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# Progress in Written Language Bursts, Pauses, Transcription, and Written Composition Across Schooling

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Research on adult writers has shown that writing proceeds through bursts of transcription activity interspersed by long pauses. Yet few studies have examined how these writing behaviors unfold during early and middle childhood. This study traces the progress of bursts, pauses, transcription, and written composition in Portuguese students from Grade 2 to 7 and tests whether bursts and pauses are related to transcription, to writing fluency, and to text quality across grades and two genres (narrative vs. opinion essay). We found that increasingly automaticity of transcription allowed for more efficient composing processes, as reflected in longer bursts, shorter pauses, and greater fluency. Regardless of grade and genre, more automatic transcription contributed to longer bursts, which along with shorter pauses contributed to higher writing fluency and text quality. These results provide useful information on children's language bursts and pauses, which may support the assessment and further training of their writing skills.

From a behavioral standpoint, writing can be described as a stream of written language bursts punctuated by long production pauses. Bursts of written language were first noticed by Kaufer, Hayes, and Flower (1986), who showed that adult writers compose in segments of about nine words, separated by pauses lasting more than 2 s. This behavioral simplicity of observable language bursts and measurable pauses contrasts with the complexity of the covert cognitive and other mental processes underlying writing. Most current cognitive models of writing largely agree that four cognitive processes support expert writing: *planning processes* that set rhetorical goals, which guide the generation and organization of ideas; *translating processes* that convert ideas into linguistic forms; *transcription processes* that draw on spelling and handwriting (or typing) to externalize language in the form of written text; and *revising processes* that monitor, evaluate, and change the intended and the actual written text (Berninger & Swanson, 1994; Berninger & Winn, 2006; Hayes, 1996; Hayes & Flower, 1980, 1986; Kellogg, 1996). Previous research has shown that translating (Chenoweth & Hayes, 2001, 2003; Hayes & Chenoweth, 2007) and transcription (Alves, 2013; Alves, Castro, Sousa, & Strömqvist, 2007) are critically involved in generating language bursts. However, this evidence is mainly derived from studies with adult writers. What about bursts of language in beginning writers? Is it the case that children readily start composing by adding stretches of about nine words? Likely not. Thus, main aims of this

study were to examine burst length across schooling and to learn about the cognitive drivers of a presumed growth in burst length.

## THE RELIANCE OF BURSTS ON TRANSLATING AND TRANSCRIPTION SKILLS

In their pioneering study, Kaufer et al. (1986) found that professional writers wrote more words per burst than college students, thus concluding that burst length was influenced by translating skill. The authors argued that the greater expertise of professional writers in converting ideas into written language allowed them to compose using larger segments of language. More recently, Hayes and Chenoweth conducted a set of studies trying to ascertain the source of the bursting phenomenon. They found that undergraduates produced longer bursts and wrote more words per minute (writing fluency) in their first language than in their second language (Chenoweth & Hayes, 2001). They also showed that reducing undergraduates' verbal working memory, through articulatory suppression, lead to decreases in burst length and writing fluency (Chenoweth & Hayes, 2003). Furthermore, skilled typists did not produce bursts in a copying task, presumably requiring only transcription processes (Hayes & Chenoweth, 2006). However, bursts were observed in a passive-to-active conversion task that called for language formulation but not idea generation (Hayes & Chenoweth, 2007). These results supported the authors' claim that translating is the key source of language bursts (for recent reviews, see Hayes, 2009, 2012). Still, they did not convincingly discard the involvement of other writing processes, such as transcription, in producing language bursts. For instance, bursts might have been absent in the study of Hayes and Chenoweth (2006) because the participants in that study were highly skilled typists. Indeed, recent studies suggested that transcription influences burst length. Alves et al. (2007) found that undergraduates with high typing skill wrote texts with longer bursts than those with low typing skill. Moreover, they found that the longer the bursts, the higher the writing fluency and the text quality. Similarly, Alves (2013) found that hampering transcription skill, by asking adults to compose with either an uppercase script or a scrambled keyboard, greatly reduced burst length. Thus, it seems that, when not automatized, transcription constitutes a bottleneck that limits the number of words that can be written in a burst.

## LANGUAGE BURSTS AS DEVELOPMENTAL MARKERS OF WRITING EFFICIENCY

The relationship between transcription and burst length should, therefore, be particularly evident in children, who are still automatizing transcription (Berninger & Swanson, 1994; Graham, Berninger, Abbott, Abbott, & Whitaker, 1997; Limpo & Alves, 2013a). Transcription is generally conceptualized as being made up of the close integration of orthographic codes of letters and written spellings with the specific finger movements required by the particular writing tool used (e.g., handwriting, typing; see Abbott & Berninger, 1993; Christensen, 2004). To the best of our knowledge, only two studies have specifically looked at children's language bursts. Alves, Branco, Castro, and Olive (2012) found that 9 year olds with high handwriting fluency produced longer bursts than those with low and average handwriting fluency, and that longer bursts were associated with better text quality. Connelly, Dockrell, Walter, and Critten (2012) replicated the correlation between burst length and text quality with 11 year olds and reported two additional key

findings: Typically developing children produced longer bursts than those with specific language impairment, and both handwriting fluency and spelling accuracy were significant predictors of burst length, above and beyond language proficiency. These two studies have, therefore, provided preliminary evidence that young writers' burst length is influenced by transcription skills and is positively related to writing fluency and text quality. Because automatization of transcription supports the efficiency with which writers can transcribe the linguistic segment temporarily held in verbal working memory, nonautomatic transcription may drain resources that are diverted from keeping the linguistic segment active, forcing writers to pause in order to reinstate it. For instance, a third grader might pause to consider the correct spelling of a word and in the meanwhile forget what message was conveying. Indeed, according to capacity theory (Just & Carpenter, 1992; McCutchen, 1996), pauses may result from the cognitive overload brought on by the many demanding processes that writers try to accomplish within the limited capacity of working memory.

