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Examining the genetic and environmental associations among spelling, reading fluency, reading comprehension and a high stakes reading test in a combined sample of third and fourth grade students

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ABSTRACT

The present study is an examination of the genetic and environmental effects on the associations among reading fluency, spelling and earlier reading comprehension on a later reading comprehension outcome (FCAT) in a combined sample of 3rd and 4th grade students using data from the 2011–2012 school year of the Florida Twin project on Reading (Taylor et al., 2013). A genetically sensitive model was applied to the data with results indicating a common genetic component among all four measures, along with shared and non-shared environmental influences common between reading fluency, spelling and FCAT.

1. Introduction

Reading comprehension skills are associated with academic success in both primary and secondary education (Slavin, Madden, Karweit, Livermon, & Dolan, 1989). Education and academic success are subsequently linked with overall health and well-being in the United States, with disparities in one contributing to disparities in another (Fiscella & Kitzman, 2009). In recognition of the important relationship among reading, academic success and health the government passed the No Child Left Behind Act (NCLB) in 2001, (Act, 2002) which seeks to improve education through standardized assessments and culpability for teachers, schools and districts when target reading levels are not met. More recently, the Common Core of State Standards Initiative is being introduced to incorporate a single set of educational standards, with the intention of all states moving towards adopting a single annual assessment of the Common Core standards. For both the NCLB Act and Common Core, reading comprehension is a key skill required for success.

Reading fluency is defined as the oral translation of text with speed and accuracy and has been identified as one of the components of reading critical to building a bridge to reading comprehension (Adams, 1990; Fuchs, Fuchs, Hosp, & Jenkins, 2001; Pikulski & Chard, 2005). Automatic and accurate word recognition is theorized to reduce the cognitive load involved with lower-level word processing during reading, which allows a greater availability of resources to the performance of higher-level comprehension functions involved with skilled reading comprehension (LaBerge & Samuels, 1974). In addition to automaticity, reading fluency involves prosody. Prosodic reading involves grouping words together into meaningful sections that follow with the syntactic structure of the text and has been theorized to be a link between automaticity and reading comprehension (Kuhn & Stahl, 2003). Fluent readers are able to quickly and accurately decode as well as successfully transfer syntactic knowledge from speech to text during silent reading. A review suggested a moderate to high association between reading fluency and reading comprehension, with correlations of .50 to .90 (Fuchs et al., 2001). Additionally, in a study of the predictive ability of fluency on reading comprehension, results showed the relation between fluency and reading comprehension improved positively as participants' fluency skills increased (Petscher & Kim, 2011). Reading fluency has also been associated with success on high stakes, state-wide reading assessments (Baker et al., 2008).

In addition to fluency skills, spelling has been identified as a skill significantly related to success in reading comprehension (Ehri, 2000; Hook & Jones, 2002; Nunes, Bryant, & Barros, 2012; Pikulski & Chard, 2005;). Spelling can be defined as the interactive process of mapping phonological (sound) representations of words onto their orthographic (written) counterparts (Hanna, 1965). Importantly, the ability to derive corresponding orthographic units from phonemic units and vice-versa plays an important role in word-decoding, reading and writing. Ehri and colleagues (e.g. Bhattacharya & Ehri, 2004; Drake & Ehri, 1984)

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have been able to illustrate the importance of phoneme–grapheme correspondence used in spelling and decoding to gains in reading fluency, but recognize that exposure through reading may also have a positive impact on spelling. Furthermore, the use and understanding of graphophonic units (units smaller than morphemes) that comprises spelling ability has been found to benefit morphological awareness and contribute to increased word reading fluency and reading comprehension (Nunes et al., 2012). A moderate and positive relation between spelling and reading comprehension has been indicated in languages with transparent orthography such as Finnish, Dutch and Greek (Mommers, 1986; Protopapas, Sideridis, Mouzaki, & Simos, 2011; Savolainen, Ahonen, Aro, Tolvanen, & Holopainen, 2008). The relation in English speakers is less-studied, although the work that is done also suggests a positive association, $r = .68–.89$ (Ehri, 2000; Foorman & Petscher, 2010). In addition, results of a longitudinal study showed spelling ability in a sample of first grade students significantly predicted reading comprehension in fifth grade (Roberts & Meiring, 2006). This growing body of work indicating a close association between spelling ability and reading comprehension has led to an increased focus on spelling as a part of reading instruction (Foorman & Petscher, 2010), though the underlying nature of spelling is often considered separate from reading comprehension (Aarnoutse, Van Leeuwe, Voeten, & Oud, 2001).

