Examining the Transcription-Writing Link: Effects of Handwriting Fluency and Spelling Accuracy on Writing Performance via Planning and Translating in Middle Grades

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Abstract

This study examined the relationships between transcription, high-level writing processes, and writing performance in Grades 7-8 (N = 196). Structural equation modeling was used to test the direct effects of handwriting fluency and spelling accuracy on planning and translating, and of these latter on writing performance, as well as the indirect effects of handwriting fluency and spelling accuracy on writing performance, via planning and translating. Results showed that the proposed model fitted the data extremely well, explaining 46% of the variability in writing performance. We found that higher handwriting fluency was associated with better planning skills, higher spelling accuracy was associated with better translating skills, and better planning and translating skills were associated with greater writing performance. We found indirect effects of handwriting fluency and spelling accuracy on writing performance, respectively, via planning and translating. These results suggest that transcription continues to impact on writing during teenage school years, by constraining high-level writing processes.

Keywords: handwriting, spelling, planning, translating, writing

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1. Introduction

Writing is a powerful tool in present-day literate societies (Bazerman, 2013). To master writing and use it effectively, writers need to manage several processes that can be characterized as either low- or high-level (Fayol, 1999; Olive, 2014). Whereas low-level processes operate fast, requiring minimal attentional resources, high-level processes are cognitively demanding and require conscious mental effort. Transcription is a low-level writing process that writers need to master from early on. Transcription is the externalization of language in the form of written text, which involves the retrieval, assembling, and selection of orthographic symbols (i.e., spelling); and the execution of motor movements required by a particular writing tool to produce those symbols (i.e., handwriting/typing; Abbott & Berninger, 1993). Despite being both considered transcription skills, spelling and handwriting tap into different processes (Abbott & Berninger, 1993). Spelling draws on multiple skills and knowledge sources such as letter-sound correspondence knowledge, or morphological, phonological, and orthographic awareness (Wood & Connelly, 2009). Though a fluency aspect can be measured in spelling (e.g., latencies; cf. Delattre, Bonin, & Barry, 2006), spelling is typically assessed in terms of accuracy, such as the number of correctly spelled words in isolation or in text (e.g., Graham, Berninger, Abbott, Abbott, & Whitaker, 1997; Limpo & Alves, 2013; Wagner et al., 2011). Handwriting draws on the integration between orthographic and motor skills (Christensen, 2004) and it can be assessed in terms of fluency or legibility (Graham, Weintraub, Berninger, & Schafer, 1998). Handwriting fluency – which is thought to impose more constraints on text production than legibility (Santangelo & Graham, 2014) – considers both accuracy and speed. This is measured through the number of legible letters or words produced accurately and quickly within a specified time (e.g., Berninger et al., 1992; Kim et al., 2011; Kim, Al Otaiba, & Wanzek, 2015). Therefore, in line with other influential writing research, the current study includes both spelling accuracy and handwriting fluency as part of the transcription process.

Mastering transcription is important because, once handwriting gets sufficiently fast and spelling gets sufficiently accurate, writers are able to simultaneously activate the high-level writing processes that underlie expert writing (Berninger & Winn, 2006; Kellogg, 1996; McCutchen, 2006; Olive & Kellogg, 2002). According to the influential writing processes view (Hayes & Flower, 1980), the two most important high-level writing processes are planning, which is the generation and organization of ideas along with the formulation of rhetorical goals, and translating, which is the conversion of generated ideas into well-formed strings of language (Chenoweth & Hayes, 2001).

Research findings have shown positive and direct relationships between transcription (i.e., handwriting fluency and spelling accuracy), the high-level writing processes (i.e., planning and translating), and writing performance. However, to the best of our knowledge, no study has yet modeled the relationship between these variables simultaneously using a multiple-indicator approach, particularly in middle school. This was the aim of the current study, in which we examined, first, the direct effects of handwriting fluency and spelling accuracy on planning and translating, and of these latter on writing performance, and, second, the indirect effects of handwriting fluency and spelling accuracy on writing performance, via planning and translating. Testing these effects is relevant in order to better understand the mechanisms through which transcription constrains the higher-order aspects of writing.

Remarkable advances have been made in understanding the relationships between transcription and high-level writing processes (for an overview, see Berninger, 2012). Even so, we are still far from having a complete picture of how individual differences in these processes relate to each other and predict writing performance. Since transcription receives little research attention beyond primary school (Medwell & Wray, 2008), this gap is even more noticeable in middle grades. Nevertheless, there is now evidence that transcription plays a non-negligible role in middle graders' writing that is worthy of scrutiny (Limpo & Alves, 2013a). It takes a long time to become proficient in transcription and there is evidence that this might only fully happen towards age 14 (Alves & Limpo, 2015a; Chartrel & Vinter, 2004, 2006; Graham et al., 1998; Pontart et al., 2013). More

efficient transcription allows children to start coordinating other writing processes in parallel rather than in sequence (Olive & Kellogg, 2002). That is, once transcription stops depleting attentional resources, children are able to sustain transcription concurrently with planning and translating processes during text production, instead of activating one process at a time (for a review on parallel vs. sequential processing in writing, see Olive, 2014). Middle school seems therefore a particularly important period to examine the relationships between transcription, high-level writing processes, and writing performance.

1.1. Effects of Transcription on Writing

There is considerable research demonstrating that more proficient transcription skills, in particular, more fluent handwriting and more accurate spelling, are associated with better writing quality (for reviews, see Graham & Harris, 2000; Graham & Santangelo, 2014; Santangelo & Graham, 2015). The relationship between transcription and writing performance is mostly noticeable in novice writers, who still struggle with the process of putting language onto the page. Graham et al. (1997) investigated the shared and unique relations of handwriting fluency and spelling accuracy to writing in Grades 1-3 and Grades 4-6. They showed that, respectively, in primary and intermediate grades, these two transcription skills, together, accounted for 41% and 66% of the variance in writing fluency, and 25% and 42% of the variance in writing quality. Interestingly, in the junior high grades (Grades 7-9) the proportion of variance accounted for by transcription dropped substantially to 16% for writing fluency and 18% for writing quality (Berninger, 1999). However, since just direct effects were examined, no conclusions could be made about whether transcription accounted for indirect effects on writing performance. Intervention studies also supported the transcription-writing link by showing that promoting either handwriting fluency (e.g., Alves et al., 2015) or spelling accuracy (e.g., Berninger et al., 2002) improves overall writing performance (for a meta-analysis, see Graham, McKeown, Kiuhara, & Harris, 2012).

