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Differential syllable effects when learning to write French and Catalan words

- 1 Handwriting involves different processing levels. According to Van Galen's (1991) model of handwriting production, from the intention of writing to the actual movement execution, there are several processing modules. There are three "linguistic modules" that are common to speech and handwriting and are responsible for the activation of intentions, semantic recovery and syntax construction (cf. Levelt, 1989). The processes involved in handwriting and speech differ at the spelling module. Then, there are three "motor modules" that allow for allograph selection, size control and muscular adjustments. This study focuses on the interaction between the spelling module and the three lower levels. We examined how the syllable structure of the words stored at the spelling module affects movement production during writing acquisition. More precisely, we investigated how the differences in complexity in letter-sound conversion rules of French and Catalan affect the way the syllable structure regulates the timing of syllable programming strategies during handwriting acquisition.
- 2 There is a considerable amount of research supporting the idea that syllables constitute processing units in various linguistic tasks. In the word production domain, for example, Levelt and colleagues proposed that speakers recover articulatory-phonetic programs from a mental syllabary (Levelt, Roelofs, Meyer, 1999; Levelt & Wheeldon, 1994). Also, a series of experiments carried out in Spanish suggest that syllabic structures are used in the phonological encoding of production (Costa & Sebastián-Gallés, 1998; Santiago, MacKay & Palma, 2002; Santiago, MacKay, Palma & Rho, 2000; Carreiras & Perea, 2004). In French, the role of the syllable has also been confirmed in word, pseudo-word and picture naming (Ferrand, Grainger, & Seguí, 1994; Ferrand, Seguí, & Grainger, 1996). Research on typewriting further indicates that letter chunking strategies are also constrained by syllable structure (Weingarten, 2005; Weingarten, Nottbusch & Will, 2004). There is also empirical evidence that syllables are relevant functional units in speech perception both in French and Spanish (Mehler, Dommergues, Frauenfelder, & Seguí, 1981; Sebastián-Gallés, Dupoux, Seguí, & Mehler, 1992) and word reading (Álvarez, Carreiras, & De Vega, 2000; Álvarez, Carreiras, & Perea, 2004; Álvarez, Carreiras, & Taft, 2001; Carreiras, Alvarez, & de Vega, 1993; Carreiras & Perea, 2002, 2004; Perea & Carreiras, 1998). Although the role of the syllable is clearly established and has been widely investigated in these tasks, there is scarce literature on the role of the syllable in handwriting.
- 3 Kandel, Álvarez and Vallée (2006) conducted an experiment in which French adults wrote words on a digitiser. The words shared the initial letters but had different syllable boundaries (e.g., *tra.ceur* (tracer) and *trac.tus* (tract); the dot indicates the syllable boundary). The participants had to write in upper-case letters and lift the pen between the letters. The idea underlying this task was that the duration of the pen lifts during the intervals between the letters provides information on the timing of motor programming. This study showed that the between-syllable inter-letter intervals (between *a* and *c* in *tra.ceur*) were longer than within syllables (between *a* and *c* in *trac.tus*). The authors concluded that these duration differences

revealed that the participants wrote the words by grouping the letters into syllable-like chunks. Other experiments confirmed these results in French and Spanish. The participants wrote cognates (i.e. words sharing the same spelling and meaning in both languages) and pseudo-words with a letter sequence that was always intra-syllabic in French and inter-syllabic in Spanish (e.g. *malgnolia* and *maglnolia*, respectively). Again, the results showed that syllable structure constrains motor programming in handwriting, since the inter-letter interval between *g* and *n* was systematically shorter in French than in Spanish, both in words and pseudo-words. This pattern of results also appears even when French-Spanish bilinguals write the same items in French and Spanish. This syllable effect was replicated with French words of various syllable lengths (Lambert, Kandel, Fayol & Espéret, 2008) as well as in Spanish with picture naming and writing under dictation tasks (Álvarez, Cottrell & Afonso Hernández, 2009). The present research investigates the way in which children of two different orthographic systems –French and Catalan– acquire syllable oriented writing strategies.

