmental influences on reading motivation and reading comprehension, reading motivation may be an area for intervention to target when working to improve reading skills.

Limitations

There are important limitations of this study to note. First, our sample may be somewhat underpowered. A larger sample may have allowed some nonsignificant estimates to be significant. Second, participants were from a largely middle class background. Previous research has shown that socioeconomic status influences the

etiologies of reading motivation and reading outcomes (Tucker-Drob & Harden, 2012a; Tucker-Drob & Harden, 2012b) so results may not be generalizable to readers from lower income families. Third, it would be useful for future studies to use different measures of listening and reading comprehension to replicate results, because oftentimes measures test different aspects of listening and reading comprehension and may lead to different results, although multiple measures of listening comprehension and reading comprehension were included to address this possibility. However, the form of assessment may also be influential, such that a questionnaire may lead to different results than a standardized test. This, too, could be examined more thoroughly by replication. Furthermore, the results found may only be applicable to the ages specifically considered in this study. Past research suggests that the correlation between listening and reading comprehension increases with age (Gough et al., 1996). On the other hand, another study suggested that deficits in comprehending are present in early school grades (Catts et al., 2006). Therefore, future research should use a more developmental approach in examining genetic and environmental influences on listening comprehension, reading motivation, and reading comprehension to better understand how the relations between the variables change or remain stable over time. This research will be carried out using future waves of the WRRMP dataset. Finally, reading motivation was assessed with a single measure, whereas listening comprehension and reading comprehension were assessed with multiple measures. This prevented a latent factor analysis on these three constructs from being conducted, which would have provided a better test of nonshared environmental effects.

Despite these limitations, this paper is among the first to examine the links between reading motivation and reading comprehension using behavioral genetic methods**.** As such, it provides necessary insight into the influences on this relation and points to the importance of tailoring learning environments to the interests and preferences of individual learners.

References

American Speech-Language-Hearing Association. (2001). Roles and responsibilities of speech-language pathologists with respect to reading and writing in children and adolescents [Position Statement]. Available from www.asha.org/policy.

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.

Byrne, B., Wadsworth, S., Corley, R., Samuelsson, S., Quain, P., DeFries, J.C., …& Olson, R.K. (2005). Longitudinal twin study of early literacy development: Preschool and kindergarten phases. *Scientific Studies of Reading, 9(3),* 219-235.

Carver, R.P. (1998). Predicting reading level in grades 1 to 6 from listening level and decoding level: Testing theory relevant to the simple view of reading. *Reading and Writing: An Interdisciplinary Journal*, *10,* 121-154.

Catts, H.W., Adlof, S.M., & Weismer, S.E. (2006). Language deficits in poor comprehenders: A case for the simple view of reading. *Journal of Speech, Language, and Hearing Research, 49,* 278-293.

Chirkov, V.I. & Ryan, R.M. (2001). Parent and teacher autonomy-support in Russian and U.S. adolescents: Common effects on well-being and academic motivation. *Journal of Cross-cultural Psychology, 32,* 618-635.

Connors, F.A. (2006). Attentional control and the Simple View of reading. *Reading and Writing, 22*, 591-613.

Dreyer, L.G. & Katz, L. (1992). An examination of "the simple view of reading." *Haskins Laboratories Status Report on Speech Research, 111/112*, 161-166.

Francis, D.J., Fletcher, J.M., Catts, H.W., & Tomblin, J.B. (2005). Dimensions affecting the assessment of reading comprehension. In S. A. Stahl & S. G. Paris (Eds.), *Children's reading comprehension and assessment* (pp.369-394). Mahwah, NJ: Erlbaum.

Gillam, R.B. & Pearson, N.A. (2004). *Test of Narrative Language.* Austin, TX: Pro-ed.

Gottfried, A.E. (1990). Academic intrinsic motivation in young elementary school children. *Journal of Educational Psychology, 82*, 525-538.

