From Preschool Language Skills to Writing in Adolescence: Evidence of Genetic Continuity

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Data, study materials, and analysis code are not available publicly but can be shared upon request (for access to data, see http://www.gripinfo.ca/grip/public/www/Etudes/en/dadprocedures.asp). This study was not preregistered. Correspondence concerning this article should be addressed to Sophie Aubé, École de psychologie, Université Laval, Pavillon Félix-Antoine-Savard, 2325 Allée des Bibliothèques, Québec, QC G1V 0A6, Canada. Email: sophie.aube.1@ulaval.ca.

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Abstract

Given the importance of writing for academic achievement, this study aimed to understand how early oral language contributes to later writing skills. The first objective was to determine if preschool language skills were associated with high school writing, and if so, whether they contributed directly or indirectly through school age language. The second aim was to explore the extent to which genetic and environmental factors explained these potential associations. The sample was drawn from the Quebec Newborn Twin Study, a longitudinal follow-up of twins born in the greater Montreal area, Quebec, Canada. Language skills were assessed when children were 1.5, 2.5, 6, 7, 10, and 12 years old. Writing skills were measured at 15 years old. Participants who completed the writing task in French were included in the study (n = 316 twin pairs: 46% males). Mothers of these participants self-identified mostly as Caucasian. About 74% of them had a postsecondary diploma or certificate, and 27% further had a university degree. Most families had an income higher than 30,000 CND. Results indicate that preschool language was modestly associated with high school writing \( (r = .25) \) and that school age language fully mediated this association. Genes explained 53% of the association between preschool language and school age language, and 64% of the association between school age language and high school writing. These results highlight the developmental continuity from oral to written language from preschool to high school and show that genetic factors largely account for this continuity.

Keywords: Writing; Oral Language; Genes; Twin Study; Longitudinal Study
Introduction

Language and writing are crucial to human development. Writing is one of the best predictors of later academic achievement (Kobrin et al., 2008; Preiss et al., 2013; Wells, 1981), which in turn predicts future educational engagement (Alivernini & Lucidi, 2011), economic security and well-being at the individual and societal levels (Dolan et al., 2008; Reynolds et al., 2011). Given that the onset of oral language precedes that of written language, and oral language provides the phonological, lexical, and syntactical bases to written language (Berninger, 2000; Berninger et al., 2006; Dionne et al., 2013), early language skills should be good predictors of writing skills. The question is whether this phenotypic continuity can be observed from the onset of language development through high school.

Many studies have shown that oral language skills are associated with writing skills at various stages of development, from preschool to high school (Abbott et al., 2010; Coker, 2006; Hooper et al., 2010; Jin et al., 2020; Kent et al., 2014; Kim et al., 2011, 2013, 2015; Kovas et al., 2007; Olson et al., 2013). However, these studies used cross-sectional designs or designs across short age spans (e.g., adjacent school levels). Furthermore, it is well established that the contribution of genetic factors to oral language increases from modest to moderate from preschool to adulthood, whereas that of environmental factors declines (Dale et al., 2010; deZeeuw et al., 2015; Hayiou-Thomas et al., 2006, 2012; Hoekstra et al., 2007). In contrast, the contribution of genes to individual differences in writing skills is high from onset (Bus & Out, 2009; Grasby et al., 2016; Oliver et al., 2007). These etiological differences warrant exploring the etiology of the association between oral language and complex writing skills as the role of common genetic and environmental bases remains unclear. The objectives of this study were to understand the continuity from early language skills to writing over the long term, and the underlying etiological processes involved. To do so, we examined the phenotypic associations between preschool language skills and high school writing skills, as well as their genetic and environmental underpinnings.
The Phenotypic Association Between Language and Writing

Language development is known to be substantially stable over time, from early childhood through adolescence (Dionne et al., 2003; Hayiou-Thomas et al., 2012; Hoekstra et al., 2007). Hayiou-Thomas and her colleagues (2012) followed a large sample of children assessed on expressive language, cognitive and behavioural development between the ages of 2 and 12 years. Results showed that, over that 10-year span, language measures were increasingly stable ($r_s = .12–.63$). In another sample of children followed over a 13-year period, from ages 5 to 18, verbal abilities showed an even higher stability into late adolescence ($r_s = .51–.64$; Hoekstra et al., 2007).

Two milestones in children’s early language development have been shown to be good predictors of their future oral language skills (Hoff, 2014). First, children’s expressive vocabulary reaches the 50-word count on average around 1.5 years of age, and this threshold is usually accompanied by the onset of word combinations. Second, around 2.5 years, children’s expressive vocabulary reaches 500 words on average, and the average mean length of utterances is 2.5 words (Benedict, 1979; Bouchard et al., 2009; Hoff, 2014). Delayed acquisition of these milestones is one indication of potential language difficulties that could persist throughout childhood and beyond (Dale et al., 2003; Rescorla, 2002). By extension, the early attainment of these milestones predicts early achievement in several academic domains (Shonkoff & Phillips, 2000; Shore, 1997).

Concerns about early language development come from the fact that it lays general foundation for the acquisition of reading and writing (Bleses et al., 2016; NICHD Early Child Care Research Network, 2005; Shanahan, 2006). For instance, when children learn to write, they can rely on the oral knowledge they have already acquired, such as phonological awareness, lexicon, and syntactic structures, to make their writing more efficient (Shanahan, 2006). Besides, it has been shown that reading and writing rely on the same linguistic knowledge (e.g., orthographic knowledge) so that the use of such knowledge in
one domain facilitates performance in the other domain (see Shanahan, 2006, for a review). In this sense, oral language, reading, and writing can all be viewed as components of language development, with common underlying processes linking the oral and written, as well as the expressive and receptive forms of language (Silvén et al., 2007; St-Pierre et al., 2010). According to this view, oral language is the receptive, expressive, and oral forms of language, reading is the receptive and written forms of language, and writing can be viewed as the end point of the language development continuum and described as the written and expressive forms of language (Dionne et al., 2013; Kent et al., 2014).

