



# The effects of genetic and environmental factors on writing development<sup>☆</sup>



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## ABSTRACT

Researchers have identified sources of individual differences in writing across beginning and developing writers. The aim of the present study was to further clarify the sources of this variability by investigating the extent to which there are differences in genetic and environmental factors underlying the associations between lexical diversity, syntactic knowledge, and semantic cohesion knowledge in relation to writing. Differences were examined across two developmental phases of writing: beginning (i.e., elementary school) and developing (i.e., middle school). Participants included 262 twin pairs (*M*<sub>age</sub> = 10.88 years) in elementary school and 247 twin pairs (*M*<sub>age</sub> = 13.21 years) in middle school. Twins were drawn from the Florida Twin Project on Reading, Behavior, and Environment. Biometric models were conducted separately for subgroups defined by phase of writing development. Results indicated significant etiological differences in writing components across the two phases, such that effects associated with genes and non-shared environment were greater while effects associated with shared environment were lower in developing writers as compared to beginning writers. Furthermore, results showed that child-specific environment was the largest contributor to individual differences in writing components and their covariation for both beginning and developing writers. These results imply that even direct instruction about writing in schools may be having different effects on children based on their unique experiences.

## 1. Introduction

The Common Core of State Standards Initiative, an educational initiative in the United States that details what K-12 students should know in English language arts at the end of each grade, provides standards for writing skills needed to meet expectations for academic success as well as in the workforce (National Governors Association Center for Best Practices, Council of Chief State School Officers [CCSSO], 2010). The guidelines outline that "... in writing, students should demonstrate increasing sophistication in all aspects of language use, from vocabulary and syntax to the development and organization of ideas, and they should address increasingly demanding content and sources" (CCSSO, 2010, p. 19). However, the National Assessment of Educational Progress (NAEP, 2002, 2011; NAEP is the largest nationally representative assessment of what American students know and can do in various subjects) results show that only 28% of fourth graders and 27% of eighth graders perform at or above proficient level in writing. Concerns over low levels of writing achievement in elementary and

middle school, together with evidence that children with writing disabilities are at greatly enhanced risk of difficulties in reading and math (Mayes & Calhoun, 2006; Sumner, Connelly, & Barnett, 2013), have motivated a large body of work to identify the sources of individual variability in writing (Abbott & Berninger, 1993; Arfe, Dockrell, & De Bernardi, 2016; Babayigit, 2014; Berninger, Abbott, Abbott, Graham, & Richards, 2002; Berninger et al., 1992; Graham, Berninger, Abbott, Abbott, & Whitaker, 1997; Graham, McKeown, Kiuahara, & Harris, 2012; Kim, Al Otaiba, Folsom, Greulich, & Puranik, 2014; Kim, Al Otaiba, Wanzek, & Gatlin, 2015; Kim et al., 2011; Kim, Park, & Park, 2013; Limpo & Alves, 2013; Olinghouse, 2008; Olinghouse, Graham, & Gillespie, 2015). One line of research that would further clarify variability in writing in elementary and middle school is investigating the etiological (genetic and environmental) factors associated with individual differences in writing.

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### 1.1. A model of writing and relations between its components

“A writer(s) within community model of writing,” recently proposed by [Graham \(in press\)](#), serves as the theoretical framework for the current study. The model establishes the importance of personal and environmental influences for successful writing and suggests that information about writing be gathered from two units that work in tandem: a writer's cognitive architecture (cognitive components of an individual that are necessary for writing and are assumed to be universal) and the writing community (specific sociocultural contexts or environments which shape writing). Components in Graham's model account for developing and skilled writing and are consistent with other developmental writing models such as the “not-so-simple view of writing” model ([Berninger & Winn, 2006](#)).

According to [Graham's \(in press\)](#) model of writing, four cognitive components within the individual support writing. (1) Long-term memory resources include knowledge about oral language, listening and reading skills, as well as specialized knowledge about writing. Oral language is related to linguistic aspects of text generation. It includes phonological, lexical, syntactic, semantic, and pragmatic knowledge. (2) Control mechanisms refer to processes, such as attention, working memory, and executive control. (3) Production processes include conceptualization, ideation, translation, transcription, and reconceptualization. (4) Lastly, modulators involve emotions, personality traits, and physiological state. All four components are interrelated and contribute to a written product. There is abundant empirical evidence to support this. For example, oral language knowledge, including phonological, lexical, syntactic, and semantic knowledge ([Arfe et al., 2016](#); [Babayigit, 2014](#); [Hooper et al., 2011](#); [Kim et al., 2014](#); [Kim et al., 2015](#); [Kim & Schatschneider, 2017](#); [McCarthy & Jarvis, 2007](#); [McNamara, Crossley, & McCarthy, 2010](#)), as well as control mechanisms ([Altemeier, Abbott, & Berninger, 2008](#); [Graham, Harris, & Olinghouse, 2007](#); [Hayes, 2000](#); [Hooper et al., 2011](#); [Kim & Schatschneider, 2017](#); [Limpo & Alves, 2013](#)), and production processes ([Abbott & Berninger, 1993](#); [Arfe et al., 2016](#); [Graham et al., 1997](#); [Hayes, 2012](#); [Kim et al., 2013, 2015](#); [Kim & Schatschneider, 2017](#); [Limpo & Alves, 2013](#)) have been shown to contribute to writing. These cognitive resources are not fixed, but are assumed to be modifiable. As such, their development is shaped by one's experiences in different environments ([Graham, in press](#)).

