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Modeling the development of written language

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Abstract

Alternative models of the structure of individual and developmental differences of written composition and handwriting fluency were tested using confirmatory factor analysis of writing samples provided by first- and fourth-grade students. For both groups, a five-factor model provided the best fit to the data. Four of the factors represented aspects of written composition: macro-organization (use of top sentence and number and ordering of ideas), productivity (number and diversity of words used), complexity (mean length of T-unit and syntactic density), and spelling and punctuation. The fifth factor represented handwriting fluency. Handwriting fluency was correlated with written composition factors at both grades. The magnitude of developmental differences between first grade and fourth grade expressed as effect sizes varied for variables representing the five constructs: large effect sizes were found for productivity and handwriting fluency variables; moderate effect sizes were found for complexity and macro-organization variables; and minimal effect sizes were found for spelling and punctuation variables.

Keywords

Writing development; Writing scoring; Writing models

Introduction

Humans have been engaged in writing for as long as they have been able to read. After all, one can only read something that has been written. Although researchers have paid more

attention to reading than writing over the years, writing research has taken off over the past couple of decades and the gap is beginning to close (see e.g., Berninger & Chanquoy, in press; Graham & Harris, 2009; Grigorenko, Mambrino, & Priess, in press; MacArthur, Graham, & Fitzgerald, 2006, for recent reviews of the writing literature).

In the United States, writing research can be traced back to Rice (1897), who reported little relation between time spent on spelling drills and spelling performance. Subsequently, parallel streams of research developed on the topics of spelling, handwriting, and composing (see Bazerman, 2008, for a review of the history of writing research).

Models of writing

Although models of reading have been proposed since the turn of the last century, the first model of writing to gain traction was that proposed by Hayes and Flowers (1980), Hayes (1996). According to the Hayes and Flowers model, writing consists of three parts: planning, translating, and reviewing. Hayes (1996) revised the original model by incorporating aspects beyond the cognitive processes used in writing such as motivation for writing, the writing context, and working memory. He also reconceptualized the original cognitive processes into the broader categories of reflection, text production, and text interpretation.

Subsequently, a simple view of writing was proposed as an analogy to the simple view of reading, in which writing can be explained in terms of ideas and spelling (Juel, Griffith, & Gough, 1986). Another simple view of writing was proposed by Berninger et al. (2002) to capture the instructional components that research on effective writing instruction had found to be effective in facilitating writing development—explicit instruction in transcription (handwriting and spelling) coupled with the executive functions in the original Hayes and Flowers model (planning, translating, and reviewing/revising) all taught with strategies (Graham & Harris, 2005; Harris, Graham, Mason, & Friedlander, 2008) to generate written text at different levels of language (words, sentences, and text). More recently, writing models have been expanded to reflect the fact that writing is an extraordinarily complex strategic activity that operates under constraints that affect other kinds of cognitive and language processing (Berninger & Winn, 2006; Torrance & Galbraith, 2006). It also is important to acknowledge that writing is done for a purpose in a sociocultural context (Nystrand, 2006). Models of writing have been proposed for adult skilled writers (e.g., the original 1980 Hayes and Flower model and the revised 1996 Hayes model) and for developing child writers (e.g., Berninger & Swanson, 1994). Finally, it is important to distinguish aspects of writing that are relatively unique to writing and aspects that are shared with reading and oral language (Mehta, Foorman, Branun-Martin, & Taylor, 2005; Shanahan, 1984, 1988, 2006; Shanahan & Lomax, 1986).

The nature of writing changes with development (Berninger & Chanquoy, in press). Compared to older expert writers, young novice writers show only rudimentary preparation in the form of reflection and planning before beginning writing. The writing task is viewed as writing what they know about a topic. Substantial differences are also found in text generation (i.e., the mental production of the to-be-written message) and transcription (i.e., transcribing the message into written text). Younger novice writers revise minimally relative to older more experienced writers (see McCutchen, 2006, for a review of developmental changes in writing). Finally, writing in the early grades consists primarily of learning to write letters, to spell, and compose short texts, but transitions by fourth grade into more extended writing as a way of learning about a topic (Berninger, Abbott, Whitaker, Sylvester, & Nolen, 1995). This of course is analogous to the idea of a developmental change in reading from learning to read to reading to learn.