Gough, P.B., Hoover, W.A., & Peterson, C.L. (1996). Some observations on a simple view of reading. In C. Cornoldi & J. Oakhill (Eds.), *Reading comprehension difficulties: Processes and intervention* (1-13). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Guthrie, J.T., Wigfield, A., Metsala, J.L., & Cox, K.E. (1999). Motivational and cognitive predictors of text comprehension and reading amount. *Scientific Studies of Reading, 3(3),* 231-256.

Harlaar, N., Cutting, L., Deater-Deckard, K., DeThorne, L.S., Justice, L.M., Schatschneider, C., Thompson, L.A., & Petrill, S.A. (2010). Predicting individual differences in reading comprehension: A twin study. *Ann Dyslexia, 60(2),* 265-288.

Harlaar, N., Dale, P.S., & Plomin, R. (2007). From learning to read to reading to learn: Substantial and stable genetic influence. *Child Development, 78(1),* 116-131.

Harlaar, N., Deater-Deckard, K., Thompson, L.A., DeThorne, L.S., & Petrill, S.A. (2011). Associations between reading achievement and independent reading in early elementary school: A genetically informative cross-lagged study. *Child Development, 82(6),* 2123-2137.

Hart, S.A., Logan, J.A.R., Soden-Hensler, B., Kershaw, S., Taylor, J., & Schatschneider, C. (2013). Exploring how nature and nurture affect the development of reading: An analysis of the Florida Twin Project on Reading. *Developmental Psychology, 49(10),* 1971-1981.

Høien-Tengesdal, I. (2010). Is the simple view of reading too simple? *Scandinavian Journal of Educational Research, 54(5),* 451-469.

Hoover, W.A. & Gough, P.B. (1990). The simple view of reading. *Reading and Writing: An Interdisciplinary Journal, 2,* 127-160.

Joshi, R.M. & Aaron, P.G. (2000). The component model of reading: Simple view of reading made a little more complex. *Reading Psychology, 21(2),* 85-97.

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.

Kendeou, P., Savage, R., & van den Broek, P. (2009). Revisiting the simple view of reading. *The British Psychological Society, 79,* 353-370.

Kirby, J.R. & Savage, R.S. (2008). Can the simple view deal with the complexities of reading? *Literacy, 42(2),* 75-82.

Kovas, Y., Garon-Carrier, G., Boivin, M., Petrill, S.A., Plomin, R., Malykh, S.B.,… Vitaro, F. (2015). Why children differ in motivation to learn: Insights from over 13,000 twins from 6 countries. *Personality and Individual Differences, 80,* 51-63.

Markwardt, F.C., Jr. (1989). *Peabody Individual Achievement Test – Revised.* Circle Pines, MN: American Guidance Service.

Morgan, P.L. & Fuchs, D. (2007). Is there a bidirectional relationship between children's reading skills and reading motivation? *Exceptional Children, 73(2),* 165-183.

Neale, M.C. (1997). Mx: Statistical modeling (4th ed). Richmond, VA: Department of Psychiatry, Virginia Commonwealth University.

Petrill, S.A., Deater-Deckard, K., Thompson, L.A., DeThorne, L.S., & Schatschneider, C.S. (2006). Genetic and environmental effects of serial naming and phonological awareness on early reading outcomes. *Journal of Educational Psychology, 98(1),* 112-121.

Petrill, S.A., Deater-Deckard, K., Thompson, L.A., Schatschneider, C., DeThorne, L.S., & Vandenbergh, D.J. (2007). Longitudinal genetic analysis of early reading: The Western Reserve Reading Project. *Reading and Writing, 20 (1-2),* 127-146.

Plomin, R., DeFries, J.C., Knopik, V.S., & Neiderhiser, J.M. (2013). Behavioral genetics (6th ed.). New York, NY: Worth Publishers.

Price, T.S., Freeman, B., Craig, I., Petrill, S.A., Ebersole, L., & Plomin, R. (2000). Infant zygosity can be assigned by parental report questionnaire data. *Twin Research, 3,* 129–133.