1.2. Effects of Planning on Writing

Planning, which involves setting goals, generating, and organizing ideas, may occur before

or during writing (Berninger & Swanson, 1994). There is much evidence that devoting time and effort to plan ahead of writing is beneficial to writing. For example, Beauvais, Olive, and Passerault (2011) found that the longer the prewriting pause and planning time of undergraduates, the better the quality of their argumentative texts. Additionally, Limpo, Alves, and Fidalgo (2014) showed that, in Grades 7-9, planning complexity predicted writing quality in opinion essays, above and beyond a set of well-known predictors of writing competence (viz., gender, school achievement, age, handwriting, spelling, and text structure). Even though the relationship between planning and writing quality is not evident in younger students (Whitaker, Berninger, Johnston, & Swanson, 1994) – probably due to their poorly developed planning skills (McCutchen, 2006) – there is strong evidence that planning instruction is an effective way to promote writing performance, from primary to high school grades (for meta-analyses, see Graham et al., 2012; Graham & Perin, 2007). Planning is important to produce good writing because it seems to help writers to generate content and to create an organized structure for their compositions. Also, the plan may function as an external memory where writers store ideas to develop in the text and outline action-plans to produce it (Graham & Harris, 2007).

1.3. Effects of Translating on Writing

As put by Fayol, Alamargot, and Berninger (2012),"translating is the fundamental cognitive process of writing " (p. 10). Indeed, a written text would not exist without writers' ability to translate their generated ideas into language forms. Translating involves several linguistic processes, from choosing appropriate words to encoding and selecting syntactic structures. Considerable research points to the construction of syntactically complex and acceptable sentences as a critical aspect of translating (Myhill, 2009a, 2009b). Many linguistic constructions appear to increase in length or complexity with age and ability (Berman & Verhoeven, 2002; Malvern, Richards, Chipere, & Durán, 2004). In addition, sentence-level translating skills seem to influence the quality of written texts (Beers & Nagy, 2009; Berninger, Nagy, & Beers, 2011). Intervention studies also support the relationship between sentence-level translating skills and writing performance.

Specifically, sentence-combining instruction, which teaches students to combine kernel sentences into one syntactically complex sentence (Strong, 1986), is highly effective in raising students' overall writing performance (for reviews and meta-analyses, see Andrews et al., 2006; Graham & Perin, 2007). Superior translating skills may contribute to writing quality by giving writers access to an enlarged syntactic repertoire for creating sentences. This not only facilitates the clear and syntactically correct expression of ideas held in mind, but also sets the stage for revision (Saddler & Graham, 2005). Furthermore, the use of well-crafted sentences may result in interesting and readable texts.

1.4. Transcription Constrains Planning and Translating

In contrast with the substantial amount of research examining the direct effects of handwriting fluency and spelling accuracy on writing performance, there is a paucity of research investigating the likely mechanisms underlying this relationship. It is generally assumed that in novice writers, handwriting and spelling drain attentional resources from high-level writing processes fundamental to produce good texts, such as planning ideas or translating them into language (Bourdin & Fayol, 1994; Fayol, 1999; Kellogg, 1996; McCutchen, 2006; Olive & Kellogg, 2002). Poor transcription skills may constrain planning and translating processes in several ways. For instance, if writers are concerned with how to produce letter forms or with how to spell a word, they may either forget already developed ideas or disregard basic rules in sequencing words within sentences (e.g., subject-verb agreement). The more often this occurs, the greater the likelihood of affecting the overall quality of the written product.

Different studies supported the association between transcription and planning, assessed in terms of either the complexity of the organization of the ideas, or the number of ideas generated. Limpo and Alves (2013a) used structural equation modeling to examine the relationship between transcription (modeled as a second-order factor comprising handwriting fluency and spelling accuracy in writing), planning complexity, revision, self-efficacy, and writing performance, in Grades 4-6 and in Grades 7-9. In both grade groups, transcription contributed directly to planning,

indicating that more fluent handwriting and more accurate spelling was associated with better planning skills. Moreover, whereas in younger students transcription contributed to writing quality directly, in older students this effect was fully mediated by planning and self-efficacy. The effect involving planning is of particular interest here and suggests that one of the mechanisms through which transcription influences writing quality is by constraining the complexity of writers' plans. Other studies have also shown an association between transcription and planning. Hayes and Berninger (2010) found that children in Grades 2, 4 and 6 produced more ideas in a dictation task, which has no transcription requirements, than in a similar writing task. Moreover, Glynn, Britton, Muth, and Dogan (1982) found that college students instructed to ignore punctuation and spelling during planning produced more arguments than those instructed to attend to these mechanical aspects.

Translating has received considerably less attention than other high-level writing processes (Alves, 2012), in particular regarding whether and how this process might be associated with transcription (Arfé, 2012). There is though some evidence suggesting that poor transcription skills may constrain translating, where translating was assessed through the length, complexity, or correctness of sentences produced. An experimental study by Olive, Alves, and Castro (2009) showed that hampering transcription skill, by asking undergraduates to compose with an unfamiliar uppercase script, greatly reduced sentence length. Moreover, Fey, Catts, Proctor-Williams, Tomblin, and Zhang (2004) demonstrated that, in Grade 2, the syntactic complexity of students' sentences was higher in oral stories, which have no transcription requirements, than in written stories. Notably, these differences between oral and written stories were substantially reduced in Grade 4, where transcription skills are more developed and demand less attentional resources. Moreover, it was recently reported that the syntactic complexity of sentences produced by a group of third graders with poor transcription skills was significantly lower than those produced by an aged-matched group but equivalent to transcription matched group of first graders (García, Crespo, & Bermúdez, 2016). Correlational evidence also suggested that, at least in school-aged writers, higher

transcription skills are associated with higher syntactic skills (Berninger et al., 2011; Kim, Al Otaiba, Wanzek, & Gatlin, 2014; Puranik, Lombardino, & Altmann, 2008; Wagner et al., 2011).

1.5. Study's Aims and Hypotheses

The current study aimed to examine the relationship between handwriting fluency, spelling accuracy, planning, translating, and writing performance in middle grades. Overall, grounded on research showing that transcription is associated with high-level writing processes, which are in turn critical to produce high-quality texts, it seems reasonable to expect that one of the mechanisms through which transcription affects writing performance is by constraining the generation of ideas and their expression in well-formed syntax. Specifically, we used structural equation modeling to test the model depicted in Figure 1. To the best of our knowledge, such a model has never been tested before. Nonetheless, all proposed paths were based on the multiple sources of evidence surveyed above and recapped next.