In the area of reading, techniques such as confirmatory factor analysis (CFA) and structural equation modeling (SEM) have proven valuable for testing alternative models of individual and developmental differences (see e.g., Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993; Wagner, Torgesen, & Rashotte, 1994). These techniques have been applied in studies of written language, albeit with less frequency. For example, Abbott and Berninger (1993) and Graham, Berninger, Abbott, Abbott, and Whitaker (1997) reported structural equation modeling studies of handwriting, spelling, and composition. These studies provided evidence of strong roles for handwriting and spelling in composition, even for intermediate writers.

Mehta et al. (2005) reported a multi-level confirmatory factor analysis of reading, spelling, writing, and verbal ability for a large sample followed longitudinally. Writing samples were scored by raters who used a five-point scale to rate eight aspects of writing: (a) addressing the prompt; (b) unity and logical organization; (c) vocabulary usage; (d) sentence completion; (e) grammar usage; (f) use of capitalization, (g) use of punctuation marks; and (h) spelling conventions. The eight ratings were treated as items in an item-response theory model, combining them into a single writing ability estimate. The data were modeled at both the level of the individual student and at the classroom level. The results were different for the two levels. At the student level, individual differences were modeled well by a two-factor model: A literacy factor made up of word reading, passage comprehension, phonological awareness, writing, and spelling; and a language factor made up of vocabulary and two subtests (similarities and information) from an IQ test. These factors were highly correlated ($r = .7$) yet distinct. At the classroom level, a single factor accounted for both the literacy and language factors.

In previous studies that have addressed the factors of writing, a wide variety of variables have been studied, including quantitative measures of amount of writing done (e.g., numbers of words or sentences), qualitative ratings of overall writing quality, and quantitative variables at the discourse-level, sentence-level, and word-level (Sanders & Schilperood, 2006; Nelson & Van Meter, 2007).

Recent research by Puranik, Lombardino, and Altmann (2008) represents an integration of these lines of inquiry by exploring the underlying structure of writing using analyses of more fine grained variables. Writing samples were obtained using a retelling paradigm in which a story was read to students and they were asked to write what they remembered from the story. Results from an exploratory factor analysis were interpreted as support for three factors: productivity (i.e., how much writing was done), complexity (i.e., the density of writing and length of sentences) accuracy (i.e., whether the writing was free from spelling and punctuation errors).

The present study was designed to evaluate alternative models of the structure of individual and developmental differences in writing. A better understanding of these differences could inform our understanding of writing development. Models of the structure of individual and developmental differences in writing also would have implications for scoring writing samples. Despite its limitations, holistic scoring, in which writing samples are given an overall rating, remains the most widely used method of scoring (see Huot & Neal, 2006, for a review of the literature on scoring writing samples). Establishing the factor structure of individual and developmental differences in writing could lead to scoring systems that reflect the identified structure. Our study also represents a replication of the Puranik et al. (2008) study and an extension of it in four ways. First, writing samples were obtained by requiring students to generate a story from a prompt as opposed to asking them to retell a story that was read to them. Second, confirmatory factor analysis was used in an attempt to confirm the framework that was proposed on the basis of the initial exploratory factor

analysis. Third, the framework was expanded by including variables that represented the macro-organizational level of text structure (using a topic sentence, number and logical ordering of ideas). Fourth, given the strength of relations between handwriting fluency and various measures of written language found in previous studies (Graham et al., 1997), the construct of handwriting fluency was added to the analyses.

Three models of the underlying structure of written composition were specified a priori. A *general model* specified a single factor of written language composition (Mehta et al., 2005). According to this model, the common variance among the observed indicators was attributable to a single latent variable or factor. A *hierarchical model* specified two factors of written language composition, one corresponding to the macro level (i.e., above the sentence level) and the other to the micro level (i.e., at the sentence or word levels) of organization. This model reflected the fact that a construct representing the macro-structure text level was added to a model (Puranik et al., 2008) that previously included only constructs representing the micro-structure text level. Finally, a *specific model* specified that the common variance among observed indicators was attributable to four distinct yet potentially related latent variables that corresponded to the constructs of macro-organization, complexity, productivity, and spelling and punctuation.