The results from an experiment by Olive and Kellogg (2002) further supported the capacity theory and were suggestive of a differential engagement of cognitive processes during bursts and pauses. Olive and Kellogg measured third graders' cognitive effort (i.e., interference in reaction time) in a text-copying task, and in bursts and pauses during text production. The authors found that cognitive effort was similar whether children were copying or during bursts. It is important to note that this level of cognitive effort was higher than that found during pauses. Presumably, during bursts children engage only in transcription and during pauses they engage in other cognitive processes required to compose a text. These results suggest that, in children, transcription is very resource demanding and leaves no spare capacity for other writing processes.

Because in beginning writers, planning and revising skills are poorly developed (Bereiter & Scardamalia, 1987; Limpo, Alves, & Fidalgo, 2014; McCutchen, 2006), their text production is likely to rely mostly on transcription and translating processes. Transcription may be preferably activated during bursts, whereas translating may be preferably activated during pauses. Still, as transcription gets more automatic and demands less attention, writers may engage in efficient parallel activation of other writing processes. That is, while transcribing the current language segment held in working memory, writers might be able to formulate the next segment to be written, revise the text just written, or even plan for the forthcoming text. Indeed, this sort of parallel activation of writing processes is typical of adult writers. Alves, Castro, and Olive (2008) showed that translating is the writing process more frequently activated during bursts and that, even if to a lesser extent, planning and revising do also occur during bursts (see also Olive, Alves, & Castro, 2009). Furthermore, increasingly fast and accurate transcription processes are likely to manifest in steady increases in burst length (Alves, 2013) and concomitant decreases in pause duration (Alamargot, Plane, Lambert, & Chesnet, 2010).

Based on the reviewed literature it is our proposal that bursts can be thought as markers of writing efficiency, that is, longer bursts may signal the ability to compose a text using larger chunks of language and to better orchestrate the recursive and parallel activation of writing processes.

## DESIGN AND AIMS OF THE CURRENT STUDY

Despite the reviewed evidence that bursts are behavioral markers of writing efficiency, how bursts progress in beginning and developing writers, and how they are related to transcription, writing

fluency, and text quality are two research questions that were not investigated before within a developmental frame. Here, we studied (a) the progress in writing from Grade 2 to 7 (7–14 years old), across two genres, by focusing on grade differences in bursts and pauses, and (b) the contribution of transcription skills to bursts and pauses, and from these to writing fluency and text quality.

Specifically, using a cross-sectional design, we asked Portuguese children from Grade 2 to 7 to write the alphabet, to spell dictated words, to compose a story, and to compose an opinion essay. The first two tasks were used to assess transcription skills, widely agreed to encompass handwriting and spelling (e.g., Berninger & Winn, 2006). The composition tasks were logged using smartpens, thus allowing for the measurement of burst length, pause duration, and writing fluency. Stories and opinion essays were collected to test whether findings would generalize over two distinct genres, which are known to pose different cognitive demands for developing writers (Kellogg, 1994).

Based on the literature reviewed, and concerning our first research question, we expected increases in transcription skills to be mirrored by increases in burst length and decreases in pause duration. This pattern should then be reflected in a steady increase in writing fluency. Concerning our second research question, we conducted hierarchical regression analyses to test the extent to which handwriting and spelling contributed to burst length and pause duration, and the extent to which burst length and pause duration contributed to writing fluency and text quality. Stemming from the previously reviewed findings, we hypothesized that more automatic transcription processes would result in longer bursts and shorter pauses, which in turn would lead to greater writing fluency and text quality. To investigate whether the pattern and strength of these relationships would hold across genres, separate analyses were conducted for stories and opinion essays.

## METHOD

### Participants

The participants in this study were 310 Portuguese native speakers in Grades 2–7. Sixty-one students were excluded from data analyses based on one or more of the following criteria: special education needs (nine students), grade retentions (36 students), and absence in one or both of the administration sessions (28 students). The final sample included 249 students: 28 second graders ( $M_{\text{age}} = 7.6$  years,  $SD = 0.3$ , age range = 7.1–8.0; 13 girls), 45 third graders ( $M_{\text{age}} = 8.5$  years,  $SD = 0.3$ , age range = 8.0–9.0; 21 girls), 51 fourth graders ( $M_{\text{age}} = 9.4$  years,  $SD = 0.3$ , age range = 9.0–10.0; 23 girls), 31 fifth graders ( $M_{\text{age}} = 10.5$  years,  $SD = 0.3$ , age range = 10.0–10.9; 21 girls), 49 sixth graders ( $M_{\text{age}} = 11.6$  years,  $SD = 0.4$ , age range = 11.1–13.5; 22 girls), and 45 seventh graders ( $M_{\text{age}} = 12.5$  years,  $SD = 0.4$ , age range = 12.0–14.2; 24 girls).