4 One of the first studies on this issue was carried out by Rieben, Meyer and Perregaux (1989). In was a longitudinal study in which French-speaking 5 and 6 year-old children elaborated a story together with the teacher. This story was written on a large sheet of paper and displayed on the classroom wall. Then, the children had to produce another text and they were told that they could use what was written in the first text as model if they did not know how to write what they wanted to say. The results revealed that at the beginning most of the children wrote the words letter-by-letter. Then they wrote them by grouping the letters into chunks. The size of these chunks increased with age. According to the authors, the evolution from one phase to the other depends on the progressive acquisition of knowledge of the alphabetical code and working memory capacities.

5 A series of developmental studies using digitiser measures also show that learning how to write implies much more than learning how to write one letter after another. Research conducted in French showed that children chunk letters into syllables and these chunks modulate the motor programming processes during handwriting acquisition. Kandel and Valdois (2006a) analysed 1st to 5th graders' production of bisyllabic words and pseudo-words. The analysis of movement time distribution provided information on the timing of handwriting production and, in particular on the local modulations at syllable boundaries. Their results yielded stable letter durations throughout the first syllable of the word. Then there was a duration peak at the first letter of the second syllable followed by a progressive decrease towards the end of the word. This pattern of duration distribution was observed systematically, regardless of school level, lexical status and item length.

6 The duration increases at syllable boundaries can be accounted for by the anticipatory conception of Van Galen's (1991) model. The different processing levels that regulate handwriting production function in a hierarchical and parallel fashion. The "linguistic" higher-order modules anticipate and process information related to forthcoming parts of the word in parallel to the processing of the lower level "motor" aspects that determine the local parameters like size, direction and force. When various modules of different representational levels are active simultaneously –and because processing capacities are limited– there is a supplementary cognitive load that results in an increase in movement duration. Thus, the simultaneous processing of the movement to prepare the following syllable and the processing of the local parameters produced movement time increases at the syllable boundary. In other words, the stability of letter duration during the production of the first syllable indicates that the children prepared the gesture to produce it before starting to write. The duration increase at the first letter of the second syllable translates that they programmed the movement to produce the second syllable while writing its first letter. The progressive duration decrease towards the end of the word reveals that the movements to produce the second syllable were entirely programmed during the production of its first letter.

- 7 Another study conducted with French 1st graders, confirmed this syllable oriented letter duration distribution (Kandel, Soler, Valdois & Gros, 2006). The results showed however that when the initial syllable of the word contains complex graphemes, like CH in the word *chanson* (song, CH= \int in / \int ã õ /), there is a first duration peak at the grapheme boundary. This reveals that the children processed the word's initial syllable grapheme-by-grapheme. The second duration peak appears, like in Kandel and Valdois (2006a), at the first letter of the second syllable, followed by a progressive decrease towards the end of the word.
- 8 Further research replicated this "syllable effect" and revealed that the syllable chunks the French children use as processing units when writing words have an orthographic rather than phonologic format (Kandel, Hérault, Grosjacques, Lambert & Fayol, 2009). In their study 3rd, 4th and 5th graders wrote words that were mono-syllables phonologically (e.g. *barque*= [baRk], boat) but bi-syllables orthographically (e.g. *barque*= *bar.que*). These words were matched to words that were bi-syllables both phonologically and orthographically (e.g. *balcon*= [bal.kõ] and *bal.con*, balcony). The results on letter duration and movement fluency yielded significant peaks at the syllable boundary for both types of words, indicating that the words were segmented according to grapho-syllabic patterns rather than determined phonologically (i.e., derived from speech production processes).
- 9 Is this grapho-syllable oriented programming strategy directly related to French handwriting or is it a characteristic of the writing of other languages as well? A cross-linguistic French-Spanish experiment conducted with 1st and 2nd graders showed that the complexity of the grapho-phonological rules of a language may determine the way children group letters into chunks (Kandel & Valdois, 2006b). Spanish has a similar syllabic structure to French, but a simpler set of orthographic rules (Seymour et al., 2003). French has rather complex grapho-phonological relationships and a great number of orthographically irregular words, which render writing acquisition an extremely complex task. Conversely, the majority of Spanish words can be written correctly by applying one-to-one grapho-phonological correspondences. Thus, Spanish has a rather *transparent* orthography whereas French a rather *opaque* orthography. In Kandel and Valdois (2006b) the children wrote French-Spanish orthographic cognates. Cognates are words that share common orthographic roots and have the same meaning in both languages (e.g. *insecte* in French and *insecto* in Spanish, which both mean insect). The results yielded a syllable oriented writing pattern in French but not in Spanish. When the French children wrote the words, there were systematic letter duration increases at the first letter of the second syllable, as in the previous study. In contrast, the Spanish-speaking children used letter chunks that were larger than the syllable. Moreover, when French-Spanish bilinguals wrote the same cognate words, the syllable effect clearly appeared when they wrote in French. When they wrote them in Spanish, the letter chunks were larger than the syllable. These results show that the child uses different chunk sizes as a function of the language in which he/she has to write.
- 10 It should be noted that in Spanish the results from children and adults might seem contradictory. As Kandel and Valdois (2006b) pointed out, there is a period in the acquisition of spelling skills in which the Spanish-speaking children seem to use processing units that are bigger than the syllable. The straightforward relations between letters and sounds facilitate phonological recoding and should enable the children to encode more orthographic information in memory (Share, 1995, 1999). In other words, phonological encoding enables the child to memorize the phonemes of the whole word. Then, the child can write it by making phoneme-grapheme conversions. This idea is supported by the fact that in Spanish, children acquiring literacy skills have a higher level of performance in writing than in reading (Borzone de Manrique, 1993). Moreover, less skilled readers can spell many words that they cannot read and have equivalent spelling abilities as skilled readers (Borzone de Manrique & Signorini, 1994).