Figure 1 about here

Since handwriting and spelling are closely intertwined and act together during the process of putting words into paper (Kandel, Hérault, Grosjacques, Lambert, & Fayol, 2009), we hypothesized that handwriting fluency would be positively correlated with spelling accuracy. Additionally, we predicted that higher handwriting fluency and spelling accuracy would be associated with better planning and translating skills. These hypotheses stem from experimental and correlational research showing that, not only in primary but also in middle grades, transcription constrains the generation and organization of ideas (e.g., Limpo & Alves, 2013a) as well as the transformation of these ideas into syntactically correct sentences (e.g., García et al., 2016). By modeling handwriting fluency and spelling accuracy separately, we were also able to examine whether these two transcription processes are differentially associated with planning and translating. Such differences were expected because some research suggests that handwriting and spelling rely on distinct processes (Abbott & Berninger, 1993) and have independent growth trajectories (Abbott, Berninger, & Fayol,

2010). Moreover, the impact of handwriting fluency and spelling accuracy on the writing process (Alves & Limpo, 2015a) and on the writing product (Graham et al., 1997) is different. Overall, stronger effects have been reported for handwriting fluency than for spelling accuracy. Based on the well-established importance of planning and translating abilities to produce good texts (Berninger & Swanson, 1994; Fayol et al., 2012; Graham & Perin, 2007; Hayes & Flower, 1980; Kellogg, 1996), we expected higher planning and translating skills to be associated with better writing performance.

1.5.1. Alternative Models. As recommended by Kline (2005), we compared the proposed model to a set of three alternative models. This procedure allowed dismissing concurrent hypotheses about the expected relationship between variables, thereby increasing support for the proposed model and results' interpretation. The generation of these models was based on theoretically- and empirically-supported predictions.

In Model 1, as suggested by Limpo and Alves (2013a), handwriting fluency and spelling accuracy factors were specified to load on a higher-order transcription factor, which was specified to predict both planning and translating skills. This model was built because transcription includes both handwriting fluency and spelling accuracy (Abbott & Berninger, 1993). We therefore tested whether a model with handwriting fluency and spelling accuracy being captured by a single transcription construct (Model 1) would fit the data better than a model specifying handwriting fluency and spelling accuracy to be dissociable but related constructs (proposed model).

In Model 2, we specified a correlation between planning and translating. Although no association was found between these variables in Grades 7-9 (Berninger, Whitaker, Feng, Swanson, & Abbott, 1996), cognitive models of writing, such as that of Kellogg (1996), conceptualize the generation of ideas and translation into text as components of a unique formulation system. Moreover, Limpo and Alves (2013b) showed transfer effects of planning and sentence-combining instruction, respectively, on sentence- and ideation-level aspects of opinion essay writing. Thus, we examined whether a model including a correlation between planning and translating (Model 2)

would fit the data better than a model assuming no correlation between these variables (proposed model).

In Model 3, direct paths from handwriting fluency and spelling accuracy to writing performance were added. This model allowed us to examine whether the transcription-writing link was fully mediate by planning and translating – as assumed in the proposed model and demonstrated by Limpo and Alves (2013a) – or whether this link was partially mediated (Model 3). Evidence for partial mediation would mean that transcription would account for some of the variability in writing performance directly, and not exclusively via planning and translating, as assumed in the proposed model.

3. Method

3.1. Participants

There were 196 student participants in the study from Grades 7-8 (116 seventh graders, 60% and 80 eight graders, 40%) with a mean age of 13.7 years (*SD* = 0.9, age range = 12.2–16.9; 112 girls). Students with special education needs and with learning disabilities were excluded from the study, but all other students present in the classroom during the day of data collection were included in the study, as long as they consented to participate (all students did). As a proxy for students' socioeconomic status, we used the educational level of their mothers, which was as follows (values within parentheses represent 2015 national statistics extracted from Fundação Francisco Manuel dos Santos, 2016): 10% completed Grade 4 or less (23%), 33% completed Grade 9 or less (27%), 25% completed high school (19%), 30% completed college or some postgraduate study (20%), and 3% was unknown. Students' school achievement was assessed through their previous marks for Portuguese and Mathematics, which are given in a scale ranging from 1 (*lowest score*) to 5 (*highest score*). Respectively, average marks for these subjects were 3.1 (*SD* = 0.7) and 3.0 (*SD* = 0.9), with national averages being 3.2 and 3.1 (Direção Geral da Educação, 2015). The sample included 47 students that had repeated a grade at least once. Despite this group of students being older (M_{age} = 14.9, *SD* = 0.8), they were within ±1 *SD* of the average of the group of children without repeats

regarding their mother's educational level and scores on their school achievement as well as handwriting, spelling, planning, translating, and writing performance measures.

3.2. Instructional Setting

Students came from 10 classes integrated in a public cluster of schools located in Porto Metropolitan Area. In Portugal, basic education lasts 9 years and comprises three stages: Grades 1–4 (age 6–10), Grades 5–6 (age 10–12), and Grades 7–9 (age 12–15). Participants were thus attending the two initial years of the last stage of basic education, in which they have 11 courses taught by different teachers. Writing is the preferred learning and assessment tool across all the school courses, but explicit writing instruction only occurs in the Portuguese language classes. Explicit teaching and guided practice of handwriting mainly occurs in Grades 1 and 2. Students are introduced to the cursive letters and practice them with cursive letter models and sample words and sentences. Also, fine motor skills and capitalization rules are usually trained through letter writing and text copying with "careful calligraphy". Portuguese orthography is best characterized as having intermediate depth (Sucena, Castro, & Seymour, 2009). Portuguese is a romance language with a simple syllabic structure and several orthographic inconsistencies and complexities (Seymour, Aro, & Erskine, 2003). Seymour et al. (2003) found that, by the end of first grade, the reading results of Portuguese children were not at ceiling, as typically found in European shallow orthographies such as Italian or Finnish, but were in the range of those shown by French and Danish children. Spelling is thus a main focus of writing instruction over primary grades, though challenges in mastering spelling continue throughout adolescence (Alves & Limpo, 2015a). Spelling instruction involves explicit instruction of orthographic rules and rote memorization, trained through dictations and error-finding activities. As for the teaching of composition, despite the curriculum recommending teachers should adopt a process-oriented approach, few guidelines are provided on how to explicitly teach planning and translating (Reis et al., 2009). Writing instruction is predominately devoted to independent text production and the teaching of grammar based on traditional whole-class methods. Text production instruction may involve pre-writing activities, such as brainstorming, but is barely

supported by the teaching of writing strategies.