### Setting

Students came from 21 classes integrated in a public cluster of schools located in an urban district in Porto, Portugal. Portuguese orthography is best characterized as of intermediate depth (Sucena, Castro, & Seymour, 2009). Portuguese is a romance language with simple syllabic structure,

predominantly open consonant–vowel, and several instances of 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. Portuguese children read correctly about 75% of the words and nonwords presented, which contrasts with 98% accuracy level of Finnish children, and the lower reading level of Scottish children (34% of words and 29% of nonwords correctly read). Teaching of reading in Portugal is based in phonics instruction with guidelines issued by the Ministry of Education. Handwriting style adopted is cursive from Grade 1, and children practice it with cursive letter models and sample words and sentences. Teaching of spelling is based on explicit teaching of orthographic rules and rote memorization.

### Procedure

Data collection occurred in groups of 15 students during two 45-min sessions 1 week apart, from November to February. In Session 1, students were given 20 min to write a story to the prompt “Tell a story about a child who lost his/her pet.” If a student stopped writing before 5 min, he or she was prompted once to continue writing. Afterward, students performed a spelling test composed of 56 words that were dictated at intervals of 15 s (Carvalhais & Castro, 2014). Similar to the first session, students started Session 2 by writing an opinion essay to the prompt “Give your opinion about children watching television whenever they can and whatever they want.” Then students performed the alphabet task (Berninger, Mizokawa, & Bragg, 1991). They were asked to write, quickly and legibly, the lowercase letters of the alphabet during 60 s. Two experimenters were always present in the room to guarantee that procedures were carried out as intended.

### Material: HandSpy

To collect and analyze temporal handwriting data we used a new web-based system called *HandSpy*. To write their texts, each student was provided with a digital pen and a paper sheet. The digital pen was a LiveScribe Pulse of regular appearance but hosting an infrared camera at its nib and running a penlet for logging handwriting data. The paper had a special microdotted pattern printed on it. The combination of the smartpen with the microdotted paper enables the precise recording of spatial and temporal coordinates about the pen trace. These data are then uploaded to the HandSpy application for online analyses. Because some children blocked the camera, the smartpen failed to register 8% and 5% of the words written in stories and opinion essays, respectively.

### Measures

#### *Transcription*

We assessed two transcription skills: handwriting fluency and spelling accuracy. Students' handwriting fluency was measured by counting the number of correct letters written in the alphabet task. A letter was considered correct when it was legible out of context and in the right alphabetical order. Students' spelling accuracy was measured by counting the number of words

spelled correctly in the dictation task composed of 56 words. These words belong to seven categories representing some complexities of the Portuguese spelling system: complex graphemes, silent letter *h*, contextual effect, position effect, inconsistency, consonantal group, and stress mark (Carvalhais & Castro, 2014). At each grade level, a second judge rescored the alphabet and spelling tasks for 20% of the students. Interrater reliability, measured by the intraclass correlation coefficient (ICC), was .99 for both measures.

### *Bursts and Pauses*

Students' stories and opinion essays were analyzed into burst length and pause duration. A burst was defined as handwriting activity between two consecutive pauses, in which at least one word was written. Burst length was calculated by averaging the number of words per burst. At each grade level, a second judge rescored the burst length for 20% of the students and ICC for stories and opinion essays was .99 and .98, respectively. A pause was defined as a period of handwriting interruption of more than 2 s, which is a common pause threshold used in studies measuring bursts (Chenoweth & Hayes, 2001; Kaufer et al., 1986; Strömqvist, Holmqvist, Johansson, Karlsson, & Wengelin, 2006). The average pause duration was provided by the HandSpy software.

### *Written Composition*

Two measures of written composition were obtained from students' stories and opinion essays: writing fluency and text quality. Writing fluency was measured by the number of words written per minute, which was calculated by dividing text length by composing time. Text length was calculated with the Computerized Language Analysis software (MacWhinney, 2000), whereas composing time was recorded with HandSpy. Text quality was assessed by two pairs of graduate research assistants, blind to study purposes. The evaluation procedure was the same across genres: One pair rated stories and the other one rated opinion essays. To remove handwriting and spelling biases on quality assessments, all texts were previously typed and corrected for spelling errors (Berninger & Swanson, 1994). Using a scale ranging from 1 (*low quality*) to 7 (*high quality*), judges were asked to rate four factors: creativity (i.e., originality and relevance of the ideas), coherence (i.e., clarity and organization of the text), syntax (i.e., syntactic correctness and diversity of the sentences), and vocabulary (i.e., diversity, interest, and proper use of the words). To control for expected differences across grades, the texts produced at each grade were grouped and rated separately. Judges were not informed about the grade they were assessing, but they were provided with representative examples of low-, medium-, and high-quality texts within each grade level (for a similar procedure, see Graham, Harris, & Fink-Chorzempa, 2002). The four ratings of each judge were summed (max = 28) and the interrater reliability was calculated per grade. ICC for stories and opinion essays was greater than .95 and .96, respectively. For both genres, the final quality score was the average across judges.