Although an adequate mastery of oral language is required for progress in school, with age, school achievement relies increasingly on writing skills. For instance, children with a better understanding of the fundamentals of writing in kindergarten and with better writing skills at school entry are likely to achieve a higher level of attainment two years later (Wells, 1981). Even though individual differences appear early in the process of writing (Berninger & Fuller, 1992), they become more salient during adolescence as written productions increase in complexity (Grasby et al., 2016; Olson et al., 2013). Indeed, around the end of mandatory schooling, written skills are one of the best predictors of the pursuit and achievement in postsecondary forms of schooling (Kobrin et al., 2008; Preiss et al., 2013; Wells, 1981), which in turn predict economic and social success, both individually and collectively (Dolan et al., 2008; Reynolds et al., 2011).

Despite the demonstrated importance of writing, few studies have investigated the association between oral language and writing. The association between oral language and reading, however, has been reviewed numerous times and spans well beyond kindergarten measures (e.g., Dionne et al., 2013; Liu et al., 2010). For instance, children’s early vocabulary (from 1.5 to 3 years of age) was found to be significantly correlated with reading outcomes at ages 7, 9, and 10 (rs = .23–.29; Harlaar et al., 2008; Lee, 2011), and even at ages 12 and 16 (rs = .25–.41; Suggate et al., 2018). These findings suggest that the
rate of oral language development in the early preschool years is already indicative of reading skills throughout childhood and adolescence (Dionne et al., 2013; Suggate et al., 2018).

The few studies exploring the relation between oral language and writing have also shown that language skills are associated with the quality of written compositions in childhood (e.g., Hooper et al., 2010; Kent et al., 2014; Kim et al., 2011, 2013, 2015) and adolescence (Olson et al., 2013), although the available studies were conducted over short periods of time. For instance, Kent and his colleagues (2014) followed 265 children from kindergarten to first grade. Expressive vocabulary and grammatical knowledge were assessed in kindergarten, and basic writing skills (development and organization of ideas) in kindergarten and first grade. The phenotypic correlation between the language and writing measures in kindergarten was .35, while correlations between language skills in kindergarten and writing in first grade varied from .33 to .42.

In another study, Olson and his colleagues (2013) examined older children between the ages of 8 and 18 years ($N = 540$) at one time point. Language was assessed using a receptive vocabulary task and writing was assessed with three tasks: writing sample, writing fluency, and handwriting copy. In the writing sample task, participants had to write a single sentence in response to the tester’s oral directives. The writing fluency task required using three target words in a complete grammatical sentence, while in the handwriting copy task, speed and accuracy were assessed. Phenotypic correlations between the language and writing measures were of the same magnitude ($rs = .34–.58$) as those observed by Kent et al. (2014), indicating substantial cross-sectional associations over the schooling period.

Oral and written language could also be associated over a longer period of time. Given the stability of individual differences in language skills throughout development (Hayiou-Thomas et al., 2012; Hoekstra et al., 2007) and the demonstration of an association between language and writing at
school age (e.g., Jin et al., 2020; Kent et al., 2014; Kim et al., 2011; Kovas et al., 2007), associations between early language and later writing could be mediated by developing language skills. As such, early language could predict later writing because early language predicts later language development, and because later language skills contribute to the development of writing skills. Accordingly, the first objective of the present study was to evaluate whether there was a longitudinal association between preschool language skills and high school writing skills, and whether this potential association could be mediated by developing language skills in primary school.

The Etiology of Oral Language and Writing

There is substantial research showing that language and writing skills are associated in childhood and adolescence (e.g., Kent et al., 2014; Kim et al., 2011; Kovas et al., 2007; Olson et al., 2013). This is not surprising given that writing is the written form of expressive language and that common underlying processes link the oral and written forms of language. However, beyond the phenotypic association between language and writing, it is essential to evaluate the extent to which genetic and environmental factors account for this association. Indeed, documenting these etiological processes would allow a better understanding of the common factors underlying oral and written language, and would thus clarify targets for intervention. For instance, the association between oral and written language may be due to children’s environment, such as the quality of schooling or literacy exposure at home. In fact, it has been demonstrated that a larger number of books available in one’s household, as well as a higher frequency of parental reading at younger ages were associated with children’s literacy skills, including language and writing (Deckner et al., 2006; Sénéchal & LeFevre, 2002). On the other hand, this association could also be due to children’s genetic endowment, such as their heritable cognitive abilities or specific genes that are associated with both language and writing (Plomin & Kovas, 2005). For instance, some highly heritable cognitive abilities, such as nonverbal intelligence and working memory, have been found to be associated with language and writing (Alloway & Alloway, 2010; Bouchard, 2004;
Chenault et al., 2006; Quinn & Wagner., 2018; Shapland et al., 2020). Early interventions targeting children with language difficulties need to consider the underlying genetic or environmental liability in the language domain as it may predispose them to difficulties in learning to write over the years.

**The Power of the Twin Design to Unravel the Etiology of Oral Language and Writing**

Twin studies compare monozygotic (MZ) and dizygotic (DZ) twin pairs’ similarities to quantify the relative contributions of genetic and environmental factors to a given phenotype (Knopik et al., 2016). Because MZ twins share 100% of their genes, whereas DZ twins share on average 50% of their genes, as do non-twin siblings, the extent to which MZ twins are more similar than DZ twins on a phenotype can be attributed to genetic factors (A). Both MZ and DZ twin pairs also share a portion of their environment, increasing their similarities. The extent to which both twins of a pair are similar on a given phenotype, regardless of their genetic similarity, can be attributed to shared environmental factors (C). Socio-economic status and parenting style are some factors likely to increase similarities between siblings. The remaining variance can be attributed to unique environmental factors (E), such as exposure to different teachers and measurement error, that can make twin siblings different.

By extension, it is possible to estimate the contributions of genetic and environmental factors to the association between two phenotypes, such as language and writing. Following the previous reasoning, the extent to which the association between one phenotype in one twin and the other phenotype in the second twin is greater in MZ than DZ twins indicates the relative contribution of genetic factors to the association. For instance, if the correlation between language and writing is higher for MZ than DZ twins, it means that the association between the two variables is at least partly accounted for by genes. By contrast, strong cross-phenotypic associations across twins, regardless of their genetic similarity, indicate a contribution of shared environmental factors to the association (Plomin et al., 2008). For example, if the correlation between language and writing is high for both MZ
and DZ twins, it means that the association between the two variables is partly accounted for by shared environment. As for a single phenotype, the remaining covariance between two phenotypes can be attributed to unique environmental factors.