3.3. Procedure

Data collection occurred in classroom groups of about 20 students, at the end of the academic year. The entire session lasted about 60 min and all tasks were handwritten. Students were asked to write two opinion essays: one without planning and another one with planning. Regarding the planning task, the experimenter gave students a blue sheet and explained to them that before writing the text they would have 3 minutes to plan it. Students were told to use that sheet as their "think pad" and to write down everything that could help them to write the text (for a similar procedures, see Berninger et al., 1996; Limpo & Alves, 2013a; 2013b). The procedure for the writing task was similar across the two opinion essays. Students had 5 minutes to write the text, and they were notified 2.5 and 1 minute before the end of the time limit. Anytime a student stopped writing he or she was prompted once to continue. Brief 5-minute writing tasks have been used extensively in prior writing research (Berninger et al., 1996; Connelly, Dockrell, Walter, & Critten, 2012; Graham et al., 1997; Kent, Wanzek, Petscher, Al Otaiba, & Kim, 2014), including curriculum-based measurement research (Espin et al., 2000), with proven validity (Dockrell, Connelly, Walter, & Critten, 2015; Lembke, Deno, & Hall, 2003). To control for potential prompt effects, half of the classes wrote the essay without planning to the prompt "Do you think teachers should give students homework every days?" and the essay with planning to the prompt "Do you think students should have extracurricular activities every days". The other half of the classes wrote to the same prompts, but in reversed order. Opinion essays were chosen because they represent a genre with which students are familiar and that allows them to write about topics directly related to their lives. Indeed, these prompts were chosen for their great interest value for Portuguese middle grade students (Limpo & Alves, 2013b), thereby maximizing task engagement and productivity. There were no differences between prompts in any of the measures extracted from texts. In-between opinion essay writing tasks, students performed a sentence-combining exercise composed of a set of six blocks of two, three, and four kernel sentences (two blocks of each). They were asked to

combine the sentences of each block in an interesting and syntactically correct sentence, while preserving the meaning of the given sentences. Finally, students were asked to copy a sentence containing nine words and all letters of the alphabet (*O rouxinol azul fugiu do jardim porque chovia bastante*) during 90 s, quickly, legibly, and as many times as possible (Alves et al., 2015), and to write the lowercase letters of the alphabet during 15 s, quickly, legibly, and as many times as possible (Berninger et al., 1992). To guarantee that experimental procedures were carried out as intended, two adults were present in the room during the entire session, which included a short break to avoid students' fatigue. This research was approved by the Ethical Committee of the University as well as by the Pedagogical Committee of the School.

3.4. Measures

3.4.1. Handwriting fluency measures. Students' handwriting fluency was assessed through the alphabet and copy tasks as described above (Alves et al., 2015; Berninger et al., 1992). The final score for the alphabet task was the number of correct letters written in 15 s. A letter was counted when it was legible out of context and in the right alphabetical order. The final score for the copy task was the number of words copied accurately in 90 s. A word was considered correct when its letters were clearly copied without any mistake.

3.4.2. Spelling accuracy measures. A measure of spelling accuracy within the context of authentic writing was provided by the percentage of words spelled correctly in both opinion essays (i.e., with and without planning). This spelling measure has been used extensively in prior research with good evidence for validity (Graham et al., 2007; Limpo & Alves, 2013a; Mackie & Dockrell, 2004; Nelson & van Meter, 2007; Wagner et al., 2011). Additionally, other studies have found that spelling in text is moderately correlated with spelling-to-dictation measures (Graham et al., 1997; Limpo & Alves, 2013a). It should also be noted that, in a structural equation modeling study that modeled spelling via two measures of spelling in text and one spelling-to-dictation measure, the researchers ended up removing this latter indicator, which was creating fitting problems in Grades 7-9 (Limpo & Alves, 2013a).

3.4.3. Planning measures. Students' written plans were scored for planning complexity with a scale ranging from 1 (*low*) to 6 (*high*). The scores 1 and 2 were attributed to plans that represent no preplanning and minimal preplanning, respectively. Plans summarizing the text received a score of 3, and plans with topics slightly elaborated in the text received a score of 4. Scores of 5 and 6 were attributed to plans with emergent subordination (i.e., rudimentary macrostructure) and structural relationships (e.g., graphic organizers), respectively. This scoring scale was based on the scales developed by Whitaker et al. (1994) and Olinghouse and Graham (2009). Students' planning skills regarding ideas generation were assessed through the number of unique reasons included to justify the premise. Repeated reasons, such as "I agree because we can have new friends" and "I agree because we make new friendships", were only counted once.

3.4.4. Translating measures. Students' translating skills were assessed through the sentence-combining task and syntactic correctness in text production. The sentence-combining task included six blocks of kernel sentences to combine (e.g., *The car is fast. The car is red*). An answer was considered correct when the student combined the given sentences into a syntactically correct sentence that preserved the meaning of the original sentences. For correct answers, one or two point were awarded, respectively, if the student used or not the word "and" (e.g., *The car is fast and red* – 1 point; *The fast car is red* – 2 points). The final score was the sum of points awarded per item (max = 12). Syntactic correctness in text production was measured through the percentage of correct word sequences (CWS) written in the opinion essay with planning. This was calculated by dividing the number of CWS by the total number of words in the essay. CWS were defined as two adjacent writing units (words and punctuation) that were semantically and syntactically acceptable within the context of the text. Although this measure may consider spelling correctness (McMaster & Espin, 2007), so that spelling and translating measures were not confounded, spelling and capitalization errors that clearly did not interfere with either the meaning or the syntactic correctness of the sentence were ignored from CWS scoring in the present study. Morpho-syntactic errors, such as

agreement violations, were not ignored. The Computer Language Analysis software (MacWhinney, 2000) was used to extract the total number of words.

3.4.5. Writing performance measures. Two measures of writing performance were extracted from the opinion essays without planning, namely, writing quality and text elements. The overall writing quality of opinion essays was rated by two trained graduate research assistants, using a scale ranging from 1 (*low quality*) to 7 (*high quality*). Raters were told to consider and give the same weight to the following factors: ideas quality, organization, sentence structure, and vocabulary. Several previous studies have showed the validity of this procedure to assess writing quality (Graham et al., 2000; Harris, Graham, & Mason, 2006; Limpo & Alves, 2013a). To avoid biased judgments all texts were typed and corrected for spelling, punctuation, and capitalization errors before being rated by judges (Berninger & Swanson, 1994). The final score was the average across judges. Regarding text elements, opinion essays were scored for the presence and elaboration of four functional essay elements: premise, reasons, elaborations, and conclusion (based on Harris & Graham, 1996). Information off-topic or with no rhetorical purpose was rated as non-functional. For premise and conclusion, one point was awarded if they were present, and two points if they were present and elaborated. For reasons, one point was awarded for each unique reason justifying the premise. For elaborations, one point was awarded for each reason explained in depth (e.g., use of examples). The final score was the total points awarded in each functional element minus the number of non-functional elements.

3.4.6. Reliability of measures. At each grade level, a second judge rescored the written products of 20% of the students. The exception to this was the assessment of writing quality, in which all opinion essays were double scored. Inter-rater reliability was analyzed using the Intraclass Correlation Coefficient (ICC), calculated with a two-way mixed effects model. Reported values are for absolute agreement and for single measures, except for writing quality, whose reported values are for average measures. ICC was as follows: .99 for alphabet and copy tasks, .93 and .95 for spelling accuracy in the opinion essays with and without planning, .96 for planning complexity, .95

for number of reasons in planning, .94 for the sentence-combining task, .94 for syntactic correctness, .91 for writing quality, and .92 for text elements.