## RESULTS

In a set of preliminary analyses we examined, first, if there were outliers and, second, if the data met the assumptions of parametric procedures. The following outliers were found: one second

grader in spelling, one third grader and one fourth grader in opinion essay pause duration, one fifth grader in story pause duration, and one seven grader in story burst length. These outliers were removed from the data analyses concerning the measures wherein they were identified. The inspection of the skewness and kurtosis of all variables by grade, group, and whole sample revealed no distributional problems ( $Sk < |1.93|$  and  $Ku < |4.72|$ ).

### Grade Differences in Writing Across Schooling

Analyses of variance (ANOVAs) were conducted to examine differences in transcription (viz., handwriting and spelling), bursts and pauses (viz., burst length and pause duration), and written composition (viz., writing fluency and text quality) from Grade 2 to 7 (see Table 1 for descriptive statistics). Because we were expecting changes across grades, significant grade effects were followed up with planned comparisons between adjacent grades.

TABLE 1  
Means and Standard Deviations for All Variables Across Grades

Measures	Grade											
	2 <sup>a</sup>		3 <sup>b</sup>		4 <sup>c</sup>		5 <sup>d</sup>		6 <sup>e</sup>		7 <sup>b</sup>	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Composing time												
Story composing time	15.36	3.98	14.93	3.35	13.84	3.54	16.59	3.65	15.61	3.29	15.18	3.44
Opinion composing time	9.39	3.83	7.47	2.50	9.39	3.46	8.54	3.14	10.02	3.89	8.59	2.62
Transcription												
Handwriting	29.39	10.58	32.78	9.80	50.90	16.06	53.35	15.03	51.16	17.94	65.84	20.46
Spelling	29.71	9.24	35.62	7.63	38.82	7.75	44.03	4.13	44.61	5.01	46.33	4.42
Bursts												
Story burst length	2.21	0.60	2.79	0.72	3.76	1.22	3.94	1.07	4.57	1.30	6.02	2.28
Opinion burst length	2.54	0.98	2.72	0.82	4.17	1.50	4.55	1.73	4.84	1.91	5.97	2.60
Pauses												
Story pause duration	9.88	3.41	8.72	3.32	7.66	2.21	7.44	3.18	6.69	1.94	6.14	1.52
Opinion pause duration	12.12	5.09	13.20	8.22	10.19	4.37	8.62	4.03	9.03	3.59	7.62	2.61
Written composition												
Story fluency	5.56	2.07	7.10	1.64	10.16	2.82	10.80	2.61	12.20	3.04	14.81	3.76
Opinion fluency	5.77	2.77	6.31	2.09	9.21	3.51	10.57	3.52	10.80	3.49	13.47	4.37
Story quality	17.05	5.28	17.38	4.79	15.96	4.19	18.16	4.84	17.20	4.07	18.48	5.15
Opinion quality	15.00	5.50	13.02	5.28	14.72	5.82	14.48	5.68	14.19	5.26	13.94	5.64

Note. Metric and possible range for reported measures are as follows: story and opinion composing time is in min; handwriting = number of correct letters in the alphabet task; spelling = number of correct words in the spelling test (0–56); burst length = number of words per burst; pause duration is in seconds; fluency = number of words per minute; quality = sum of the four quality scales (4–28).

<sup>a</sup> $n = 28$ . <sup>b</sup> $n = 45$ . <sup>c</sup> $n = 51$ . <sup>d</sup> $n = 31$ . <sup>e</sup> $n = 49$ .



### *Transcription*

Grade differences in handwriting fluency and spelling accuracy were analyzed with two one-way ANOVAs. As predicted, a significant effect of grade was found, both for handwriting,  $F(5, 243) = 28.97, p < .001, \eta^2_p = 0.37$ , and for spelling,  $F(5, 242) = 32.76, p < .001, \eta^2_p = 0.40$ . For handwriting fluency, we found significant increases from Grade 3 to 4 ( $p < .001, d = 1.36$ ) and 6 to 7 ( $p < .001, d = 0.76$ ). No significant differences were found from Grade 2 to 3 ( $p = .38, d = 0.33$ ), 4 to 5 ( $p = .50, d = 0.16$ ), and 5 to 6 ( $p = .55, d = -0.13$ ). For spelling accuracy, we found significant increases from Grade 2 to 3 ( $p = .002, d = 0.64$ ), 3 to 4 ( $p = .01, d = 0.42$ ), and 4 to 5 ( $p < .001, d = 0.84$ ). No significant differences were found from Grades 5 to 6 ( $p = .69, d = 0.13$ ) and 6 to 7 ( $p = .19, d = 0.36$ ).