The Lexical Quality Hypothesis of reading comprehension classifies components of language processing as having an influence on accuracy and fluency of word identification through their contributions to the lexical quality of the word (Perfetti, 2007; Perfetti & Hart, 2001). Under this hypothesis, aspects of orthography and phonology influence the lexical quality of words within text and, in combination with semantic knowledge, account for much of the variance in text comprehension. The Lexical Quality Hypothesis suggests that variations in orthographic (spelling) and phonological decoding contribute to variations among word reading and comprehension skills, therefore, spelling is considered a key predictor of reading comprehension, outside of the more commonly studied phonological decoding predictors. More recently, reading fluency, spelling and reading comprehension have been examined together (Foorman & Petscher, 2010; Foorman, Petscher, & Bishop, 2012; Nunes et al., 2012). One study explored the role of reading fluency and reading comprehension on spelling, with the results indicating that reading fluency accounted for more variance in spelling than did reading comprehension (Foorman & Petscher, 2010). In addition, high ability spellers outperformed low ability spellers on both fluency and reading comprehension (Foorman & Petscher, 2010). Additionally, spelling ability has been identified as an independent predictor of reading comprehension, above and beyond both morphological awareness and reading fluency (Nunes et al., 2012). In another recent examination, a model with reading fluency, spelling, prior reading comprehension, and morphology explained nearly all of the between classroom variance in reading comprehension skills, indicating that spelling and reading fluency are both important predictors of reading comprehension ability for students in grades 3–10 (Foorman et al., 2012). While there is considerable literature on the nature of spelling and reading comprehension or fluency and reading comprehension skills, more research on the relations between reading fluency, spelling and reading comprehension is needed to learn how these three skills interplay and, ultimately, how reading comprehension skills develop.

Quantitative genetic methodology allows the unique opportunity to examine the genetic and environmental components underlying the relations among achievement measures. Specifically, twin study methodologies compare the known genetic and environmental similarity between monozygotic and dizygotic twins to examine the proportion of variance attributable to additive genetic influences (or heritability; h^2), shared environmental influences (i.e., non-genetic influences that make siblings more similar; c^2), and non-shared environmental influences (i.e., non-genetic effects that make siblings different, plus error; e^2) on a given measure. Previous twin work has found moderate to high heritability estimates for comprehension ($h^2 = .32–.82$),[1] fluency ($h^2 = .29–.49$) and spelling ($h^2 = .54$ and .51; Bates et al., 2007; Byrne et al., 2008; Hart, Petrill, & Thompson, 2010; Keenan, Betjemann, Wadsworth, DeFries, & Olson, 2006; Logan et al., 2013; Petrill et al., 2011). Shared environmental influences on fluency are mostly non-significant and non-shared environmental estimates are significant, but smaller than additive genetic effects (.29–.39; Hart, Petrill, Thompson, & Plomin, 2009; Petrill et al., 2012). However, in one study examining a younger sample of twins in the pre-reading stage, results indicated low to moderate and significant estimates of shared environmental influence on fluency ($c^2 = .10–.36$; Taylor & Schatschneider, 2010). Studies of spelling ability have generally shown non-significant shared environmental effects ($c^2 = .00–.19$) while estimates of non-shared environmental influence have been found to be significant, but varied ($e^2 = .49$ and .23; Bates et al., 2007; Byrne et al., 2008). Univariate analysis of reading comprehension reveals a pattern of influence similar to fluency and spelling with non-significant estimates of shared environmental influence, and significant non-shared environmental influence (.30–.54; Hart, Soden, Johnson, Schatschneider, & Taylor, 2013; Keenan et al., 2006; Logan et al., 2013).

Importantly, multivariate genetic methods can also examine genetic and environmental influences on the covariance among reading fluency, spelling, and reading comprehension. Previous work examining the genetic and environmental influences shared between reading fluency and reading comprehension has shown evidence of a significant common genetic influence between these two skills as well as significant independent genetic influences on fluency, but not reading comprehension (Hart et al., 2010; Petrill et al., 2012). Shared environmental effects were significant between reading fluency and reading comprehension, but not significant for independent shared environmental influences for either (Hart et al., 2010; Petrill et al., 2012). However, no multivariate work has explored the genetic and environmental association of the relation between spelling and reading comprehension or among all three skills simultaneously.

Florida mirrors the national movement in the U.S. towards universal end-of-year assessments of educational standards. Annual student performance in reading, particularly focused on reading comprehension skills, is assessed by the Florida Comprehensive Assessment Test 2.0 (FCAT; http://fldoe.org). Due to the importance of passing the end-of-year, high-stakes FCAT for both students and teachers, the state has also developed the Florida Assessment for Instruction in Reading (FAIR). The FAIR is designed to act as a predictor of success on the FCAT. Importantly, the FAIR measures specific component reading skills hypothesized to be predictive of reading comprehension measured by the FCAT, namely reading fluency, spelling and a separate test of reading comprehension. Scores from FAIR Maze Task (reading fluency), Word Analysis (spelling), and Reading Comprehension are used to estimate the probability of a student passing the reading comprehension portion of the FCAT at the end of the same school year (Foorman & Petscher, 2010). As the U.S. moves towards the Common Core standards (CCSS), there will be increased pressure for more interim assessments intended to predict success on the important end-of-year tests and provide a rubric for mid-year intervention efforts. Importantly, even with the growing body of literature on the relationship between reading fluency, spelling and reading comprehension and its important role in assessing student achievement, the nature of these relations is still not well understood. Understanding the nature of this association is salient in understanding how to prepare students for the standardized assessments called for in response to No Child Left Behind (NCLB, 2002) and more recently the Common Core. Additionally, these assessments were chosen in order to capture the breadth of comprehension,

[1] The wide range of heritability estimates included may, in part, be due to different age ranges (early childhood through adolescence) or different demographic characteristics (i.e. race, nationality) of the included samples.