3.5. Data-Analytic Strategy

Structural equation modeling was the primary strategy for data analysis. The hypothesized model depicted in Figure 1 was fitted with the R system for statistical computing (R Development Core Team, 2005). Since data collection occurred in classroom groups ($N = 10$), structural equation modeling was conducted using the lavaan.survey package, which allows structural equation modeling analyses of clustered data (Oberski, 2014). The method of estimation was maximum-likelihood with robust standard errors, which takes into account the non-independence of the observations and any effects of non-normality. Latent variables were scaled by imposing unit of loading identification constraints. Specifically, the variance of all latent factors was constrained to equal 1.0, so that all factor loadings could be freely estimated. To evaluate model fit we used the chi-square statistic (χ^2), the confirmatory fit index (CFI), and the root-mean-square error of approximation (RMSEA). CFI values greater than .95 and .90, and RMSEA values less than .06 and .10 are considered good and adequate fits, respectively (Hu & Bentler, 1999). The fit of each alternative model was compared against that of the proposed model with the Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC), with smaller values indicating better models. For nested models, we also used a chi-square difference test.

4. Results

4.1. Descriptive Statistics and Preliminary Analyses

Descriptive statistics for all measures are displayed in Table 1. The inspection of skewness and kurtosis of these variables revealed no distributional problems, as the absolute values of these indexes were below 1.65 and 3.10, respectively (Kline, 2005). Table 2 presents the bivariate correlations among observed variables. Generally, correlations were positive and modest in size. Three overall findings are worth mentioning: handwriting fluency and spelling accuracy indicators were moderately correlated ($.18 < r\text{s} < .36$); handwriting fluency indicators were correlated with

planning indicators (.15 < *r*s < .27), whereas spelling accuracy indicators were correlated with translating indicators (.17 < *r*s < .38); and almost all variables were correlated with writing performance indicators (.14 < *r*s < .34).

Tables 1 and 2 about here

4.2. Structural Equation Modeling Results

Structural equation modeling was used to examine and compare the fit of the proposed and alternative models (cf. Table 3 for a summary of the goodness-of-fit statistics). The proposed model fitted the data extremely well, $\chi^2(28, N = 196) = 20.52$, $p = .85$, CFI = 1.00, RMSEA = .00, 90% CI [.00, .03], $P(\text{rmsea} \leq .05) = .99$. This model was then compared with the three alternative models. Model 1 modeled handwriting and spelling as first-order factors loading on a second-order transcription factor. Even though model fit was good, $\chi^2(29, N = 196) = 37.58$, $p = .13$, CFI = .97, RMSEA = .04, 90% CI [.00, .07], $P(\text{rmsea} \leq .05) = .70$, there was a decrement in fit as noted by higher AIC and BIC values. Thus, alternate Model 1 was rejected. Model 2 added the covariance between planning and translating. This model had an excellent fit to the data, $\chi^2(27, N = 196) = 20.21$, $p = .82$, CFI = 1.00, RMSEA = .00, 90% CI [.00, .03], $P(\text{rmsea} \leq .05) = .99$, but did not differ from the proposed model, $\Delta\chi^2(1) = 0.32$, $p = .57$. Model 3 added direct paths from handwriting and spelling to writing performance. Again, this model fitted the data extremely well, $\chi^2(26, N = 196) = 19.59$, $p = .81$, CFI = 1.00, RMSEA = .00, 90% CI [.00, .03], $P(\text{rmsea} \leq .05) = .99$, but did not differ from the proposed model, $\Delta\chi^2(2) = 0.93$, $p = .63$. Importantly, none of the paths added in the alternate Models 2 and 3 reached statistical significance (*p*s > .35). Therefore, although these models fitted the data as good as the proposed model, for parsimony, the proposed model was accepted.

An examination of the structural relationships specified in the proposed model revealed some non-significant paths, namely, from handwriting fluency to translating ($p = .84$), and from spelling accuracy to planning ($p = .60$). Based on these findings, we tested another model from

which these non-significant effects were removed. The fit of this simplified model was excellent, $\chi^2(30, N = 196) = 21.00$, $p = .88$, CFI = 1.00, RMSEA = .00, 90% CI [.00, .02], $P(\text{rmsea} \leq .05) = .99$, and similar to that of the proposed model, $\Delta\chi^2(2) = 0.48$, $p = .79$. These results suggested that this more parsimonious model should be preferred and thus it was used to examine the relationship between variables.

Parameter estimates concerning both the measurement and structural parts of the final model are displayed in Table 4. Regarding the measurement part of the model, all standardized factor loadings were statistically significant and ranged from moderate to strong (range = .40–.95). Regarding the structural part of the model, results showed that handwriting fluency and spelling accuracy were correlated with each other ($r = .41$, $p < .001$). Additionally, handwriting fluency was uniquely and positively related to planning ($\beta = .50$, $p = .001$) and spelling accuracy was uniquely and positively related to translating ($\beta = .59$, $p < .001$). Both planning ($\beta = .61$, $p = .003$) and translating ($\beta = .22$, $p = .05$) were uniquely and positively associated with writing performance. Indirect effects were tested through bootstrapping, using the bias corrected percentile method. Results showed significant indirect effects of handwriting fluency on writing performance via planning, $\beta = .31$, $p = .001$, 90% CI [0.16, 0.48], as well as of spelling accuracy on writing performance via translating, $\beta = .12$, $p = .003$, 90% CI [0.00, 0.27]. Overall, handwriting fluency, spelling accuracy, planning, and translating accounted for 46% of the total variance in writing performance.

Table 3 and 4 about here

5. Discussion

The current study aimed to investigate the shared and unique relationships between transcription, high-level writing processes, and writing performance in middle school (Grades 7-8). In particular, we examined, first, the direct effects of handwriting fluency and spelling accuracy on planning and translating, and of these latter on writing performance, and, second, the indirect

effects of handwriting fluency and spelling accuracy on writing performance via planning and translating. Structural equation modeling was used to test the model depicted in Figure 1.