- 11 The present research is a cross-linguistic study that compared French to Catalan writing acquisition processes. Catalan orthography is shallower than French, but deeper than Spanish. In terms of syllabic structure, Catalan has clear syllabic boundaries like French, but has variable stress and vowel reduction like English (Sebastián-Gallés, Dupoux, Seguí, Mehler, 1992; Badia, 2002). In Soler and Kandel (2009) Catalan 1st graders wrote bisyllabic and trisyllabic words. The authors observed a significant letter duration peak at the first letter of the second syllable for bisyllables, which is in line with the French syllable oriented writing strategies. For trisyllables, they only observed a letter duration peak at the first letter of the third syllable. This suggests that the children programmed the first two syllables before starting to write and then prepared the movements to produce the third syllable while writing its first letter. These results show that, unlike Spanish and as French, the syllable structure may regulate the programming of Catalan words, at least when they are bisyllabic. The results are less clear for trisyllabic words. Furthermore, we cannot compare this data to French because all the French studies conducted with children mostly used bisyllabic words.
- 12 The present experiment therefore investigated how French and Catalan children write trisyllabic words. Do the French children still prepare their gestures syllable by syllable when they have to deal with words that have more than one syllable boundary? Do the Catalan children only produce a letter duration peak at the first letter of the third syllable? French and Catalan 1st graders wrote cognate trisyllabic words. Since French children group letters as syllable chunks, we expected to observe a letter duration peak at each syllable boundary. If the Catalan children program the two initial syllables before starting to write, we should only observe one peak at the first letter of the third syllable. We studied 1st graders because Kandel & Valdois (2006b) showed that most French-Spanish writing strategies differences were observed in 1st grade and almost disappeared in 2nd grade.

Method

Participants

- 13 Forty-two right-handed 1st grade right-handed children participated in this experiment. There were 21 French children (mean age 6;5) and 21 Catalan children (mean age 6;6). The French were all pupils of a school in the Grenoble urban area and were tested in April. The teachers reported the reading method was mixed. The Catalan children attended a school in the south of Barcelona and were tested in February. The teachers reported the reading method was based on grapho-phonological correspondences. In the French, as well as in the Catalan schools, reading and writing explicit instruction started in 1st grade. None of the participants were repeating nor skipping a grade and they were attending their grade at the regular age. They all had normal or corrected-to-normal vision and reported no hearing impairments, learning disability, brain or behavioural problems. School attendance was regular. They participated in the experiment under parental consent.