Method

Participants

Writing samples were collected from 208 1st- and 4th-grade students who were sampled from two public schools in a small southeastern city. Writing samples were obtained from all first- and fourth-grade students whose parents provided consent. Of the 208 writing samples collected, 186 were coded and the remaining 22 samples were not coded because the students did not complete the task or because the writing was considered illegible by at least two coders. The coded writing samples included 98 from 1st-grade students and 88 from 4th-grade students. Because we only obtained teacher-administered writing samples from participants, specific demographic information is not available. However, the participants were representative of the population of students in schools from which they were drawn. This population included 49% White and 43% Black students. The remaining 8% classified as Other were primarily Asian. The Hispanic representation was 4%. Socioeconomic status was primarily middle and lower class. Finally, in the United States, 1st-grade children typically are 6-years-old and 4th-grade children are typically 9-years-old.

Measures

The measures consisted of a compositional writing sample and two handwriting fluency measures.

Compositional writing sample—To obtain the writing sample, the task was introduced by saying:

We are going to write about choosing a pet for the classroom. When you are writing today, I want you to stay focused and keep writing the whole time. Don't stop until I tell you to. Also, if you get to a word that you don't know how to spell, sound it out and do your best. I'm not going to help you with spelling today. If you make a mistake, cross out the word you don't want and keep writing. Don't erase your mistake because it will take too long. Keep writing until I say stop.

A demonstration of crossing out a word on the board was given. Participants then were instructed:

Remember, today we are writing about choosing a pet for your classroom. Imagine that you could have any animal in the world for a classroom pet. What would that animal be? Explain why you would like to have that animal for a classroom pet.

Remember to write the whole time, cross out any mistakes and do not erase them, and sound out any words you can't spell.

Students were given 10 min to write. Students who stopped writing before the time was up were prompted:

What more could you write about choosing this pet?

Handwriting fluency—Handwriting fluency was assessed by an alphabet handwriting fluency task and a sentence copying fluency task. These tasks were introduced by saying:

We're going to play a game that will show me how well and quickly you can write. First, you are going to write the lowercase or small letters of the alphabet as fast and as carefully as you can. Then I'm going to ask you to copy a sentence as fast and carefully as you can. Don't try and erase any of your mistakes, just cross them out and go on.

The alphabet handwriting fluency task was administered by saying:

When I say "ready, begin," you are going to write the small letters of the alphabet as fast and as carefully as you can. Keep writing until I say stop. If you make a mistake, draw a line through the letter and keep going. Ready, begin.

Students were given 60 s to complete the task. The score was the number of letters correctly printed regardless of order.

For the sentence copying fluency task, the sentence to be copied was printed on the board. The students were then instructed:

We are going to do some more writing. This time, I want you to copy this sentence, (point to the sentence on the paper) 'The quick brown fox jumps over the lazy dog,' as many times as you can while writing as fast and carefully as you can. I'm going to time you again, and it's important that you write the whole time until I say stop. If you get to the end of the sentence, start over again. If you make a mistake, draw a line through it and keep going. When I say stop, please stop writing and put down your pencil. Ready, begin.

Students were given 60 s to complete the task. The score was the number of words correctly copied in order.

Writing variables coded

Written samples were transcribed into a computer database according to *Systematic Analysis of Language Transcript* conventions (SALT, Miller & Chapman, 2001) by two trained coders. T-units were used as the unit of segmentation (Scott & Stokes, 1995; Scott & Windsor, 2000) and written samples were analyzed using a modification of Nelson, Bahr, and Van Meter's (2004) protocol for analyzing written language. A T-unit is defined as the shortest grammatically allowable sentence into which language can be divided, or minimally terminable unit. It refers to a dominant clause and its dependent clauses. Ten variables were coded. Detailed description of each of the variables is provided below along with their tentative assignments to constructs for subsequent confirmatory factor analytic modeling:

Macro-organization—Three variables were coded that represented the higher level organization of the writing sample:

- 1 *Topic*. Whether a topic sentence was present or not.
- 2 *Logical ordering of ideas*. Logical ordering of ideas was rated on a 1- to 4-point rating scale.
- 3 *Number of key elements*. One point was given each for the presence of a main idea, body, and conclusion, yielding a maximum possible score of three.