**The Etiology of Oral Language**

In preschoolers, studies have shown that individual differences in language skills are largely explained by shared environmental factors ($C \approx .50$), and to a lesser extent by genes ($A \approx .30$; Dionne et al., 2003; Hayiou-Thomas et al., 2012; Samuelsson et al., 2005; Spinath et al., 2004). For instance, the International Longitudinal Twin Study, a study of 4- and 5-year-old twins from Australia, Scandinavia, and the United States, found that individual differences in receptive vocabulary and grammatical skills were mainly accounted for by shared environmental factors ($C = .59–.60$) and moderately by genetic factors ($A = .29–.32$; Samuelsson et al., 2005; $N = 1,254$).

Results change in older children, as the genetic contribution to individual differences in language increases. A meta-analysis of 61 studies from 11 cohorts of primary school twins, aged between 6 and 12 years old (deZeeuw et al., 2015; $N = 12,414$), showed that 64% of individual differences in overall language skills were explained by genetic factors, with only a 15% contribution from shared environmental factors. Dale et al. (2010) obtained similar findings in slightly older children. They administered four measures of receptive language (vocabulary, grammar, figurative language, and inferences) in a sample of 12-year-old twins ($N = 4,892$). Results indicated that genes were the main factor explaining individual differences ($A = .25–.36$). Indeed, increasing heritability of phenotypes with development is a frequent finding (Haworth et al., 2010; Hayiou-Thomas et al., 2012; Hoekstra et al., 2007). More importantly, one study investigating the genetic and environmental sources of continuity and changes from preschool to early adolescence (Hayiou-Thomas et al., 2012; $N = 15,772$) found that, while etiologic patterns changed and new genetic factors came into play by middle childhood (7, 9 and
10 years old), the stability of language skills was largely accounted for by genes ($r_{yg} = .36–.85$). Possibly, the environment becomes more homogeneous across children as they enter school, leaving less room for environmental factors to explain individual differences.

**The Etiology of Writing**

Several longitudinal studies have shown that individual differences in reading throughout childhood are mainly accounted for by genes ($A = .49–.73$; Andreola et al., 2021; deZeeuw et al., 2015; Little et al., 2017). Similarly, the etiology of writing differs from that of language in that the contribution of genetic factors is high from onset (Bus and Out, 2009; Grasby et al., 2016; Kovas et al., 2007; Oliver et al., 2007). In a small sample of 4-year-old twins from the Netherlands Twin Register ($N = 66$), Bus and Out (2009) assessed early writing skills (writing one’s name and “mama”) and estimated that 63% and 73% of individual differences, respectively, depended on genetic factors. Findings are similar in older children. In an Australian sample of twins between 8 and 15 years of age ($N = 1,940$), Grasby and her colleagues (2016) assessed reading, spelling, grammar, punctuation, and text writing using the National Assessment Program in Numeracy and Literacy test. The writing task was marked using several criteria, including text structure, development of ideas, vocabulary, cohesion, punctuation, and spelling. The heritability of writing was moderate and remained quite stable from primary to high school, explaining from 39% to 52% of the variation in scores, whereas the contribution from shared environment was minimal ($C = .01–.12$). The contribution from unique environment was moderate, possibly driven from measurement error ($E = .42–.52$). Indeed, due to their complexity, writing measures are known to be vulnerable to measurement error (Grasby et al., 2016). In sum, between 4 and 15 years of age, writing, like reading, remains largely heritable, with minimal contribution from shared environment and moderate contribution from unique environment.

**The Etiology of the Association Between Oral Language and Writing**
Aside from assessing the etiology of language and writing skills separately, twin studies can also estimate the extent to which the same genetic and environmental factors contribute to individual differences in language and writing skills. In one study addressing this question, Kovas and her colleagues (2007) assessed a large sample of twins at 7, 9, and 10 years of age (N = 5,084–11,482). At each age, the twins’ teachers assessed broad abilities based on the U.K. National Curriculum, including speaking, listening, reading, and writing in English, using a 5-point scale. Phenotypic correlations between language and reading were strong (r = .64 at 7 years; r = .69 at 9 years; r = .71 at 10 years) and explained by the same genetic factors at all ages (rs_g = .67, .72, and .63 at 7, 9, and 10 years, respectively; Kovas et al., 2007). Several other studies on the association between oral language and reading, including longitudinal studies, obtained similar findings (e.g., Byrne et al., 2006; Hayiou-Thomas et al., 2006, 2010; Tosto et al., 2017). The pattern of results for writing was the same as for reading: phenotypic correlations between language and writing were high from onset and slightly increasing with age (r = .56 at 7 years; r = .67 at 9 years; r = .71 at 10 years). Results indicated that the correlations between language and writing were largely explained by the same genetic factors at all ages (rs_g = .72, .80, and .61 at 7, 9, and 10 years, respectively; Kovas et al., 2007). These results show that, cross-sectionally, genetic factors largely explain the associations between language and writing. However, we lack longitudinal data to address this question. Accordingly, the second objective of the present study was to determine the extent to which genetic and environmental factors could explain the longitudinal association between preschool language skills and high school writing skills.

The Present Study

Most studies on the association between language and writing were cross-sectional (Abbott et al., 2010; Kovas et al., 2007) or used short time intervals within the same grade level (Coker, 2006; Kent et al., 2014; Kim et al., 2011, 2013), across adjacent grade levels (Coker, 2006; Kent et al., 2014), or with up to three-year spans (Hooper et al., 2010; Jin et al., 2020; Kim et al., 2015). We need studies that span
a longer developmental window to further examine processes underlying the language domain continuum from the oral to the written forms. To do so, children’s early language development should be the starting point. Moreover, writing skills in late adolescence should reach the level of complexity needed to pursue educational goals beyond high school, because they provide a proper end point to this developmental window. Within this developmental window, school age language skills provide a midpoint that enables to test for hypothesized mediational processes.