Material

- 14 The stimuli were 9 orthographic French-Catalan cognates (Appendix 1). The reason for using cognates was to have an equivalent material in both languages. The cognates were all seven letters long and trisyllabic. They had exactly the same syllable structure. We made sure that the children considered all the words as trisyllabic by asking them to clap their hands each time there was a syllable. All the words had a CV initial syllable, then another CV second syllable, and a final CVC syllable. Our references for word frequency were the LEXIQUE 2 French data base for French words (New, Pallier & Ferrand 2003) and the IEC data base for Catalan words (Rafel, 1996). The words have similar frequencies in both languages with a mean frequency of 65.27 pm in French and 91.37 pm in Catalan.

Procedure

- 15 The experiment was conducted with *Ductus* –a new handwriting software package recently developed in our laboratory for the study of handwriting production (Guinet & Kandel, 2010). Each word was presented in front of the child, on the centre of the screen of a laptop written in upper case Times New Roman size 18. An auditory signal and a fixation point (200 ms duration) preceded word presentation. The participants' task was to copy the word on a digitiser (Wacom Intuos 1218, sampling frequency 200 Hz, accuracy 0.02 mm). The digitiser was connected to a computer that monitored the movements the child executed. The children were instructed to copy the items as they did in class, i.e., in cursive handwriting. They had to write with a special pen (Intuos Inking Pen) on a lined paper that was stuck to the digitiser. This paper was like the one they use to write when they are in school (the vertical limit is 0.8 cm and the horizontal limit is 17 cm). The children became familiar with the material by writing their name. Two practice items (*maison-casa* and *chat-gat*) preceded the experiment. No time limit or speed constraints were imposed. The following word was presented once the child accomplished the previous one.
- 16 The nine items were randomised across participants. The experiment lasted between 20 to 30 minutes and the children were tested individually in a quiet room inside the school.