Complexity—Two variables were used to represent the complexity with which the writing sample conveyed information:

- 4 *Mean length of T-unit*. A commonly used measure of syntactic complexity obtained by dividing total number of words by the number of T-units.
- 5 *Clause density*. Clause density (Hunt, 1965), is another index of syntactic complexity used to study the writing of children and adolescents. Clause density is the ratio of the total number of clauses (main and subordinate) divided by the number of T-units.

Productivity—Two variables represented how much writing was accomplished:

- 6 *Total number of words*. Total number of words is frequently used by researchers when measuring productivity in written language (Berman & Verhoeven, 2002; Houck & Billingsley, 1989; Mackie & Dockrell, 2004; Nelson, et al., 2004; Puranik, Lombardino, & Altmann, 2007; Scott & Windsor, 2000), which is also referred to as computational fluency in the writing research literature. Total number of words was the number of words produced in writing by the child. Words or phrases that did not relate to the prompt such as “The end” or “That’s all I remember” were deleted when calculating total number of words. Incomplete sentences or phrases, usually found at the end of the written sample, were also omitted when calculating total number of words.
- 7 *Number of different words*. This measure of lexical diversity was automatically generated by SALT.

Spelling and punctuation—Three variables represented spelling and punctuation:

- 8 *Number of spelling errors*. Number or percentage of spelling errors has been used extensively in studies examining writing (Mackie & Dockrell, 2004; Moran, 1981; Nelson et al., 2004; Nelson & Van Meter, 2002). A word was counted as a spelling error only once if the participant used the same (incorrect) spelling. If, however, a word was spelled incorrectly but differently, each incorrect spelling was counted as an error. Number of spelling errors was the sum of spelling errors in a child’s written sample.
- 9 *Number of capitalization errors*. A capitalization error was counted if a child did not begin a sentence with a capital letter or used a lower case letter when spelling a proper noun. Additionally, if a participant used a capital letter unnecessarily (e.g., Pet or Hamster), it was counted as an error.
- 10 *Number of errors involving a period*. Errors included missing and unnecessary use of end periods.

Transcription, coding, and reliability

The second author trained all the research assistants in SALT coding. After practicing and establishing coding guidelines, two research assistants coded all writing samples. Twenty percent of the writing samples were randomly chosen to obtain a measure of inter-rater reliability and reliability was assessed for the items total number of words, number of different words, number of clauses, number of spelling errors, number of punctuation errors, and number of capitalization errors. Inter-rater reliability ranged from 89 to 100% for coded items across transcripts.

Procedure

The three tasks were group administered in the students' classrooms by their teachers with members of the research team in the classroom to monitor task administration and answer any questions.

Results

Basic statistics and developmental differences

Descriptive statistics for the composition variables and the handwriting fluency variables are presented in Table 1. For the first grade sample, there was minimal skewness or kurtosis associated with any of the variables. For the fourth grade sample, the distributions were normal with the exception of some positive skewness for the number of spelling errors and a ceiling effect for the topic variable reflecting the fact that most of the fourth-grade writing samples included a topic statement. It is difficult to evaluate the performance level of the students in the study because norms are not available and how much writing is produced often varies based on the specific prompt used.

We were interested in the magnitude of developmental differences between first and fourth grade samples for each of the 10 composition variables and the 2 handwriting fluency variables.¹ We report effect sizes for the first to fourth grade differences along with significance tests in Table 1. An interesting pattern of differences emerged. Large differences between first- and fourth-grade means were noted for variables associated with the productivity and handwriting fluency constructs. These effect sizes ranged from 1.7 to 2.7 in magnitude. Moderate differences were noted for variables associated with macrostructure organization and complexity, with effect sizes ranging from 0.6 to 0.9. Finally, minimal differences were noted for variables associated with spelling and punctuation, with effect sizes ranging from .16 to .28. A Bonferroni adjustment to the probability values associated with the significance tests, which takes into account the fact that twelve tests were done, did not eliminate any significant differences.