Accordingly, the first aim of this study was to determine whether preschool language skills contribute to high school text writing, and if so, whether they do so directly or indirectly through school age language. To further examine these processes, the second aim was to determine the extent to which genetic and environmental factors accounted for these associations. To reach these aims, we conducted a longitudinal twin study in which 316 twin pairs were assessed on oral language at 1.5, 2.5, 6, 7, 10, and 12 years old and on writing at 15 years old.

**Methods**

**Participants**

The sample was drawn from the Quebec Newborn Twin Study (QNTS; Boivin et al., 2019), a longitudinal follow-up of a birth cohort of twins born between 1995 and 1998 in the greater Montreal area, Quebec, Canada. The goal of the QNTS is to document individual differences in cognitive, behavioral, and social-emotional aspects of development across childhood, adolescence, and adulthood, their early bio-social determinants, as well as aspects of the environment surrounding the twins. A total of 662 families of twins were initially recruited when the twins were 6 months old. Inclusion criteria at onset were the fluent use of French or English by the mother and no major medical complications at birth. Children were followed quasi-annually from birth to adolescence: They were assessed five times during preschool (average ages 0.5, 1.5, 2.5, 4, and 5 years old), five times during primary school
(average ages 6, 7, 9, 10, and 12 years old), and four times during high school (average ages 13, 14, 15, and 17 years old).

The study was approved by Université Laval’s research ethics board (#2009-166: *Individual, family and school level predictors of text writing skills in high school: A longitudinal twin study*). Parental consent was obtained before each data collection. In this study, we included families for which both twins completed the writing task in French at age 15 (n = 316 twin pairs: 46% males and 54% females). There were 118 MZ twin pairs and 192 DZ twin pairs. Zygosity was missing for 6 pairs. Participants who completed the writing task in English (n = 119) were excluded given that the scores for the English version of the task are calculated differently than those for the French adaptation (Wechsler, 2001, 2005). Mothers of our sample self-identified mostly as Caucasian (79%), and a minority as Black (2%), Asian (< 1%), or multi-racial (1.6%), others being missing or unknown. At 5 months old, most of the twins (72%) had a mother with a postsecondary diploma or certificate; 27% of the mothers further had a university degree. Most families (66%) had an income higher than 30,000 CND.

Data, study materials, and analysis code are not available publicly, but can be shared upon request (for access to data, see Groupe de recherche sur l’inadaptation psychosociale chez l’enfant, 2022). This study was not preregistered.

**Measures and Procedures**

**Preschool Language**

At both 1.5 and 2.5 years, receptive and expressive language were assessed with a parent-rated 77-word (1.5 years old) or 100-word (2.5 years old) checklist adapted for this study (Dionne et al., 2008). Parents indicated words the child was able to say (expressive) and words the child only understood (receptive). There was an interval of two weeks that separated the completion of each of the twins’ questionnaire to minimise spurious inflation of the correlations between the twins. This parental
questionnaire was inspired from the MacArthur Communicative Development Inventories (Fenson et al., 1994), a measure of child language validated in several languages, including French (Boudreault et al., 2007).

The correlations between the four measures ranged from modest to strong ($r = .22–.66$; see Table 1). Scores on each measure at each time point were corrected for gestational age and were standardized to $Z$ scores. Then, we averaged the four $Z$ scores to create a preschool language composite score. Aggregating measures from multiple sources allows to simplify the model, hence, having more statistical power.

**School Age Language**

At school age, language was assessed using a variety of direct and teacher-report measures. At both 6 and 7 years, when children were in kindergarten and first grade, teachers completed eight items from the Communication Skills domain of the French version of the Early Development Instrument (EDI; Janus & Offord, 2007), each one being on a 1-to-5-point scale from *very poor* to *excellent*: “ability to listen in French”, “ability to tell a story”, “ability to take part in imaginative play”, “ability to communicate own needs in a way understandable to adults and peers”, “ability to understand on first try what is being said to him/her”, “ability to articulate clearly, without sound substitutions”, “ability to use language effectively in French”, “answers questions showing knowledge about the world”. These eight items were averaged and converted to a 0-to-10 scale, following Janus and Offord’s recommendations (2007). The internal consistency of this scale was calculated for our sample and is excellent ($\alpha = .91$), which is consistent with the one calculated by Janus and Offord (2007; $\alpha = .95$).

When participants were 7, language was assessed using the Vocabulary subtest of the French version of the third edition of the Wechsler Intelligence Scale for Children (WISC-III; Wechsler, 1991) and the French adaptation of the Peabody Picture Vocabulary Test (PPVT; Dunn et al., 1993). Both were
administered in laboratory settings. In the Vocabulary subtest of the WISC-III, participants were asked to define a list of 30 words. Answers were scored on a 0-to-2 scale depending on accuracy. Following WISC-III standard administration, the task was stopped after four consecutive failed items (ceiling was reached). Inter-rater reliability is good for this measure, with an intra-class correlation coefficient of .98 (Wechsler, 1991). In the PPVT, participants had to choose, out of a set of four black and white pictures, the one that best depicted a word given by the tester. The test includes 170 words, each worth 1 point, and following PPVT instructions, the task was stopped after the occurrence of six failed items out of eight (ceiling was reached). Stability is good for the PPVT, with a test-retest correlation coefficient of .84 (Bracken & Murray, 1984).

At ages 10 and 12, when children were in fourth and sixth grade respectively, teachers rated children’s oral language using one item (“ability to clearly express an idea”) on a scale from 1 (significantly below average) to 5 (significantly above average). The association between teachers’ ratings and children’s academic achievement, including oral language, has been demonstrated to be strong in several studies ($r = .60–.63$; Kowalski et al. 2018; Südkamp et al., 2012).

Correlations among measures ranged from .29 to .58 (see Table 1). Scores on each measure at each time point were corrected for gestational age and were standardized to $Z$ scores. The three $Z$ scores at 7 were first averaged. Then, the $Z$ scores at 6, 7, 10, and 12 were averaged into a school age language composite. This aggregation was done for the same reasons than for the preschool language.