Rhemtulla, M. & Tucker-Drob, E.M. (2012). Gene-by-socioeconomic status interaction on school readiness. *Behavioral Genetics, 42,* 549-558.

Roberts, J.A. & Scott, K.A. (2006). The simple view of reading: Assessment and intervention. *Topics in Language Disorders, 26(2),* 127-143.

Ryan, R.M. & Deci, E.L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55,* 68-78.

Savage, R. (2001). The 'simple view' of reading: Some evidence and possible implications. *Educational Psychology in Practice, 17(1),* 17-33.

Scarborough, H.S. & Dobrich, W. (1994a). Another look at parent-preschooler bookreading: How naked is the emperor? A response to Lonigan (1994) and Dunning, Mason, and Stewart (1994). *Developmental Review, 14,* 340-347.

Scarborough, H.S. & Dobrich, W. (1994b). On the efficacy of reading to preschoolers. *Developmental Review, 14,* 245-302.

Semel, E., Wiig, E.H., & Secord, W.A. (2003). *Clinical Evaluation of Language Fundamentals, Fourth Edition*. San Antonio, TX: Harcourt Assessment, Inc.

Sesma, H.W., Mahone, E.M., Levine, T., Eason, S.H., & Cutting, L.E. (2009). The contribution of executive skills to reading comprehension. *Child Neuropsychology, 15(3),* 232-246.

Spinath, F.M., Spinath, B., & Plomin, R. (2008). The nature and nurture of intelligence and motivation in the origins of sex differences in elementary school achievement. *European Journal of Personality, 22,* 211-229.

Stromswold, K. (2001). The heritability of language: A review and metaanalysis of twin, adoption, and linkage studies. *Language, 77(4),* 647-723.

Tucker-Drob, E.M. (2012). Preschools reduce early academic-achievement gaps: A longitudinal twin approach. *Psychological Science, 23(3),* 310-319.

Tucker-Drob, E.M. & Harden, K.P. (2012a). Intellectual interest mediates gene x socioeconomic status interaction on adolescent academic achievement. *Child Development, 83(2)* 743-757.

Tucker-Drob, E.M. & Harden, K.P. (2012b). Learning motivation mediates gene-by-socioeconomic status interaction on mathematics achievement in early childhood. *Learning and Individual Differences, 22,* 37-45.

Tunmer, W.E. & Chapman, J.W. (2012). The simple view of reading redux: Vocabulary knowledge and the independent components hypothesis.

Wadsworth, S.J., Corley, R.P., Hewitt, J.K., Plomin, R., & DeFries, J.C. (2002). Parent-offspring resemblance for reading performance at 7, 12, and 16 years of age in the Colorado Adoption Project. *Journal of Child Psychology and Psychiatry, 43(6),* 769-774.

Wang, Z. Lukowski, S.L., Hart, S.A., Lyons, I.M., Thompson, L.A., Kovas, Y.,… Petrill, S.A. (in press). Is mathematics anxiety always bad for math learning: The role of math motivation. *Psychological Science.*

Wells, G. (1985). Preschool literacy-related activities and success in school. In D.R. Olson, N. Torrance, & A. Hildyard (Eds.). *Literacy, language, and learning* (pp. 229-255). Cambridge: Cambridge University Press.

Wigfield, A. (1997). Reading motivation: A domain-specific approach to motivation. *Educational Psychologist, 32(2),* 59-68.

Wigfield, A. & Guthrie, J.T. (1997). Relations of children's motivation for reading to the amount and breadth of their reading. *Journal of Educational Psychology, 89,* 420-432.

Wigfield, A., Guthrie, J. T., & McGough, K. (1996). A questionnaire measure of children's motivations for reading (Instructional Resource No. 22). Athens, GA: Universities of Georgia and Maryland College Park.

Wigfield, A., Guthrie, J.T., Tonks, S., & Perencevich, K.C. (2004). Children's motivation for reading: Domain specificity and instructional influences. *The Journal of Educational Research, 97(6),* 299-310.