Bivariate correlations are presented in Table 2 for the first-grade sample and Table 3 for the fourth-grade sample. Inspection of the two correlation tables revealed moderate correlations among variables belonging to a construct with small correlations among variables belonging to different constructs. The only exception noted was that the three macrostructure variables were minimally correlated for the fourth-grade sample.

¹Our approach to developmental comparisons may seem somewhat minimalist. For mean differences, we simply reported effect sizes and the results of multiple *t*-tests, noting that a Bonferroni adjustment did not result in a significant difference becoming nonsignificant. We took this approach for several reasons. First, our primary interest was in the magnitudes of the effect sizes. Finding significant differences in the mean performance of first and fourth grade students on language measures would not be groundbreaking. Similarly, given our modest sample sizes, we merely reported the results of separate confirmatory factor analyses of the first- and fourth-grade samples, focusing on the overall pattern of results as opposed to the results of a detailed, multi-group analysis of significant differences in parameter estimates that may not generalize.

Confirmatory factor analyses

Confirmatory factor analyses were carried out to test the alternative models of the underlying structure of written language composition described previously. Handwriting fluency was also included in the models so as to estimate the magnitude of relations among handwriting fluency and the written language composition constructs.

For the first-grade sample, the confirmatory factor analysis supported the specific model. These results are presented in Fig. 1. The specific model provided an adequate fit to the data: $\chi^2 (44, N = 98) = 74.3, p = .003$; $\chi^2/df = 1.7$; Comparative Fit Index (CFI) = .93; Tucker-Lewis Index (TLI) = .88; Root Mean Squared Error of Approximation (RMSEA) = .09. The unidimensional and hierarchical models provided substantially and significantly poorer fits to the data. Inspection of the correlations among the latent variables suggests that the four factors of written composition are moderately related at first grade, with handwriting fluency being moderately correlated to several of the factors of written composition.

Turning to the fourth-grade sample, the confirmatory factor analysis again supported the specific model. These results are presented in Fig. 2. The specific model provided an excellent fit to the data: $\chi^2 (44, N = 88) = 45.5, p = .41$; $\chi^2/df = 1.0$; CFI = .97; TLI = .99; RMSEA = .02. As was the case for the first-grade results, the general and hierarchical models provided substantially and significantly poorer fits to the data. Inspection of the correlations among the latent variables suggests that the four factors of written composition are relatively independent at fourth grade, with handwriting fluency being surprisingly highly correlated to several of the factors of written composition.

We highlight the correlations between handwriting fluency and the four factors of written composition in Table 4. In first grade, handwriting fluency was significantly and moderately related to three of the four factors of written composition, with the strongest relation found for productivity. This seems reasonable in that young children who are more fluent in handwriting are able to generate longer writing samples. What is more remarkable is the magnitude of the relations between handwriting fluency and the factors of writing in fourth grade. The magnitude of the relation between handwriting fluency and productivity is nearly double that found in first grade. Even more surprising was the magnitude of the relation between handwriting fluency and macro-organization.

Discussion

The results of our study replicate and extend the results of Puranik et al. (2008). An expanded model that included the three factors proposed by Puranik et al. (i.e., productivity, complexity, and accuracy) and a factor that represents macro-organization was supported in confirmatory factor analyses of writing samples generated in response to a prompt by first- and fourth-grade students. The magnitude of developmental differences between first- and fourth-grade students was remarkably variable, with effect sizes ranging from near 0 to 2.7.

The most striking result was the strength of relations between handwriting fluency and both macro-organization and productivity for the fourth grade sample. We imagined that handwriting fluency might place a strong constraint on all aspects of writing for first-grade students, but did not expect it to be as strongly related to written composition for fourth-grade students. However, Graham et al. (1997) reported standardized path coefficients in the range of .5–.7 from handwriting fluency to composition quality as well as composition fluency for large samples of students from first through sixth grade.