**High School Writing**

In the third year of high school, when the twins were 15 years old on average, they were met at their home and completed the French adaptation of the Written Expression scale of the Wechsler Individual Achievement Test-II (WIAT-II; Wechsler, 2005). This scale includes three subtests: Word Fluency, Sentences, and Essay. In the Word Fluency subtest, participants had to write as many words
representing circular objects as they could in one minute. The score for each word varied between 0 and 2: 0 point was assigned if the answer did not refer to a circular object, 1 point was assigned for each correct answer corresponding to a one-syllable word (e.g., ball), and 2 points were assigned if the correct answer corresponded to a multiple-syllable word (e.g., orange). Following WIAT-II instructions, the total score was converted into quartiles (maximal score of 4). In the five-item Sentences subtest, participants had to combine short sentences read out loud into one longer, well-constructed sentence without using the link word “and”. One point was awarded for each semantically and grammatically correct sentence and an additional point was awarded if spelling, verb tense, and punctuation were accurate for a maximal total score of 10. In the Essay subtest, participants were given 10 minutes to handwrite an approximately 20-line argumentative text (minimum 30 words) on mandatory physical education at school. The text was graded on 24 criteria evaluating Mechanics, Organization, Theme Development, Vocabulary, and Grammar, with a maximal score of 41.

The scores from each subtest were added for a maximum of 55. The scale has good test-retest reliability (r = .82; Wechsler, 2005). The inter-rater agreement calculated on 69 participants from the present study is excellent for Word Fluency (α = .96), Sentences (α = .83), each component of the Essay subtest (α = .83–.95), and the total score (α = .94).

Knowing that oral language provides the phonological, lexical, syntactical, and semantic bases to writing (Dionne et al., 2013), we also calculated a writing score that is less dependent on oral language with the goal of replicating our results with that measure of higher-order writing skills. Indeed, finding an association between early oral language and later higher-order writing skills would be a strong demonstration of a link between language and writing. The measure of higher-order writing skills was computed by adding all items that are more specific to writing and to the organization of an argumentative text, that is, all scores from the Word Fluency subtest, as well as the Mechanics component, the Theme Development component, and the Organization component (all items but A and
B, which evaluate sentence organization rather than text organization) of the Essay subtest (maximum score of 29).

The total score of writing (i.e., sum of the three subtests) and the calculated measure of higher-order writings skills were each corrected for gestational age and converted to Z scores. The total score of writing was used in the main analyses and the measure of higher-order writings skills was used solely to replicate these analyses.

**Statistical Analyses**

Data preparation was performed using all data available in the QNTS. No univariate outliers were identified in our scores. The preschool language measure was transformed by inverting the scores to correct skewness. Following these changes, all our variables were normally distributed (skewness ranged from $.01$ to $.45$ and kurtosis ranged from $.26$ to $2.05$). Two multivariate outliers from one twin pair were identified. Results were the same with or without the multivariate outliers, so they were kept in our analyses. Our final sample included 316 twin pairs.

Descriptive statistics and phenotypic correlations were computed with raw scores in IBM SPSS Statistics 26. Mediation and genetic analyses were carried out using Z scores on Mplus 8. Missing data were handled with Full Information Maximum Likelihood to obtain the parameter estimates for all available data (Arbuckle, 1996; Finkbeiner, 1979; Lai, 2020; Lee, 1986).

First, a mediation model was tested for a direct path from preschool language to high school writing, as well as for an indirect path through school age language (see Figure 1). Given that twins from a pair come from the same family, the robust maximum likelihood estimator was used in all analyses to control for the non-independence of the data. Bootstrap procedures were used to test the significance of the indirect effects. We drew 2000 random samples with replacement from the original sample to generate bias-corrected confidence intervals.
Second, intraclass correlations between MZ and DZ twins, as well as univariate and multivariate genetic analyses were conducted to estimate the contributions of genes, shared environment, and unique environment to the variance of the three measures (preschool language, school age language, and high school writing) and to each path of the mediation model (see Figure 2). Specifically, the univariate models provided information on the contributions of genes, shared environment, and unique environment to each measure, while the multivariate model specified the proportion of variance that was unique to each measure or shared with another measure. For instance, a univariate model could show that 50% of the variance in a variable is explained by genetic factors, 30% by shared environmental factors, and 20% by unique environmental factors. A multivariate model could further show that 25% of the variance in the variable is explained by genetic factors that are unique to the variable, while the other 25% is explained by genetic factors that are shared with another variable. The multivariate model also indicated the proportion of covariance accounted for by genes, shared environment, and unique environment; in other words, for a given association between two variables (e.g., for a given path in the mediation model), the multivariate model indicated the contributions of genes, shared environment, and unique environment. For instance, the multivariate model could show that 60% of the covariance between two variables is accounted for by genetic factors, 35% by shared environmental factors, and 5% by unique environmental factors.

Three indices were used to quantify goodness of fit in the multivariate genetic analyses: the comparative fit index (CFI), the root mean square error of approximation (RMSEA), and the ratio of chi-square to degrees of freedom ($\chi^2/df$). A CFI value of .90 or higher, a RMSEA value below .05, and a $\chi^2/df$ less than 3 are indicators of a good fit (Kline, 2010; McDonald & Ho, 2002). A power analysis based on RMSEA and sample size (Preacher & Coffman, 2006) revealed reasonable power for our multivariate model (.79) given the usual recommended threshold (i.e., .80, see Hancock & Freeman, 2001).

Results
Descriptive Statistics

Descriptive statistics for individual language and writing measures are presented in Table 2 and correlations between measures are presented in Table 1. Correlations between language and writing were modest and increased slightly with age (from $r = .15-.24$ at 1.5 year to $r = .40$ at 12 years). Correlations between composite scores were also computed. The correlation between preschool language and high school writing ($r = .25, p < .001$) and the one between school age language and high school writing ($r = .51, p < .001$) were both significant.

Mediation Model

In regard to the first aim of the study, Figure 1 shows the results of the mediation model. A mediation was observed whereby preschool language predicted school age language, which in turn predicted high school writing. The indirect predictive association through school age language was significant (estimate = .20, 95% CI = .14-.26), whereas the direct association from preschool language to high school writing was not (95% CI = -.04-.16), such that the mediation was total. Approximately 27% of the variance of high school writing was accounted for by the model. The pattern of results was similar when using the measure of higher-order writings skills instead of the total score of writing.