As to the environmental influences, [Graham's \(in press\)](#) model suggests two aspects that are of particular interest for the current report, because they could represent potential environmental sources underlying variability in writing. Settings in which children's writing mostly takes place, such as home or school setting, as well as members of a writing community, including peers or teachers, may both underpin individual differences in writing. Overall, [Graham's \(in press\)](#) model provides a clear statement on the importance of personal and environmental influences in writing. Moreover, it indicates that cognitive components involved in writing and the environments writers seek to produce text work in concert rather than independently. They both add their contribution to explaining to what extent differences in writing can be attributable to personal versus environmental factors. This has implications for research such as the present study, which is aimed at understanding to what extent children differ in their performance in writing as well as in the cognitive components related to writing due to genetic and environmental factors.

### 1.2. Individual differences in writing

Like reading, language, and essentially any other achievement outcome, writing shows clear individual differences. [Graham's \(in press\)](#) model as well as other developmental models of writing (e.g., not-so-simple view by [Berninger & Winn, 2006](#); Direct and Indirect Effects model of Writing [DIEW] by [Kim & Schatschneider, 2017](#)) highlight cognitive components that likely provide some of the sources for

individual differences in writing. Unpacking the broad etiological sources associated with individual differences in a phenotype like writing can be accomplished using twin study methodology. A twin study methodology may help identify sources of variation in writing skills, such as conditions that are due to shared and/or individual specific environment (e.g., oral language environment; [Hart & Risley, 1995](#), and/or experience with independent reading; [Fukkink, Blok, & de Glopper, 2001](#); [Swanborn & de Glopper, 1999](#)) as well as those aspects that are due to genetic factors (e.g., working memory and other executive functions; [Little et al., 2015](#)).

This study examined the extent to which genetic and environmental influences underlie covariance between what [Graham \(in press\)](#) would refer to as the component of long-term memory resources and writing. Specifically, we examined in three separate models to what extent lexical diversity, syntactic knowledge, and semantic cohesion knowledge are etiologically related to writing. From an empirically informed point, a focus on these specific components of writing is justified by the fact that although other cognitive mechanisms (e.g., working memory; [Kim & Schatschneider, 2017](#)) account for substantial portions of variation in writing, they do not account for all the variation. Thus, this leaves room for investigation of other components, which contribute to individual differences in the compositional quality ([Abbott & Berninger, 1993](#)) and are malleable by instruction. Moreover, focus on these components lends itself well to word (lexical diversity), sentence (syntactic knowledge), and discourse level (semantic cohesion knowledge) activities children engage in at school when learning about writing. Indeed, the findings from examination of the variation and covariation of these components could inform interventions to prevent low achievement in writing, in a way that components could themselves be targets of educational interventions to boost writing achievement.

Lexical diversity was defined in the present study as the range of different words used in a text, with a greater range indicating a higher diversity ([McCarthy & Jarvis, 2010](#)). It has been found to be indicative of writing quality ([McCarthy & Jarvis, 2007](#)), and to be a significant predictor of other important constructs such as language proficiency, language complexity, and lexical proficiency ([Crossley, 2013](#); [Crossley, Salsbury, McNamara, & Jarvis, 2011](#)). Syntactic knowledge was operationalized as syntactic complexity, which refers to diversity and complexity of sentences used in written composition ([Graesser, McNamara, Louwerse, & Cai, 2004](#)). Syntactic complexity in written composition has been shown to predict essay quality ([McNamara, Crossley, & McCarthy, 2010](#)). Semantic cohesion knowledge was operationalized as semantic cohesion and defined as conceptual similarity between each sentence and the text. It has been shown to be related to writing ([McNamara, Louwerse, McCarthy, & Graesser, 2010](#)). Finally, writing was operationalized as writing quality. It refers to aspects of writing such as ideas and organization ([Kim & Schatschneider, 2017](#)). It is an essential, and arguably the most important aspect to be evaluated in writing ([Kim et al., 2015](#)). Taken together, examining the common genetic and environmental effects underlying writing and each of the components will extend our understanding of factors individual differences in writing can be attributed to.

### 1.3. Developmental differences in writing

Writing development undergoes considerable changes during the individual's years in school. Beginning writing starts to emerge in elementary school grades, and continues to develop in middle and high school grades and beyond ([Berninger & Swanson, 1994](#)). As noted, writing is underpinned by cognitive components and their contribution to writing may vary during different phases of writing development ([Berninger & Swanson, 1994](#)). The present study focuses on two phases: (1) beginning or elementary school writing, and (2) developing or middle school writing. Three differences between these two phases in terms of contributions of cognitive components to writing are worthy of

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