What might explain the striking relations between handwriting fluency and written composition, including macro aspects of organization of writing for fourth-grade students? One possibility is that an individual who is fluent at handwriting fluency has more attentional resources that can be devoted to planning and composing when writing compared to an individual who is not fluent at handwriting and must devote attentional resources to this aspect of writing. Flowers and Hayes (1980) provided an apt description of the processing demands of writing:

As a dynamic process, writing is an act of dealing with an excessive number of simultaneous demands or constraints. Viewed this way, a writer in the act is a thinker on full-time cognitive overload (p. 33, cited by Torrance & Galbraith, 2006).

A large literature that includes both correlational and experimental methods supports this explanation of relations between handwriting fluency and higher-level aspects of writing (Alves, Castro, Sousa, & Stromqvist, 2007; Chanquoy & Alamargot, 2002; Christensen, 2005; Connelly, Campbell, MacLean, & Barnes, 2006; Connelly, Dockrell, & Barnett, 2005; Dockrell, Lindsay, & Connelly, 2009; Graham et al., 1997; McCutchen, 2006; Olive, Alves, & Castro, in press; Olive & Kellogg, 2002; Peverly, 2006; Torrance & Galbraith, 2006). The argument that handwriting fluency affects higher level aspects of writing because of capacity limitations is analogous to that made to explain the relation between fluent decoding and comprehension.

In addition to direct or mediating effects of handwriting fluency on higher level aspects of writing, it is also possible that measures of handwriting fluency actually tap deeper and richer language centers than might be assumed. The idea here is that as a result of considerable writing experience over years, the perceptual and motor aspects of handwriting become associated and even integrated with language networks, much as graphemes and letter strings become attached to corresponding phonemes and morphemes. As a result, relations between handwriting fluency and higher level aspects of writing and language more generally might actually be bidirectional: handwriting fluency influences higher level writing directly or as a mediator, but also is a by-product of the development of higher levels aspects of writing and language.

The fact that five distinct yet related factors of written composition and handwriting were found for both first and fourth graders might be viewed as conflicting with the Mehta et al.'s conclusion that literacy is a unidimensional construct. We believe the apparent conflict is resolved by recognizing that the Mehta et al.'s study and the present study were analyzing individual differences at different levels of analysis. In the Mehta et al. study, ratings of 8 aspects of writing were combined into a single writing score. This writing score in turn was included with measures of word reading, phonological awareness, reading comprehension, and spelling as indicators of a single construct of writing. The fact that their model fits were adequate suggests that there is a fair amount of common variance at this level of analysis. However, the internal consistency reliability of the writing score was modest (.81), and the loadings of the indicators in the confirmatory factor analysis were variable (.33–.99), both of which suggest the promise of modeling the data at a lower level as we did. Another difference between the two studies that might also account for the difference in results is in the kind of writing variables that were modeled. Mehta et al.'s writing score was a composite of quality ratings (0 = poor to 4 = excellent) of the eight aspects of writing they coded. The writing variables modeled in the present study were not limited to quality ratings but included quantitative variables such as mean length of T-unit, clause density, number of words, and number of different words. Given the substantial differences, we don't believe there is a conflict between the results of Mehta et al. and those of the present study. The findings of the two studies apply to different levels and aspects of literacy.

Interpretation of the spelling and punctuation (i.e., accuracy in Puranik et al., 2008) construct may not be as straightforward as it first appears to be. Fayol (1997) argues that punctuation is an integral part of transforming thought into the linear dimension that writing requires. As such, it may be more related not only to thought but also to simple grammar. Relatedly, a recent fMRI study by Richards, Berninger, and Fayol (2009) reported that spelling activated areas of the brain associated with thought.