Woodcock, R. W. (1987). *Woodcock Reading Mastery Tests, Form G-Revised*. Circle Pines, MN: American Guidance Service, Inc.

Appendix A: Tables and Figures

Table 1. Descriptive statistics for listening comprehension measures, the reading motivation measure, and reading comprehension measures.

Measure	N	Min	Max	Mean	Standard Deviation
Listening Measures					
CELF Understanding Spoken Paragraphs	489	1	15	10.72	3.04
TNL Narrative Comprehension	562	12	39	31.42	3.84
Listening Comp Factor Score	500	-3.50	1.89	.00	1.00
Reading Motivation					
MRQ	408	60	197	143.24	24.17
Reading Measures					
WRMT-R Passage Comprehension	524	1	57	38.49	7.66
PIAT-R Reading Comprehension	555	22	97	64.64	13.07
Reading Comp Factor Score	533	-4.98	2.44	.00	1.00

Note: CELF = Clinical Evaluation of Language Fundamentals- Fourth Edition; TNL = Test of Narrative Language; MRQ = Motivations for Reading Questionnaire; WRMT-R = Woodcock Reading Mastery Test- Revised; PIAT-R = Peabody Individual Achievement Test - Revised.

Table 2. Phenotypic correlations.

	1	2	3	4	5	6	7
Listening Measures							
1. CELF Understanding Spoken Paragraphs	1.00	.47*	.86*	.09	.47*	.42*	.49*
2. TNL Narrative Comprehension		1.00	.86*	.12	.53*	.47*	.54*
3. Listening Comp Factor Score			1.00	.12	.58*	.51*	.60*
Reading Motivation							
4. MRQ				1.00	.22*	.16*	.21*
Reading Measures							
5. WRMT-R Passage Comprehension					1.00	.70*	.92*
6. PIAT-R Reading Comprehension						1.00	.92*
7. Reading Comp Factor Score							1.00

Note: *p < .01. CELF Understanding Spoken Para. = Clinical Evaluation of Language Fundamentals- Fourth Edition, Understanding Spoken Paragraphs; TNL= Test of Narrative Language; MRQ = Motivations for Reading Questionnaire; WRMT-R = Woodcock Reading Mastery Test- Revised; PIAT-R = Peabody Individual Achievement Test - Revised.

Table 3. Monozygotic and dizygotic twin intraclass correlations.

	MZ	DZ
Listening Comprehension	.67**	.33**
Reading Motivation	.30*	.00
Reading Comprehension	.75**	.28**

Note: *p < .05, **p < .01.

Table 4. Univariate analyses.

Variable	a^2 (CI)	c^2 (CI)	e^2 (CI)
Listening Comprehension	.67* (.33-.76)	.00 (.00-.27)	.33* (.24-.46)
Reading Motivation	.24 (.00-.46)	.00 (.00-.21)	.76* (.54-1.0)
Reading Comprehension	.73* (.53-.80)	.00 (.00-.17)	.27* (.20-.37)

Note: *p < .05.

Table 5. Trivariate ACE analyses of listening comprehension, reading motivation, and reading comprehension.

Variable	A1 (CI)	A2 (CI)	A3 (CI)
Listening Comprehension	.80* (.32-.88)		
Reading Motivation	.13 (.00-.31)	.44 (.00-.64)	
Reading Comprehension	.71* (.50-.89)	.00 (.00-.60)	.46 (.00-.62)
	C1 (CI)	C2 (CI)	C3 (CI)
Listening Comprehension	.20 (.00-.77)		
Reading Motivation	.07 (.00-.46)	.00 (.00-.45)	
Reading Comprehension	.00 (.00-.42)	.00 (.00-.42)	.00 (.00-.42)
	E1 (CI)	E2 (CI)	E3 (CI)
Listening Comprehension	.57* (.48-.67)		
Reading Motivation	.08 (.00-.31)	.88* (.75-1.0)	
Reading Comprehension	.07 (.00-.20)	.14* (.02-.26)	.41* (.43-.59)

Note: *p < .05. A = additive genetic pathways; C = shared environmental pathways; E = nonshared environmental pathways.