Genetic Models

Table 3 summarizes the results of the intraclass correlations between MZ, same-sex DZ and opposite-sex DZ twins. For all variables, the intraclass correlations were higher for MZ twins than for DZ twins, suggesting genetic contributions to the variables. Generally, correlations were also high for both MZ and DZ twins, especially for the language measures, suggesting contributions of shared environment to these variables. Of course, the correlations among MZ twins were not perfect, indicating a contribution of unique environment, including measurement error.
Table 3 also presents the results of the univariate genetic models. Consistent with the intraclass correlations, the contributions of genetic factors, shared environment, and unique environment were significant for the two language measures, although with a stronger genetic component for school age language than for preschool language, for which shared environment accounted for more than half of the variance. Writing was mainly characterized by a strong contribution of genetic factors, leaving only 29% of the variance to unique environment. The pattern of results was similar when using the measure of higher-order writings skills instead of the total score of writing.

Figure 2 presents the multivariate genetic model, in which paths represent proportions of variance that are unique to each measure or shared with another measure (see also Supplementary Table 1 for the unstandardized estimates). The multivariate model fits the data well: $\chi^2(34) = 25.02$, $p = .89$, RMSEA = .00, CFI = 1.00, $\chi^2/df = .74$.

In this model, in addition to the partitioning of variance for each variable, the main interest lies in the nature of the estimated multivariate paths. For instance, 48% of the variance in school age language was accounted for by genetic factors, as well as 11% and 20% by shared and unique environmental factors, respectively, that were unique to school age language. Yet, more importantly, approximately 15% of the variance in school age language could be traced back to the genetic contribution shared with preschool language, and an additional 7% of the variance originated from the shared environmental contribution to preschool language. We further calculated that overall, 53% of the covariance between preschool language and school age language (path of .40 in the mediation model) was explained by genetic factors, and 47% by shared environmental factors, whereas the unique environmental contribution to the covariance between preschool language and school age language was negligible (not shown in Figure 2).
Figure 2 also reveals that high school writing could be predicted by several paths from earlier language. Specifically, 44% and 28% of the variance was accounted for by genetic factors and unique environmental factors that were specific to high school writing, but more importantly, around 12% of the variance in high school writing could be accounted for by the genes underpinning school age language, and a small but significant 2% by unique environment underlying school age language. The model also reveals that 9% of the variance in high school writing could be traced back to genetic factors underlying preschool language. However, this result should be interpreted with caution as the direct phenotypic path from preschool language to high school writing was not significant in the mediation model (path of .01). Overall, 64% of the covariance between school age language and high school writing (path of .49 in the mediation model) was accounted for by genes, 18% by unique environment, whereas the contribution of shared environment was negligible (not shown in Figure 2). Again, the multivariate genetic model was computed using higher-order writing skills instead of the total score of writing, with similar results.

Discussion

The Longitudinal Association Between Oral Language and Writing

The first objective of this study was to determine if preschool language was associated with high school writing, and if so, whether it contributed directly to writing or indirectly through school age language. The longitudinal correlation revealed that preschool language was modestly associated with high school writing, more than 12 years later ($r = .25$). This result is consistent with other studies showing modest stability within oral language over a similar timeframe (e.g., $r = .18$ between vocabulary at 2 and 12 years of age; Hayiou-Thomas et al., 2012). The fact that the present study documents this continuity over two distinct variables, language and writing, is compelling. It is also consistent with previous studies that have shown associations between oral language and reading (e.g., Dionne et al.,
2013; Harlaar et al., 2008; Lee, 2011; Suggate et al., 2018), as well as between oral language and writing, although over much shorter time spans for the latter (e.g., Kent et al., 2014; Kim et al., 2011, 2013; Kovas et al., 2007; Olson et al., 2013). One novel contribution of the present study is thus to show that this latter spans over a much longer period of time than previously documented.

The present study also shows that language development evolves over the oral-written continuum through some stability of language from the very early stages. Indeed, the mediation model revealed that the contribution of preschool language to high school writing was not direct but rather indirect, through the mediation of school age language. This total mediation suggests that the stability from preschool to school age language is central in explaining the long-term associations with written language. Furthermore, by replicating our results with a measure of higher-order writing skills, less dependent on language, we further demonstrated that the predictive association could not be explained solely by the common linguistic knowledge shared between language and writing.

These findings bear some practical implications. Indeed, around the end of mandatory schooling, written skills are one of the best predictors of postsecondary school attainment, as well as economic and social success (Dolan et al., 2008; Kobrin et al., 2008; Preiss et al., 2013; Reynolds et al., 2011; Wells, 1981). This could be due to the omnipresence of written language in all academic domains, as well as in a myriad of daily activities. Our results provide empirical evidence that early language development is the steppingstone from which other language domain skills evolve, and not just within developmental stages. In that respect, early identification and interventions may provide very long-term benefits.

**The Genetic Association Between Oral Language and Writing**

The second objective of this study was to determine the extent to which genetic and environmental factors explained the associations between oral language and writing skills. As expected,
we found genetic contributions to both language and writing, with a shared environmental contribution to language only. This contribution of shared environment to early oral language is well documented, especially in younger children (Dale et al., 2010; deZeeuw et al., 2015; Hayiou-Thomas et al., 2006; 2012; Hoekstra et al., 2007). The magnitude of the contribution of genes to writing is also consistent with previous studies across the lifespan (Bus & Out, 2009; Grasby et al., 2016; Oliver et al., 2007). Given that the WIAT-II writing task requires a complex production, it is noteworthy that the contribution of unique environment, which encompasses measurement error, remained modest. This provides support for the validity and reliability of this measure, as writing measures are known to be vulnerable to measurement error (Grasby et al., 2016).