Finally, we note a close correspondence between three of the factors described in the present study and a levels of language framework that has been applied to writing (Whitaker, Berninger, Johnston, & Swanson, 1994): Our macro-organization factor corresponds to the text level; our complexity factor corresponds to the sentence level; and our productivity factor corresponds to the word level. Our findings substantiate potential intraindividual differences in the three levels of language (Whitaker et al., 1994; Puranik et al., 2008). Findings from this study highlight the need to assess individual students' strengths and weaknesses at the word, sentence, and discourse level such that intervention can be tailored to meet those needs. The findings from this study also extend previous research by showing that more than handwriting fluency is involved in transcription. Similar to analyzing writing at different levels of language, analyses of transcription errors should include spelling, and punctuation.

Regarding limitations of the present study, the cross-sectional design limits our ability to test alternative models of relations between handwriting fluency and written composition that could be tested in a longitudinal study. Further exploration of the factor structure of written composition in a longitudinal study that also includes oral language and reading would seem to be a productive area for further research. The results were based on a single writing sample. It will be important to validate them by obtaining additional writing samples using different prompts.

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Fig. 1.
Confirmatory factor analysis of writing for first-grade sample

Fig. 2.
Confirmatory factor analysis of writing for fourth-grade sample

Table 1

Descriptive statistics for the composition and handwriting fluency variables and effect sizes and significance tests associated with developmental differences between the first- and fourth-grade samples

	1st Grade <i>M</i> (SD)	4th Grade <i>M</i> (SD)	Cohen's	
			<i>D</i>	<i>t</i>
<i>Macro-organization</i>				
1. Topic	0.78 (0.41)	0.97 (0.18)	0.56	3.78***
2. Logical ordering of ideas	2.81 (0.94)	3.44 (0.62)	0.80	5.42***
3. Number of key elements	2.00 (0.61)	2.37 (0.55)	0.67	4.46***
<i>Complexity</i>				
4. Mean length of T-units	7.07 (2.03)	9.84 (2.10)	0.94	6.36***
5. Clause density	1.25 (0.27)	1.51 (0.29)	0.91	6.24***
<i>Productivity</i>				
6. Total number of words	43.77 (18.00)	112.32 (41.09)	2.17	15.04***
7. Number of different words	28.06 (9.71)	62.76 (17.30)	2.48	17.14***
<i>Spelling and punctuation</i>				
8. Number of spelling errors	5.99 (5.10)	5.14 (5.08)	0.16	1.09
9. Number of capitalization errors	2.23 (2.23)	1.57 (2.10)	0.28	1.96
10. Number of period errors	1.32 (1.80)	1.05 (1.50)	0.16	1.07
<i>Handwriting fluency</i>				
11. Alphabet printing fluency	8.39 (5.02)	22.19 (11.47)	1.65	11.12***
12. Sentence copying fluency	6.98 (3.25)	20.64 (5.73)	2.69	17.08***

 $p < .001$

Correlations between compositional and handwriting fluency variables for first-grade sample

1. Topic	1
2. Logical ordering of ideas	.35 1
3. Number of key elements	.33 .58 1
4. Mean length of T-units	.32 .09 .08 1
5. Clause density	.21 .30 .25 .57 1
6. Total number of words	.16 .21 .28 .13 .28 1
7. Number of different words	.15 .25 .28 .18 .27 .92 1
8. Number of spelling errors	-.03 .07 .22 -.03 .14 .38 .38 1
9. Number of capitalization errors	-.25 -.22 -.02 -.34 -.25 .27 .25 .50 1
10. Number of period errors	-.23 -.35 -.09 -.14 -.09 .25 .19 .22 .54 1
11. Alphabet printing fluency	.05 .18 .17 .15 .14 .19 .23 -.09 -.17 -.13 1
12. Sentence copying fluency	.16 .24 .33 .19 .23 .27 .29 .04 -.15 -.11 .39 1

 $N = 98$

Values greater than .19 are significant at $p < .05$

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Table 4

Correlations between latent handwriting fluency and compositional variables for first-and fourth-grade samples

	<u>Handwriting fluency</u>	
	1st Grade	4th Grade
<i>Compositional constructs</i>		
Macro-organization	.32*	.81***
Complexity	.28*	.07
Productivity	.40***	.72***
Spelling and punctuation	-.15	-.03

* $p < .05$;

*** $p < .001$