Before discussing results, it is worth emphasizing that the tasks used to assess latent constructs were independent of each other. This procedure allows controlling for effects between factors due to bounded measures. Handwriting fluency was assessed outside text production in alphabet and copy tasks with well-established validity (Alves et al., 2015; Berninger et al., 1992;). Planning was assessed in a free planning task that students made before writing an opinion essay (Berninger et al., 1996; Limpo & Alves, 2013a; 2013b). Translating was measured in the opinion essay written after the planning, together with a sentence-combining exercise. In both measures, spelling errors were not considered. Also importantly, translating tasks required little planning and imposed varying constraints on the translating process (cf. van Gelderen & Oostdam, 2005). In the opinion essay task, students generated ideas before writing and put them freely into sentences during text production. In the sentence-combining task, students were given a pre-determined set of sentences and had a narrow range of options to correctly combine them (Berninger et al., 2011; Strong, 1986). Spelling accuracy was assessed in the context of writing, in the opinion essays with and without planning (Graham et al., 2007; Limpo & Alves, 2013a; Mackie & Dockrell, 2004; Nelson & van Meter, 2007; Wagner et al., 2011). The opinion essay without planning was only used to extract writing performance measures, excepting one of the spelling measures. Still, to set apart transcription skills from writing performance assessments, all texts were typed and corrected for spelling, punctuation, and capitalization errors before being rated by judges (Berninger & Swanson, 1994).

Descriptive statistics and preliminary correlational analyses supported the adequacy of the data for using structural question modeling. There were no distributional problems in any of the indicators, which were found to be positively and moderately correlated with each other. These results were in line with prior research (e.g., Graham et al., 1997; Limpo & Alves, 2013a).

Structural equation modeling results indicated that the proposed model was an excellent

description of the data. Concerning the measurement part of the model, we found moderate to strong factor loadings, indicating that the observed variables were good indicators of the latent constructs. Concerning the structural part of the model, initial testing showed some non-significant paths that were removed for parsimony, without compromising model's fit. Overall, we found that greater transcription skills were associated with higher planning and translating skills, which, in turn, were associated with better writing performance. The full model accounted for about half of the total variance in writing performance. Together, these results are consistent with the view that transcription, planning, and translating are crucial for good writing (Abbott et al., 2010; Berninger & Winn, 2006; Hayes & Flower, 1980; Kellogg, 1996; Kim et al., 2011; Limpo & Alves, 2013a).

In line with our hypothesis, we found that spelling accuracy was moderately and positively correlated with handwriting fluency (r = .41). This result fits well with extant research suggesting that the act of putting words onto paper requires the close integration of the orthographic letter codes and written spellings with the sequential finger movements required by the writing tool (Abbott & Berninger, 1993; Christensen, 2004; Kandel et al., 2009). We additionally examined whether spelling accuracy and handwriting fluency were better modeled as dissociable but related constructs (proposed model) or as being captured by a single transcription construct (alternate Model 1). Similarly to prior research, which successfully modeled spelling accuracy and handwriting fluency as either correlated (Graham et al., 1997) or first-order factors (Limpo & Alves, 2013a), both models fitted the data well. Even so, the correlated factors model was better than the alternate model. Therefore, one of the main findings of the current study was that handwriting fluency and spelling accuracy were differentially associated with planning and translating.

We found that more fluent handwriting was associated with better planning skills (β = .50), whereas more accurate spelling was associated with better translating skills (β = .59). As anticipated, both high-level processes were positively associated with writing performance, even though the effect of planning (β = .61) was stronger than that of translating (β = .22). Moreover, we found indirect effects of transcription on writing performance via high-level processes. Handwriting

fluency contributed to writing performance through planning (β = .31), whereas spelling accuracy contributed to writing performance through translating (β = .12). The comparison between the proposed model and alternate Model 3 demonstrated that the effects of transcription on writing were fully mediated by high-level processes, which fits with the results of Limpo and Alves (2013a). In other words, neither handwriting fluency nor spelling accuracy directly accounted for individual differences in writing performance, as it is commonly reported in primary-grade students (Graham et al., 1997; Limpo & Alves, 2013a). These results support the claim that, in middle grades, transcription influences text production by exerting a bottom-up constraint on high-level processes, and are consistent with research showing that children generated more ideas and produced more syntactically complex sentences in oral than in written text production tasks (Fayol, 1999; Fey et al., 2004; Hayes & Berninger, 2010). Furthermore, this modality difference decreased with age, as students' transcription skill improves and so frees resources for high-level writing processes.

The dissociable effect of transcription on high-level processes mirrors prior findings reported by studies using measures equivalent to ours. On the one hand, Olinghouse and Graham (2009) found that planning complexity was positively correlated with handwriting fluency, but not with spelling accuracy. It seems that greater handwriting fluency may allow writers to devote more attention and effortful thought to ideation and to quickly register generated ideas before they vanish. On the other hand, using structural equation modeling, Kim, Al Otaiba, Folsom, Gruelich, and Puranik (2014) found that spelling accuracy, but not handwriting fluency, was associated with syntactic complexity (see also Berninger et al., 2011). Greater spelling accuracy may allow writers to shift their linguistic concerns from single words to the organization of those words into larger units. The spelling-translating relationship was already implied in research into the writing of people with dyslexia, who have difficulties in reading and spelling, but not in handwriting execution (Sumner, Connelly, & Barnett, 2013). Using a text-retell procedure, Puranik, Lombardino, and Altmann (2007) found that, compared to age-matched peers, those with dyslexia showed poorer performance on complex sentence production. Consistent with our finding that spelling accuracy is

not associated with planning, they found that the two groups did not differ on the amount of ideas produced.

Importantly, the current results reflect other substantial theoretical and empirical evidence about the importance of planning and translating abilities to produce good writing (Berninger & Swanson, 1994; Fayol et al., 2012; Graham & Perin, 2007; Hayes & Flower, 1980; Kellogg, 1996). As anticipated, those students with better planning and translating skills displayed higher writing performance. This result is consistent with intervention research showing that promoting these two skills is among the best effective ways to boost school-aged children writing performance (Graham & Perin, 2007). Indeed, a recent study directly comparing the effects of planning and translating interventions in Grades 5-6 (Limpo & Alves, 2013b) showed that both interventions had a strong and positive impact on writing quality. Additionally, the authors reported some transfer effects of planning and translating instruction, respectively, on sentence- and ideation-related aspects of writing. This result suggested a possible connection between writers' planning and translating skills. Yet, this was not supported by current findings. Results comparing models specifying planning and translating to be either uncorrelated (proposed model) or correlated (alternate Model 2), showed that these two skills seem to be independent of each other. The ability to generate and organize ideas for composition does not seem related to the ability to produce well-crafted sentences (for similar results, see Berninger et al., 1996). This is an educationally relevant finding. It implies that teenage students need systematic and explicit instruction addressing both planning and translating.

6. Limitations and Future Directions

Interpretation of current findings is qualified by at least five limitations that may hint at possible avenues for future research. First, because data were obtained at a single time point and because this study is correlational in nature, causality inferences should be avoided. Further research is needed to replicate reported results, particularly, through experimental tests of the mechanisms underlying transcription effects on writing.