The more striking result from the genetic analyses was that genetic factors contributed largely to the association between oral language and writing. By decomposing the mediation model into its genetic and environmental sources of variance, we observed several genetic contributions common to language and writing. In particular, we found that genes accounted for a substantial 64% of the association between school age language and high school writing, as well as 53% of the association between preschool language and school age language. Kovas et al. (2007), who investigated the nature of the cross-sectional associations between language, reading, and writing at 7, 9, and 10 years of age, also found that they were largely explained by genes \( r_s = .61–.80 \); see also Byrne et al., 2006; Hayiou-Thomas et al., 2006, 2010; Kovas et al., 2007; Tosto et al., 2017 for the genetic association between language and reading). The finding that genes explain stability is a common result in the field of behavioural genetic (Plomin et al., 2016). Our results add the longitudinal perspective that previous studies on writing lacked: The development of language domain skills, from oral to written, from preschool to high school, appears largely explained by genes.

The genetic factors common to oral language and writing could be language specific. For instance, Dale et al. (2020) recently identified six language-associated genes (ATP2C2, CMIP, CNTNAP2,
that have now been replicated in various studies (Eising et al., 2021; Newbury et al., 2019; Plomin & Kovas, 2005; Rice et al., 2009). Recent studies have also found that the molecular genetic architecture of language and writing is largely polygenic, with a very large number of genetic markers accounting for a significant proportion of variance (Allegrini et al., 2019; Eising et al., 2021; Luciano et al., 2013). For example, in a large sample of children followed longitudinally from 7 to 16 years of age, polygenic scores based on the number of years of education (EduYears) predicted a significant portion of the variance in reading (5%; Selzam, Dale et al., 2017) and in educational attainment (9%), which comprised measures of oral and written language (Selzam, Krapohl et al., 2017).

More broadly, generalist genes could be responsible for a range of learning abilities and disabilities, including oral language and writing, through cognitive mechanisms (Plomin & Kovas, 2005). For example, both oral language and writing are associated with nonverbal intelligence and working memory (Alloway & Alloway, 2010; Campbell et al., 2001; Chenault et al., 2006; Gathercole et al., 2004; Phillips et al., 2014; Quinn & Wagner, 2018; Rescorla, 2009), which in turn are highly heritable (Bouchard, 2004; Christopher et al., 2016; Hoekstra et al., 2007; Shapland et al., 2020). Notwithstanding, the nature of specific genes involved in language and writing remains largely unknown.

Another important finding of our study was that over and above the genetic contribution, the association between preschool language and school age language was partly accounted for by shared environment. That is, shared environment explained 47% of the longitudinal association between preschool language and school age language. This result is not surprising given that oral language has previously been associated with shared environment (deZeeuw et al., 2015; Dionne et al., 2003; Hayiou-Thomas et al., 2012; Samuelsson et al., 2005; Spinath et al., 2004).

On the other hand, we found a lack of common environmental contribution to the association between language and writing, which is also consistent with previous research (Kovas et al., 2007). This finding means that environmental factors, such as shared exposure to oral and written language at
home or teaching style at school, do not seem to contribute to the association between language and writing. Some studies have shown that early exposure to written language at home is associated with writing in childhood (e.g., Deckner et al., 2006; Sénéchal & LeFevre, 2002), but these findings depart from our results. It could be due to the fact that in the present study, writing was measured in adolescence. In fact, the environment becomes more homogeneous across children as they enter school, leaving less room for environmental factors to explain individual differences (Hayiou-Thomas et al., 2012).

Our results fit better with the idea that it is each twin’s unique environment, such as the amount of reading they choose to do by themselves, that explains individual differences in writing. Also, the possibility of gene-environment correlations, a process through which adolescents select their environment on the basis of their genetic predispositions (e.g., Harlaar et al., 2007; Plomin et al., 2008), cannot be excluded.

**Limits of the Study**

Our findings need to be considered in the context of the study’s limitations. First, the number of participants ($n = 632$) was relatively small compared to other twin studies (Dale et al., 2010; $N = 4,892$; Grasby et al., 2016; $N = 1,940$; Hayiou-Thomas et al., 2012; $N = 15,772$; Kovas et al., 2007; $N = 5,084–11,482$), which reduced the possibility to detect small effect sizes, including potential direct predictive associations from preschool language to high school writing in the mediation model, as well as contributions from shared environment to writing and its association with oral language. Second, the participants of the present study were exclusively French speaking, which limits generalizing the findings to other populations. However, the fact that the general etiological pattern was similar to that observed elsewhere in English speaking participants is reassuring. Third, due to attrition, the sample was likely biased towards more socioeconomically advantaged individuals (Boivin et al., 2019); this may have
constrained the variance in early language and later writing, as more vulnerable children and adolescents are likely to show lower scores on these outcomes. It is also unclear whether the predictive associations apply to these more vulnerable populations. Fourth, because the same parent rated both twins at 1.5 and 2.5 years, it is possible that a rater bias inflated the contribution of shared environment to the measure of preschool language. However, this could be seen as a minimal risk given that studies using direct assessment of preschool language found comparable estimates (e.g., Samuelsson et al., 2005). Finally, given the small sample size, we aggregated language measures over specific developmental periods, that is, for preschool and for primary school. While this may have improved the reliability of our general school age language measures, it did not allow to test for specific processes within developmental periods.

Conclusion

In the present study, we provided evidence for a longitudinal continuum from the oral to the written forms of language, from preschool to high school. The story appears to unfold through mediation processes whereby early individual differences in language skills persist into school age to contribute to complex writing by high school. Furthermore, the backbone of this story appears to rely on genetic liabilities. Indeed, the long-term associations between language and writing were mostly accounted for by genetic factors. In sum, our results highlight the developmental continuity from oral to written language from preschool to high school and show that genetic factors largely account for this continuity. Early interventions targeting children with language difficulties need to take into account this underlying genetic liability in the language domain as it may predispose them to difficulties in learning to write over the long term. More research is needed to clarify the nature and role of these genetic factors, as well as how they unfold over time.
References


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https://doi.org/10.1044/2020_JSLHR-19-00286