Table 6. Trivariate ADE Analyses of Listening Comprehension, Reading Motivation, and Reading Comprehension

Variable	A1 (CI)	A2 (CI)	A3 (CI)
Listening Comprehension	.61 (.00-.87)		
Reading Motivation	.00 (.00-.61)	.00 (.00-.62)	
Reading Comprehension	.58 (.00-.88)	.00 (.00-.63)	.36 (.00-.63)
	D1 (CI)	D2 (CI)	D3 (CI)
Listening Comprehension	.55 (.00-.87)		
Reading Motivation	.26 (.00-.73)	.49 (.00-.71)	
Reading Comprehension	.39 (.00-.88)	.46 (.00-.62)	.32 (.00-.62)
	E1 (CI)	E2 (CI)	E3 (CI)
Listening Comprehension	.57* (.49-.67)		
Reading Motivation	.05 (.00-.29)	.83* (.68-.99)	
Reading Comprehension	.07 (.00-.19)	.14* (.01-.26)	.50* (.43-.58)

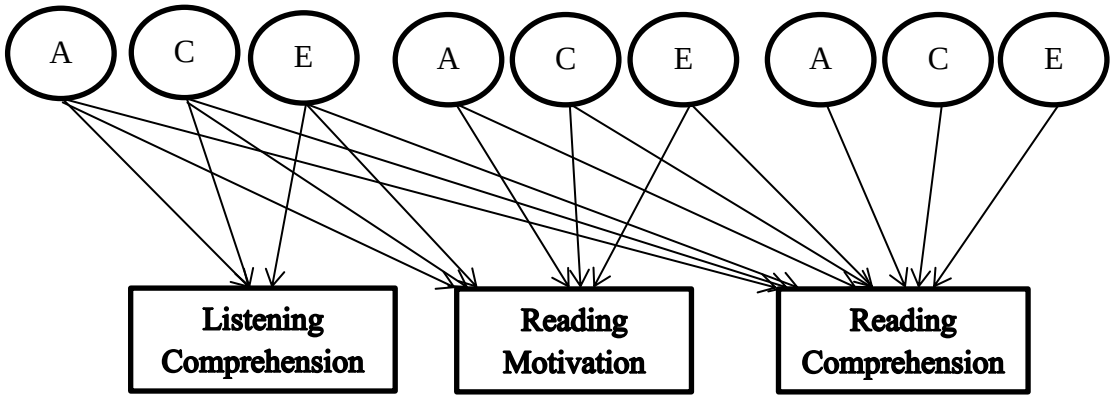
Note: *p < .05. A = additive genetic pathways; D = dominance pathways; E = nonshared environmental pathways.

Table 7. Comparisons of the AE, ACE, and ADE models for trivariate analyses.

	-2LL	df	AIC	BIC	-2LL Change	df Change	p
AE	2925.49	1099	727.49	-1633.57			
ACE	2925.49	1093	739.49	-1616.67	0.00	6	1.0
ADE	2923.11	1093	737.11	-1617.86	2.38	6	.88

Note: All model comparisons are based on the AE model.

Figure 1. Trivariate Cholesky model. This model decomposes the variance in and covariance between Listening Comprehension, reading motivation, and Reading Comprehension into latent genetic (A), shared environment (C), and nonshared environmental (E) components that are common to listening comprehension, reading motivation, and reading comprehension (A1, C1, E1), that are common to reading motivation and reading (A2, C2, E2), and that are unique to reading comprehension (A3, C3, E3).



Appendix B: Motivation for Reading Questionnaire.

How Do You Feel About Reading?

We are interested in your reading. The statements on the next page tell how some students feel about reading. Read each statement and decide whether it talks about a person who is **like** you or **different** from you. There are no right or wrong answers. We only want to know how you feel about reading.