### *Bursts and Pauses*

Grade differences in burst length and pause duration across genres were analyzed by means of two 2 (genre)  $\times$  6 (grade) ANOVAs, with repeated measures on the first factor. Regarding burst length, we found a main effect of genre,  $\Lambda = .97, F(1, 242) = 8.56, p = .004, \eta^2_p = 0.03$ , meaning that students wrote fewer words per bursts in story than opinion essay writing. Moreover, we found a main effect of grade,  $F(5, 242) = 36.53, p < .001, \eta^2_p = 0.43$ . Planned contrasts revealed that, regardless of genre, burst length significantly increased from Grade 3 to 4 ( $p < .001, d = 1.21$ ) and 6 to 7 ( $p < .001, d = 0.65$ ). There were no significant differences from Grade 2 to 3 ( $p = .24, d = 0.54$ ), 4 to 5 ( $p = .34, d = 0.23$ ), and 5 to 6 ( $p = .13, d = 0.34$ ). The Genre  $\times$  Grade interaction was not significant.

Regarding pause duration, we found a main effect of genre,  $\Lambda = .81, F(1, 240) = 56.69, p < .001, \eta^2_p = 0.19$ , indicating that the pauses produced in story writing were shorter than those produced in opinion essay writing. Furthermore, we found a main effect of grade,  $F(5, 240) = 13.01, p < .001, \eta^2_p = 0.21$ . Planned contrasts revealed that, regardless of genre, pause duration significantly decreased from Grade 3 to 4 ( $p < .001, d = 0.54$ ). There were no significant differences from Grade 2 to 3 ( $p = .51, d = 0.12$ ), 4 to 5 ( $p = .14, d = 0.41$ ), 5 to 6 ( $p = .83, d = -0.06$ ), and 6 to 7 ( $p = .09, d = 0.49$ ).

### *Written Composition*

Grade differences in story and opinion essay fluency were examined by means of a 2 (genre)  $\times$  6 (grade) ANOVA, with repeated measures on the first factor. We found a main effect of genre,  $\Lambda = .94, F(1, 243) = 16.77, p < .001, \eta^2_p = 0.07$ . Students wrote more words per minute in the story than in the opinion essay. Moreover, we found a main effect of grade,  $F(5, 243) = 49.61, p < .001, \eta^2_p = 0.51$ . Writing fluency significantly increased from Grade 3 to 4 ( $p < .001, d = 1.28$ ) and 6 to 7 ( $p < .001, d = 0.80$ ). No differences were found from Grade 2 to 3 ( $p = .12, d = 0.55$ ), 4 to 5 ( $p = .12, d = 0.36$ ), and 5 to 6 ( $p = .20, d = 0.29$ ). The Genre  $\times$  Grade interaction was not significant.

### *Correlations*

Table 2 shows the intercorrelations among the regression variables for Grades 2–4 and 5–7. The overall pattern of correlations appears to be similar across groups and three findings are

TABLE 2  
Correlations Between Regression Variables by Grade Group

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Grade		-.17	.05	.56	.39	.55	.50	-.28	-.15	.63	.44	-.11	.01
2. Story composing time	-.15		.26	-.15	-.05	-.25	-.29	.13	.05	-.37	-.26	.35	.06
3. Opinion composing time	-.02	.37		.13	.07	.10	.03	.15	.10	.003	-.11	.12	.31
4. Handwriting	.28	-.09	-.02		.39	.58	.59	-.23	-.12	.62	.53	.06	.30
5. Spelling	.20	.21	.19	.33		.43	.45	-.23	-.09	.43	.43	.41	.35
6. Story burst length	.44	-.29	-.09	.51	.21		.74	-.18	.03	.84	.57	.11	.24
7. Opinion burst length	.26	-.25	-.10	.39	.11	.67		-.25	.15	.76	.74	.17	.38
8. Story pause duration	-.22	.20	-.09	-.08	.05	-.23	-.14		.40	-.49	-.35	-.29	-.11
9. Opinion pause duration	-.13	-.07	-.11	-.22	-.22	-.11	-.03	.28		-.21	-.51	-.13	-.15
10. Story fluency	.44	-.38	-.08	.52	.11	.77	.57	-.52	-.14		.71	.13	.25
11. Opinion fluency	.30	-.15	-.12	.53	.27	.53	.68	-.31	-.46	.65		.22	.35
12. Story quality	.04	.30	.19	.41	.39	.16	.04	-.21	-.20	.27	.21		.40
13. Opinion quality	-.04	.17	.31	.29	.30	.18	.11	-.13	-.27	.19	.28	.54	

*Note.* Correlations for Grades 2–4 ( $n = 124$ ) are above the diagonal and correlations for Grades 5–7 ( $n = 125$ ) are below the diagonal. Values above .29 are statistically significant at an alpha level of .001, which was set due to the number of comparisons.

noteworthy: Handwriting and spelling were moderately correlated with each other as well as with both bursts and written composition, bursts and pauses were more correlated with writing fluency than quality, and story variables had moderate to strong correlations with the corresponding opinion variables.

### Contribution of Transcription to Bursts and Pauses

To examine whether handwriting and spelling made a unique contribution to burst length and pause duration, we conducted separate regressions for stories and opinion essays. In these analyses, three adjacent grades were collapsed as to create two contrasting groups (Grades 2–4 vs. 5–7). This also allowed for more robust and powerful regression models, thereby maximizing their predictive validity. For each analysis, we entered grade and composing time on Step 1. Grade was added because three adjacent grades were grouped, and composing time was added because there was no time limit for text production. Next, on Step 2, we entered handwriting and spelling (see Table 3). We further examined whether the variance explained by Step 2 predictors was similar across grades and groups. Following the guidelines of Pedhazur and Schmelkin (1991), we first standardized the variables and then computed the interactions between handwriting and spelling with grade and group. Interaction terms were introduced separately into the models.