Table 1

Correlations Between the Measures of Language and Writing

<table>
<thead>
<tr>
<th>Measure</th>
<th>Age (years)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
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</thead>
<tbody>
<tr>
<td>1. Receptive language</td>
<td>1.5</td>
<td>–</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Expressive language</td>
<td>1.5</td>
<td>.61**</td>
<td>–</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Receptive language</td>
<td>2.5</td>
<td>.37**</td>
<td>.22**</td>
<td>–</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Expressive language</td>
<td>2.5</td>
<td>.46**</td>
<td>.44**</td>
<td>.66**</td>
<td>–</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. EDI</td>
<td>6</td>
<td>.28**</td>
<td>.33**</td>
<td>.28**</td>
<td>.47**</td>
<td>–</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. EDI</td>
<td>7</td>
<td>.16**</td>
<td>.22**</td>
<td>.25**</td>
<td>.39**</td>
<td>.58**</td>
<td>–</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. WISC-III vocabulary</td>
<td>7</td>
<td>.21**</td>
<td>.30**</td>
<td>.22**</td>
<td>.40**</td>
<td>.34**</td>
<td>.37**</td>
<td>–</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. PPVT</td>
<td>7</td>
<td>.33**</td>
<td>.34**</td>
<td>.27**</td>
<td>.44**</td>
<td>.44**</td>
<td>.43**</td>
<td>.56**</td>
<td>–</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Oral language</td>
<td>10</td>
<td>.10</td>
<td>.11*</td>
<td>.12*</td>
<td>.20**</td>
<td>.47**</td>
<td>.49**</td>
<td>.29**</td>
<td>.36**</td>
<td>–</td>
<td></td>
<td></td>
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<tr>
<td>10. Oral language</td>
<td>12</td>
<td>.15**</td>
<td>.18**</td>
<td>.16**</td>
<td>.27**</td>
<td>.47**</td>
<td>.51**</td>
<td>.36**</td>
<td>.32**</td>
<td>.49**</td>
<td>–</td>
<td></td>
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<tr>
<td>11. WIAT-II writing score</td>
<td>15</td>
<td>.15**</td>
<td>.24**</td>
<td>.18**</td>
<td>.25**</td>
<td>.46**</td>
<td>.40**</td>
<td>.32**</td>
<td>.30**</td>
<td>.43**</td>
<td>.40**</td>
<td>–</td>
</tr>
</tbody>
</table>

*Note.* EDI = Early Development Instrument; WISC-III = Wechsler Intelligence Scale for Children-III; PPVT = Peabody Picture Vocabulary Test; WIAT-II = Wechsler Individual Achievement Test-II.  
**p < .01; *p < .05
Table 2

Descriptive Statistics of the Measures of Language and Writing

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Measure</th>
<th>Type</th>
<th>N</th>
<th>Range</th>
<th>M</th>
<th>SD</th>
</tr>
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<tbody>
<tr>
<td>1.5</td>
<td>Receptive language</td>
<td>Parent-rated</td>
<td>458</td>
<td>0–77</td>
<td>54.01</td>
<td>15.61</td>
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<tr>
<td>1.5</td>
<td>Expressive language</td>
<td>Parent-rated</td>
<td>458</td>
<td>0–77</td>
<td>21.75</td>
<td>17.32</td>
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<tr>
<td>2.5</td>
<td>Receptive language</td>
<td>Parent-rated</td>
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<td>0–100</td>
<td>95.17</td>
<td>11.02</td>
</tr>
<tr>
<td>2.5</td>
<td>Expressive language</td>
<td>Parent-rated</td>
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<td>0–100</td>
<td>85.00</td>
<td>21.33</td>
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<tr>
<td>6</td>
<td>EDI</td>
<td>Teacher-rated</td>
<td>411</td>
<td>0–10</td>
<td>7.34</td>
<td>1.93</td>
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<tr>
<td>7</td>
<td>EDI</td>
<td>Teacher-rated</td>
<td>453</td>
<td>0–10</td>
<td>7.13</td>
<td>2.05</td>
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<tr>
<td>7</td>
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<td>Direct</td>
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<td>0–60</td>
<td>13.11</td>
<td>5.02</td>
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<tr>
<td>7</td>
<td>PPVT</td>
<td>Direct</td>
<td>495</td>
<td>0–170</td>
<td>89.73</td>
<td>15.58</td>
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<tr>
<td>10</td>
<td>Oral language</td>
<td>Teacher-rated</td>
<td>459</td>
<td>1–5</td>
<td>3.37</td>
<td>1.11</td>
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<tr>
<td>12</td>
<td>Oral language</td>
<td>Teacher-rated</td>
<td>412</td>
<td>1–5</td>
<td>3.45</td>
<td>1.22</td>
</tr>
<tr>
<td>15</td>
<td>WIAT-II writing score</td>
<td>Direct</td>
<td>632</td>
<td>0–55</td>
<td>32.79</td>
<td>6.92</td>
</tr>
</tbody>
</table>

*Note. EDI = Early Development Instrument; WISC-III = Wechsler Intelligence Scale for Children-III; PPVT = Peabody Picture Vocabulary Test; WIAT-II = Wechsler Individual Achievement Test-II.*
Table 3

Summary of the MZ and DZ Intra-Class Correlations and of the Results of the Univariate Genetic Models of Language and Writing

<table>
<thead>
<tr>
<th>Measures</th>
<th>ICC</th>
<th>A</th>
<th>C</th>
<th>E</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>MZ</td>
<td>SS</td>
<td>OS</td>
<td>UE</td>
</tr>
<tr>
<td></td>
<td>DZ</td>
<td>DZ</td>
<td></td>
<td>[95% CI]</td>
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<td>.56</td>
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<tr>
<td>School age language</td>
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<td>.41</td>
<td>.52</td>
<td>.61</td>
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<tr>
<td>High School Writing</td>
<td>.70</td>
<td>.41</td>
<td>.25</td>
<td>.84</td>
</tr>
</tbody>
</table>

Note. ICC = intraclass correlation; MZ = monozygotic twins; DZ = dizygotic twins; SS = same sex; OS = opposite sex; A = genetic factors; C = shared environmental factors; E = unique environmental factors and error; UE = unstandardized estimates; CI = confidence interval; % = proportion of variance explained.
Figure 1

Model of the Association between Preschool Language and High School Writing, Mediated by School Age Language

Note. Standardized estimates are presented.

*p < .05

Figure 2

Multivariate Genetic Model of Language and Writing

Note. Paths represent proportions of variance. A = genetic factors; C = shared environmental factors; E = unique environmental factors and error.