Second, text production measures were solely derived from 5-minute opinion essay writing tasks. The topics of the essays were chosen to be close to students' experiences, thereby facilitating text production, but to elaborate an opinion during a 5-minute task might have been challenging for middle graders. Additionally, given that different textual genres have distinct requirements in terms of both organizational principles and linguistic expression (Berman & Nir-Sagiv, 2007), it cannot not be assumed that the proposed model generalizes across genres. Future studies should aim at replicating present findings in more prolonged writing assignments as well as across genres with varying structural and linguistic features.

Third, any conclusion drawn from current results is limited to the measures used. Particularly in regards to planning and translating, the indicators used are common in writing research and have been consistently linked to writing performance (Berninger et al., 2011; Kim, Al Otaiba, Wanzek, et al., 2014; Limpo & Alves, 2013a; Olinghouse & Graham, 2009). However, planning and translating are complex writing processes that undoubtedly involve many other aspects than those assessed here (for reviews on planning and translating measures, see Hayes & Nash, 1996, and Beers & Nagy, 2009, respectively). Hence, testing similar models with other planning and translating indicators is clearly warranted. It should also be noted that our spelling accuracy measures were derived from within the written compositions. There is some evidence that, at least in 9-year old children with dyslexia, poor spelling may influence written vocabulary, thereby affecting writing quality (Sumner, Connelly, & Barnett, 2016). Though the writers in this study did not seem overly poor in their spelling ability, it is possible that some students have avoided using words they did not know how to spell. However, ad hoc analyses examining the possibility of spelling in text being associated with vocabulary usage, revealed no correlations between spelling and vocabulary measures, such as corrected-type token ratio, lexical density, or word mean length (rs < .15). It is also worth mentioning that, consistent with prior research, this study measured handwriting in terms of fluency and spelling in terms of accuracy. It could thus be possible that results might reflect the choice of measure rather than the students' actual handwriting

and spelling abilities. Future studies are needed to examine whether results would vary as a function of the transcription measure, for example, considering handwriting legibility in non-timed tasks as well as latencies in spelling-to-dictation tasks.

Fourth, writing motivation was not examined in the present study. The impact of students' writing self-efficacy beliefs, writing achievement goals, or attitudes toward writing on their writing performance has been widely discussed in the literature (Alves & Limpo, 2015b). Future studies may considerer adding motivation variables to models examining the relationships among transcription, high-level processes, and writing. Results may provide further insights on the putative factors influencing students' coordination of low- and high-level processes in writing. Another variable not considered in the current model was gender. Since some studies indicated that girls display better writing skills than boys (e.g., Kim et al., 2014; Reynolds, Scheiber, Hajovsky, Schwartz, & Kaufman, 2015), it would be interesting to examine to what extent writers' gender influence the model here tested. Future studies could perhaps use multiple-group structural equation model to compare the strength of the relationships among transcription, high-level writing skills, and writing performance across girls and boys.

Finally, we did not assess how transcription is associated with the online management of planning and translating during writing. It is known that writing performance seems to depend on having the skills as much as on how the skills are implemented throughout the moment-to-moment production of a text (Beauvais et al., 2011). Thus, it would be particularly relevant to address how transcription may shape the dynamics of writing.

7. Educational Implications

Taken together, findings of the current study carry important messages to those concerned with the teaching and learning of writing. As indicated by current results, handwriting fluency and spelling accuracy may constrain high-level writing processes that underlie high-quality text production. Therefore, as a building block of writing development, transcription should be taught and practiced from very early on, so that the acquisition of high-level writing processes is not

compromised later. There is now plenty of evidence on the effectiveness of handwriting and spelling instruction to promote fast and accurate transcription, and, critically, to boost text production (e.g., Alves et al., 2015; Berninger et al., 2002). This kind of instruction is particularly important in the initial years of learning to write. However, when slow handwriting and/or poor spelling skills are identified in teenage school years, transcription instruction should be provided. This may be achieved by adapting current transcription programs to older students, which can be implemented as supplementary curriculum. Christensen (2004) showed the effectiveness of a typing intervention for seventh and eighth graders identified as slow typists. Similar programs focused on either handwriting or spelling should be devised and tested, to provide teachers with effective tools to deal with middle graders still struggling with the low-level processes of writing.

It is worth cautioning, however, that the direct effects of handwriting on planning and of spelling on translating do not mean that transcription instruction is sufficient for students to develop their ability to generate ideas and express them into language. Though transcription might be related to planning and translating, specific writing instruction is needed to boost such complex skills, which, as also shown here, are critical to produce good texts. Prior research has already shown the effectiveness of strategy-focused interventions to promote planning and translating skills in middle grades (Graham & Perin, 2007). Given that transcription skills continue to develop (Graham et al., 1998) and constrain writing (Limpo & Alves, 2013a) well beyond primary grades, the inclusion of transcription training in such programs could increase their effectiveness, similarly to what has been shown in Grade 2 (Limpo & Alves, in press). These multicomponent programs might be particularly effective for middle graders with slow handwriting and/or poor spelling.

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Table 1

Descriptive Statistics for all Observed Variables

Variables		Descriptive statistics					
		M	*SD*	Min	Max	Sk	Ku
Handwriting fluency	Alphabet task	18.08	5.19	4.00	33.00	0.11	-0.26
	Copy task	36.01	6.96	14.00	54.00	-0.17	0.14
Spelling accuracy	Spontaneous spelling[a]	96.90	3.63	81.40	100.00	-1.39	1.82
	Spontaneous spelling[b]	97.01	3.38	81.82	100.00	-1.65	3.10
Planning	Planning complexity[a]	3.76	1.33	1.00	6.00	-0.73	0.24
	Reasons in planning[a]	2.27	1.64	0.00	7.00	0.43	-0.38
Translating	Sentence combining	5.47	2.24	0.00	11.00	0.07	-0.32
	Syntactic correctness[a]	89.75	5.23	72.73	100.00	-0.48	0.49
Writing performance	Writing quality[b]	3.61	1.20	1.00	6.50	-0.11	-0.53
	Text elements[b]	5.04	1.69	1.00	10.00	0.32	0.17

[a]Measures extracted from opinion essay with planning. [b]Measures extracted from opinion essay without planning.

Table 2

Bivariate Correlations Between Observed Variables

		1	2	3	4	5	6	7	8	9	10
Handwriting fluency	1. Alphabet task	–	.62***	.28***	.18*	.17*	.15*	.13	.12	.18**	.19**
	2. Copy task		–	.36***	.25***	.27***	.23***	.10	.12	.29***	.29***
Spelling accuracy	3. Spontaneous spelling[a]			–	.51***	.13	.01	.19**	.38***	.18*	.15*
	4. Spontaneous spelling[b]				–	.09	.04	.18*	.17*	.13	.002
Planning	5. Planning complexity[a]					–	.27***	.06	.08	.32***	.26***
	6. Reasons in planning[a]						–	.09	-.01	.25***	.34***
Translating	7. Sentence combining							–	.26***	.26***	.14*
	8. Syntactic correctness[a]								–	.17*	.08
Writing performance	9. Writing quality[b]									–	.69
	10. Text elements[b]										–

[a]Measures extracted from opinion essay with planning. [b]Measures extracted from opinion essay without planning.