Here are some examples:

1. If the statement is very different from you, circle a "1".
2. If the statement is a little different from you, circle a "2".
3. If the statement is a little like you, circle a "3".
4. If the statement is a lot like you, circle a "4".

Here are some practice questions:

	Very Different From Me	A Little Different From Me	A Little Like Me	A Lot Like Me
1. I like ice cream.	1	2	3	4
2. I like to swim.	1	2	3	4
3. I like spinach.	1	2	3	4

	Very Different From Me	A Little Different From Me	A Little Like Me	A Lot Like Me
1. I visit the library often with my family.	1	2	3	4
2. I like hard, challenging books.	1	2	3	4
3. I know that I will do well in reading next year.	1	2	3	4
4. I do as little schoolwork as possible in reading.	1	2	3	4
5. If the teacher discusses something interesting, I might read more about it.	1	2	3	4
6. I read because I have to.	1	2	3	4
7. I like it when the questions in books make me think.	1	2	3	4
8. I read about my hobbies to learn more about them.	1	2	3	4
9. I am a good reader.	1	2	3	4
10. I read stories about fantasy and make believe.	1	2	3	4
11. I often read to my brother or sister.	1	2	3	4
12. I like being the only one who knows an answer in something we read.	1	2	3	4
13. I read to learn new information about topics that interest me.	1	2	3	4
14. My friends sometimes tell me I'm a good reader.	1	2	3	4
15. I learn more from reading than most students in my class.	1	2	3	4
16. I like to read new things.	1	2	3	4
17. I like hearing the teacher say I read well.	1	2	3	4
18. I like being the best at reading.	1	2	3	4
19. I look forward to finding out my reading grade.	1	2	3	4
20. I sometimes read to my parents.	1	2	3	4
21. My friends and I like to trade things to read.	1	2	3	4
22. It is important for me to see my name on a list of good readers.	1	2	3	4
23. I **don't** like reading something when the words are too difficult.	1	2	3	4
24. I make pictures in my mind when I read.	1	2	3	4
25. I always do my reading work exactly as the teacher wants it.	1	2	3	4
26. I usually learn difficult things by reading.	1	2	3	4
27. I **don't** like vocabulary questions.	1	2	3	4
28. Complicated stories are no fun to read.	1	2	3	4
29. I am happy when someone recognizes my reading.	1	2	3	4
30. I feel like I make friends with people in good books.	1	2	3	4

	Very Different From Me	A Little Different From Me	A Little Like Me	A Lot Like Me
31. My parents often tell me what a good job I'm doing in reading.	1	2	3	4
32. Finishing every reading assignment is very important to me.	1	2	3	4
33. I like mysteries.	1	2	3	4
34. I talk to my friends about what I am reading.	1	2	3	4
35. If I am reading about an interesting topic, I sometimes lose track of time.	1	2	3	4
36. I like to get compliments for my reading.	1	2	3	4
37. Grades are a good way to see how I'm doing in reading.	1	2	3	4
38. I like to help my friends with their schoolwork in reading.	1	2	3	4
39. I read to improve my grades.	1	2	3	4
40. My parents ask me about my reading grade.	1	2	3	4
41. I enjoy a long, involved story or fiction book.	1	2	3	4
42. I like to tell my family about what I am reading.	1	2	3	4
43. I try to get more answers right than my friends.	1	2	3	4
44. If a project is interesting, I can read difficult material.	1	2	3	4
45. I enjoy reading books about people living in different countries.	1	2	3	4
46. I read a lot of adventure stories.	1	2	3	4
47. I always try to finish my reading on time.	1	2	3	4
48. If a book is interesting, I don't care how hard it is to read.	1	2	3	4
49. I like to finish my reading before other students.	1	2	3	4
50. In comparison to my other school subjects, I am best at reading.	1	2	3	4
51. I am willing to work hard to read better than my friends.	1	2	3	4
52. I **don't** like it when there are too many people in the story.	1	2	3	4
53. It is very important to me to be a good reader.	1	2	3	4
54. In comparison to other activities I do, it is very important for me to be good at reading.	1	2	3	4