#### *Story Burst Length*

There were no significant interactions between handwriting and spelling with grade ( $ps > .31$ ), but there was a marginally significant interaction between handwriting and group ( $p = .07$ ). Therefore, we conducted separate regressions for Grades 2–4 and 5–7. Step 1 accounted for 32% and 24% of the variability in story burst length, respectively in Grades 2–4 and 5–7. The

TABLE 3  
Regression Analyses of the Contribution of Handwriting and Spelling to Burst Length and Pause Duration in Stories and Opinion Essays

Outcome	Step 1			Step 2		
	R <sup>2</sup>	Grade ( $\beta$ )	Composing Time ( $\beta$ )	R <sup>2</sup>	Handwriting ( $\beta$ )	Spelling ( $\beta$ )
Story burst length						
Grades 2–4	.32***	.26**	-.14*	.45***	.33***	.19*
Grades 5–7	.24***	.31***	-.19*	.39***	.39***	.04
Opinion burst length						
Grades 2–7	.30***	.29***	-.07	.40***	.36***	.09
Story pause duration						
Grades 2–7	.19***	-.33***	.11	.20	-.04	-.13
Opinion pause duration						
Grades 2–7	.12***	-.25**	.04	.13	-.09	-.07

Note. The standardized betas are from the final step of the regression model.

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

entry of handwriting and spelling resulted in a significant increase in the prediction of burst length in Grades 2–4 and 5–7, additionally explaining 13% and 15% of the variance, respectively. In younger students handwriting and spelling significantly contributed to story burst length, whereas in older students only handwriting did.

### Opinion Essay Burst Length

Because handwriting and spelling did not interact with grade and group ( $ps > .19$ ), a single regression was conducted for the whole sample. Step 1 explained 30% of the variance in opinion essay burst length. When handwriting and spelling were added there was a significant increase of 10% in the amount of variance explained, with only handwriting making a reliable contribution.

### Story and Opinion Essay Pause Duration

Because handwriting and spelling did not interact with grade and group in both genres ( $ps > .10$ ), regression analyses were conducted for the whole sample. Step 1 accounted for 19% and 12% of the variability, respectively, in story and opinion essay pause duration. Step 2 did not reach significance.

### Contribution of Bursts and Pauses to Written Composition

To examine whether burst length and pause duration made a unique contribution to writing fluency and quality, we conducted separate regressions for stories and opinion essays, including grade and composing time on Step 1, and burst length and pause duration on Step 2 (see Table 4). To test whether the variance explained by Step 2 predictors was similar across grades and groups, we followed the procedure previously described.

TABLE 4  
Regression Analyses of the Contribution of Burst Length and Pause Duration to Writing Fluency and Quality in Stories and Opinion Essays

Outcome	Step 1			Step 2		
	R <sup>2</sup>	Grade ( $\beta$ )	Composing Time ( $\beta$ )	R <sup>2</sup>	Burst Length ( $\beta$ )	Pause Duration ( $\beta$ )
Story fluency						
Grades 2–4	.47***	.15***	-.14***	.86***	.67***	-.31***
Grades 5–7	.27***	.05	-.13**	.77***	.66***	-.30***
Opinion fluency						
Grade 2	.001		-.22	.57***	.77***	-.13
Grade 3	.06		-.19*	.76***	.48***	-.71***
Grade 4	.11*		-.07	.70***	.63***	-.45***
Grade 5	.001		.03	.65***	.70***	-.42***
Grade 6	.004		-.13	.62***	.57***	-.60***
Grade 7	.10*		-.12	.77***	.77***	-.48***
Story quality						
Grades 2–4	.12***	-.32***	.42***	.33***	.33***	-.37***
Grade 5	.06		.32	.25*	.01	-.44*
Grade 6	.03		.08	.08	-.20	-.22
Grade 7	.30***		.65***	.49**	.32*	-.22
Opinion quality						
Grades 2–4	.09**	-.27**	.32***	.29***	.48***	-.14
Grades 5–7	.10**	-.11	.30***	.18**	.17*	-.25**

Note. The standardized betas are from the final step of the regression model.

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

### Story Fluency

Burst length and pause duration did not interact with grade ( $ps > .33$ ), but they did interact with group ( $ps < .01$ ). Thus, separate regressions were conducted for Grades 2–4 and 5–7. Step 1 explained 47% and 27% of the variance in story fluency, respectively, in Grades 2–4 and 5–7. The entry of burst length and pause duration resulted in a significant increase in the prediction of story fluency in Grades 2–4 and 5–7, additionally explaining 39% and 50% of the variability, respectively. Despite burst length and pause duration were significant predictors in both groups, an inspection of the unstandardized beta weights revealed that burst length contributed more to story fluency in younger than older students (1.76 vs. 1.43), whereas pause duration contributed more to story fluency in older than younger students ( $-0.53$  vs.  $-0.30$ ).