* $p < .05$. * $p < .01$. * $p < .001$.

Table 3

Summary of Goodness-of-Fit Statistics for the Proposed, Alternative, and Final Models

Model	χ^2	*df*	*p*	CFI	RMSEA	RMSEA 90%CI	*P(rmsea*<.05)	AIC	BIC
Proposed model	20.23	28	.85	1.00	.00	[.00, .03]	.99	9145.69	9266.98
Model 1	37.58	29	.13	.97	.04	[.00, .07]	.70	9163.39	9281.40
Model 2	20.21	27	.82	1.00	.00	[.00, .03]	.99	9147.05	9271.62
Model 3	19.59	26	.81	1.00	.00	[.00, .03]	.99	9149.36	9277.21
Final model	21.00	30	.88	1.00	.00	[.00, .02]	.99	9142.31	9257.04

Table 4

Parameter Estimates for the Final Model

Paths	*B*	*SE*	*p*	β
Measurement part				
Handwriting fluency				
Alphabet task	3.37	0.46	< .001	.65
Copy task	6.60	0.71	< .001	.95
Spelling accuracy				
Spontaneous spelling[a]	1.84	0.48	< .001	.54
Spontaneous spelling[b]	3.38	0.43	< .001	.94
Planning				
Planning complexity[a]	0.64	0.11	< .001	.56
Reasons in planning[a]	0.69	0.11	< .001	.49
Translating				
Sentence combining	2.77	0.56	< .001	.66
Syntactic correctness[a]	0.73	0.27	.01	.40
Writing performance				
Writing quality[b]	0.77	0.15	< .001	.87
Text elements[b]	0.91	0.11	< .001	.74
Structural Part				
Handwriting fluency → Planning	0.58	0.18	.001	.50
Spelling accuracy → Translating	0.73	0.16	< .001	.59
Planning → Writing performance	0.72	0.25	.003	.61
Translating → Writing performance	0.25	0.12	.05	.22
Handwriting fluency ↔ Spelling accuracy	0.41	0.10	< .001	.41

Note. Non-significant paths (viz., from handwriting fluency to translating and from spelling accuracy to planning) were removed from this final model. [a]Measures extracted from opinion essay with planning. [b]Measures extracted from opinion essay without planning.

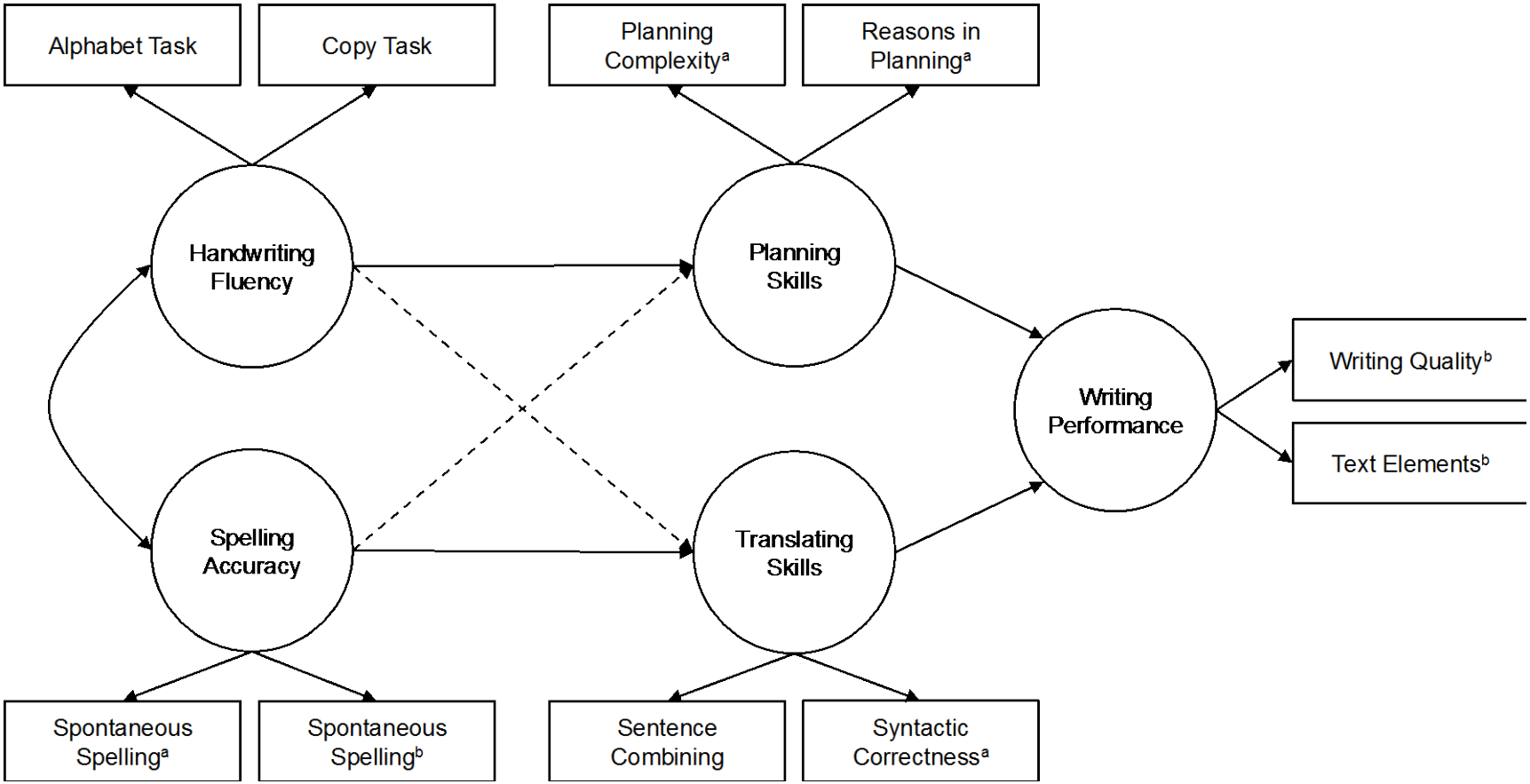

Figure 1. Proposed model of the relationship between handwriting fluency, spelling accuracy, planning, translating and writing performance. Circles represent latent variables, rectangles represent observed variables, and arrows represent direct paths (dashed lines represent paths that were dropped from the final model). [a]Measures extracted from opinion essay with planning. [b]Measures extracted from opinion essay without planning.