### Opinion Essay Fluency

Due to a significant interaction between pause duration and grade in both groups ( $ps < .01$ ), regressions were conducted by grade. Step proved significant in Grades 4 and 7, accounting for 11% and 10% of the variance, respectively. When burst length and pause duration were entered, there was a significant increase in the amount of variance explained in all grades, ranging from 57% to 70%. Except in Grade 2, both burst length and pause duration significantly predicted opinion essay fluency.

### *Story Quality*

There were no significant interactions between burst length and pause duration with grade in the younger group ( $ps > .35$ ), but there was a marginally significant interaction between burst length and grade in the older group ( $p = .07$ ). Therefore, we conducted a single regression for Grades 2–4 and separate regressions for Grades 5, 6, and 7. In Grades 2–4, Step 1 accounted for 12% of the variability in story quality. When burst length and pause duration were included there was an increase of 20% in the amount of variance explained, with both predictors significantly contributing to story quality. In Grades 5–7, Step 1 explained 30% of the variability in seventh graders' story quality. The entry of burst length and pause duration resulted in a significant increase in the prediction of story quality in Grades 5 and 7 (19%). Pause duration was a significant predictor in Grade 5, whereas burst length was a significant predictor in Grade 7.

### *Opinion Essay Quality*

Burst length and pause duration did not interact with grade ( $ps > .39$ ), but they did interact with group ( $ps < .05$ ). Thus, separate analyses were conducted for Grades 2–4 and 5–7. Step 1 accounted for 9% and 10% of the variance in opinion essay quality, respectively, in Grades 2–4 and 5–7. When burst length and pause duration were added, there was a significant increase in the prediction of opinion essay quality in Grades 2–4 and 5–7, additionally explaining 20% and 9% of the variability, respectively. In younger students, only burst length significantly predicted opinion essay quality, whereas in older students both burst length and pause duration did.

## DISCUSSION

This study used online logging to investigate the progression of bursts and pauses, transcription, and written composition from Grade 2 to 7, and to analyze how these processes were related to each other, across two genres (stories vs. opinion essays). Throughout schooling, we found a growing trend in transcription, as well as greater efficiency in composing, reflected in longer bursts, shorter pauses, and greater fluency. Overall, regardless of grade group and genre, bursts and pauses were found to be dependent upon students' transcription skills, and, crucially, to contribute to writing fluency and text quality.

### Progress in Writing Across Schooling

As expected students' transcription skills showed increased automaticity throughout schooling. Handwriting fluency had a remarkable increase, with the number of alphabet letters written in 1 min by seven graders doubling that of second graders. Growth was also found in spelling accuracy, but with a more pronounced increase from Grade 2 to 5 than from Grade 5 to 7. In line with our expectations, the automatization of transcription across schooling allowed writers to become more automatic in transcribing language, as reflected by longer bursts, and likely more strategic in activating writing processes, as reflected by shorter pauses. Burst length in stories increased from about two words in Grade 2 to six words in Grade 7 and was found to be slightly shorter than burst length in opinion essays. With respect to pause duration in stories, this was found to

decrease from about 9 s in Grade 2 to 6 s in Grade 7 and to be about 2 s shorter than pause duration in opinion essays. This pattern in bursts and pauses across schooling was mirrored by a steady increase in writing fluency, with seven graders writing almost 3 times more words per minute in stories than second graders. Students were slightly less fluent in opinion essays, even though the growth trend was very similar across genres. Taken together, the longer pauses and slower writing fluency in opinion essays compared to stories corroborates the assumption that expository writing is cognitively more challenging than narrative writing (Berman & Nir-Sagiv, 2007; Olive, 2004). Noticeably, increases in writing fluency kept pace with increases in both handwriting fluency and burst length. For the three measures, the strongest increases occurred between Grade 3 and 4 and between Grade 6 and 7. As far as we know, this is the first time that cross-sectional increases in burst length are documented. This was shown in an orthography of intermediate depth, Portuguese.

### Contribution of Transcription to Bursts and Pauses

We found that more automatic transcription skills resulted in longer bursts. This result joins a growing body of research showing that poor transcription skill creates a bottleneck that hinders the process of putting words into paper (Alves, 2013; Alves et al., 2012; Alves et al., 2007; Connelly et al., 2012). This study has also provided further original results about language bursts in children. On the one hand, we demonstrated that transcription consistently influenced burst length across grades and genres. On the other hand, we found that handwriting and spelling influenced bursts differently. Handwriting fluency contributed to burst length in both younger and older students and in both genres. Spelling accuracy contributed to stories burst length only in younger students but to a lesser extent than handwriting. Notably, a similar pattern was found for the contribution of transcription to writing fluency (Graham et al., 1997), which seems to be closely tied to language bursts. Different growth trends suggest that automatizing handwriting may require more years than mastering spelling, which may account for handwriting acting as the strongest constraint to bursts. Indeed, despite the progressive increase of handwriting throughout schooling, in Grade 7, students were far way from adults' performance, who were able to produce about 100 letters per minute in the same task (Alves, 2013). On the contrary, we found little improvement in spelling after Grade 5, in which students were already able to spell correctly 79% of the dictated words. Actually, other studies have shown that students in Grades 4–6 correctly spelled about 95% of the words written during composition (Graham et al., 1997; Limpo & Alves, 2013a). Furthermore, we found that whereas individual differences in handwriting tended to increase with age, those in spelling tended to decrease. Although these results suggest that achieving automaticity in handwriting is critical for transcribing text quickly, with shorter interruptions, further research is needed to disentangle the different role that handwriting and spelling play in children's language bursts. Particularly, as spelling systems vary in orthographical depth, cross-linguistic studies would be instructive to further specify the contribution of spelling to bursts.

The contribution of transcription to pauses was found to be similar across grades and genres. Neither handwriting nor spelling made significant contributions to average duration of pauses. This result might be explained by the use of a 2 s pause threshold, which seems more sensitive to the involvement of higher order rather than transcription processes (Alves et al., 2008; Wengelin, 2006). Research using a lower pause threshold reported that children with poor transcription

skills spent, indeed, more time pausing than their normally achieving peers (Prunty, Barnett, Wilmut, & Plumb, 2013; Sumner, Connelly, & Barnett, 2013). Although the threshold of 2 s might be adequate for burst analyses, lower thresholds might be needed to uncover the link between transcription and pause duration.

### Contribution of Bursts and Pauses to Written Composition

Another key finding of the present study was that, as predicted, individual differences in burst length and pause duration accounted for a significant proportion of the variance in students' fluency and text quality. Those students who composed texts using longer bursts and shorter pauses wrote more words per minute and wrote better texts than those who showed shorter bursts interrupted by longer pauses. Overall, these results support the claim that bursts and pauses are markers of writing efficiency. Longer bursts and shorter pauses are likely to reflect greater abilities in converting ideas into language and in externalizing it in writing, which, in turn, result in more fluent and better writing. Noteworthy, the contribution of bursts and pauses to writing fluency was clearly more sizeable than that to text quality. The full regression models accounted for more than a half in writing fluency variability (explained variance ranged from 57% to 86%). It is also important to note that the contribution of bursts to writing fluency was higher than that of pauses. These findings suggest that bursts of written language seem to be a fine-grained measure of writing fluency, conveying useful information about writers' efficiency in writing.

It is worthy to highlight that, although burst length and pause duration as well as writing fluency and text quality differed across genres, there were only slight differences between the contribution of transcription to bursts and pauses in stories and opinion essays, and of these latter to writing fluency and text quality. This seems to indicate that the previously discussed relationships, rather than being genre specific, may represent basic processing patterns in writing not open to the rhetorical constraints imposed by different genres. Actually, these results are congruent with those of Olive et al. (2009), who found that adults' activation of writing processes across bursts and pauses in narrative and argumentative writing was similar.

### Limitations

The findings reported here should be considered in view of at least three limitations that may set the basis for future research. First, we did not differentiated bursts regarding whether they were initiated and terminated by a pause or a revision, because novice writers were found to barely engage in spontaneous online revising (Berninger & Swanson, 1994; Torrance, Fidalgo, & García, 2007). Moreover, this bursts classification system was grounded on expert writers' text production in typing (Baaijen, Galbraith, & de Glopper, 2012). Future studies should explore if this taxonomy is also valid for handwritten texts produced by children. Second, we did not measure a language skill that has been shown to be relevant for writing quality, that is, vocabulary (Olinghouse & Wilson, 2013). It might well be that taking into account vocabulary growth, particularly related to print exposure throughout schooling, might uncover another specific source of language bursts development. Finally, although the results provided original insights into the nature and functioning of bursts and pauses in beginning and developing writing, the correlational nature of the study advises caution in making causality inferences. Further research using

experimental designs as well as more powerful statistical methods are needed to deepen our understanding about the role of bursts and pauses in writing development.

### Practical Implications

The current study showed that the automatization of transcription (mainly, handwriting) resulted in a steady increase in burst length, which was associated to increased writing fluency and better text quality. These findings have practical implications for both assessment and promotion of students' composing abilities. Assessing bursts can be informative for characterizing children's efficiency with written language and for tracking developmental progress in writing. This information may assist in the identification of struggling writers and guide the design of interventions likely to enhance children's ability to put words into paper. These interventions should primarily target transcription processes, given that, when not sufficiently automatic, they can hinder fluent and high-quality writing well beyond primary grades (Limpo & Alves, 2013a). Several studies have already shown that promoting fast and accurate transcription enhances children's writing performance (e.g., Berninger et al., 2002; Berninger et al., 1998; Christensen, 2004; Graham et al., 2002; Jones & Christensen, 1999), but none have looked at how these interventions alter the moment-to-moment production of a text. Indeed, intervention studies usually assess instructional effects on measures of overall writing performance (e.g., text length, fluency, and quality of writing), rather than on specific measures, either at the process or at the product level (for an exception, see Limpo & Alves, 2013b). Notwithstanding the importance of the former, the later are pivotal to increase knowledge about how effective interventions work and how these can be tailored to students' writing needs. Future studies should scrutinize handwriting and spelling interventions' effects by looking at their impact on children's language bursts, which, as shown here, are foundational indicators of expertise in writing.

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