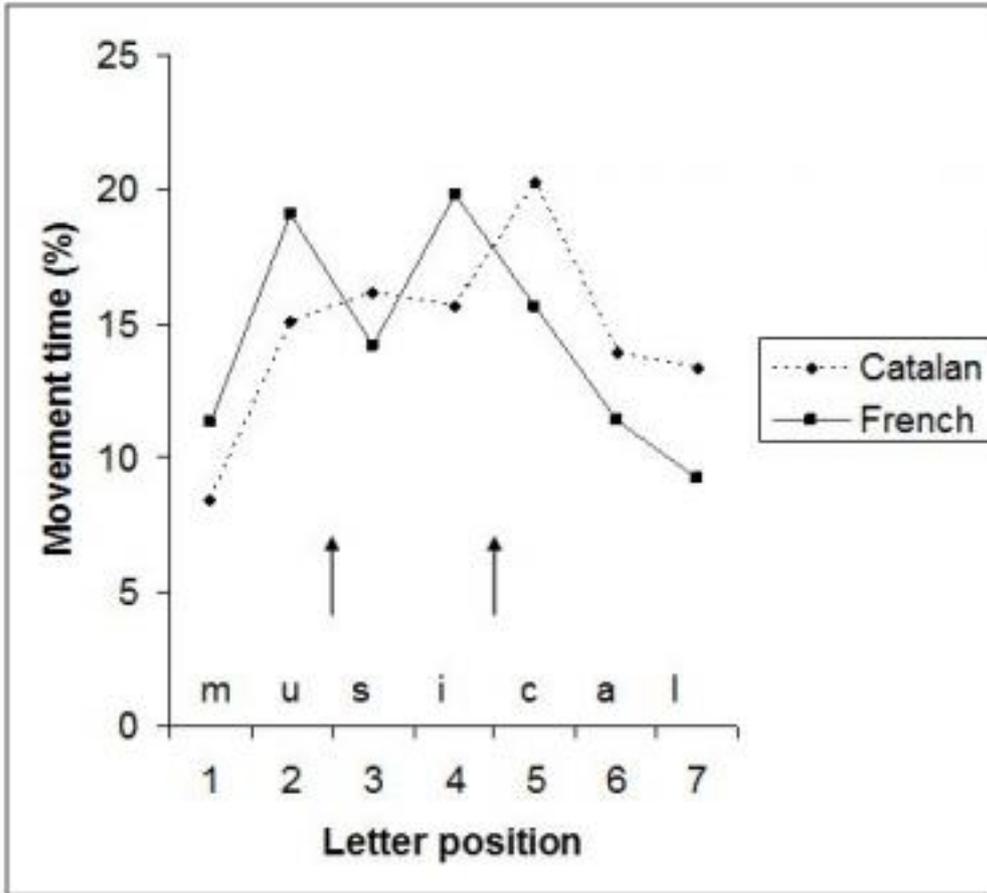
Data analysis

- 17 *Ductus* also has a semi-automatic handwriting analysis module (see Guinet & Kandel, 2010 for information on the analysis procedure). *Ductus* smoothed the data with a Finite Impulse Response filter (Rabiner & Gold, 1975) with a 12 Hz cut-off frequency. Then, we segmented the words into their letter constituents by hand so we could obtain data on the timing of the movement that produced each letter (cf. Kandel & Valdois, 2006a). Since the children wrote in cursive, we segmented the words into their letter constituents according to curvature maxima in the trajectory and velocity minima in the velocity profile. The duration measure concerned the time the children took to write each letter. Since the number of strokes in each letter was different, we had to normalise duration values with respect to the number of strokes per letter, as in Bogaerts et al. (1996). For example, if the durations for an *l* (2 strokes) and a *b* (3 strokes) are both 180 ms, the mean stroke durations are $180/2=90$ and $180/3=60$ ms, respectively. The duration values of each letter were divided by the number of strokes it contained, according to a letter segmentation procedure presented by Meulenbroek and Van Galen (1990). Then, for each letter, we calculated the ratio of the mean stroke duration to the sum of all the mean stroke durations of the word, and then converted it to percentages. Letter duration percentages reveal information on the global organisation of the handwriting gesture because they provide information on the distribution of the duration throughout the entire word. With this procedure, we can see how duration increases or decreases at specific locations within the word. In addition, duration percentages allow comparisons among all participants, from very slow to very fast ones. For instance, the mean stroke duration of a given letter is 100 ms for one child and 200 ms for another, but the duration percentages are around 15%. This means that both children organise their handwriting movements in the same manner.

Results

- 18 This section presents the results calculated from movement duration. Analyses of variance was conducted using language (French, Catalan) and letter position as factors, both by participants (F^1) and items (F^2).
- 19 Figure 1 presents mean stroke duration percentages for the French and Catalan words as a function of letter position. The analysis revealed that the Catalan children produced longer durations than the French children but this main effect of language did not reach significance in the by-items analysis, $F^1(1,40)=24.18$, $p < .001$; $F^2 < 1$. The effect of letter position was

significant, $F^1(6,42)=47.41, p < .001$; $F^2(6,48)=9.01, p < .001$. The results yielded a significant interaction between language and letter position, $F^1(6,240)=16.17, p < .001$; $F^2(6,48)=8.35, p < .001$.



Figure

1. Movement time percentage for each letter in French and Catalan words. The arrows show the position of the two syllable boundaries. The word *musical* in the lower part of the figure illustrates how each letter is represented.

20 As Figure 1 shows, movement time analysis for the French children revealed two peaks at letters 2 (first syllable boundary) and 4 (second syllable boundary). Letter duration percentages increased from letter 1 to 2, $F^1(1,40)=76.20, p < .001$; $F^2(1,8)=9.60, p < .01$; decreased from letter 2 to 3, $F^1(1,40)=31.54, p < .001$; $F^2 < 1$. It increased again from letter 3 to 4, $F^1(1,40)=36.33, p < .001$; $F^2(1,8)=10.75, p < .01$. It decreased progressively from letter 4 to 5, $F^1(1,40)=14.92, p < .001$; $F^2(1,8)=4.66, p < .05$. Then, it continued decreasing from letter 5 to 6, $F^1(1,40)=14.21, p < .001$; $F^2(1,8)=7.02, p < .05$ and from letter 6 to 7, $F^1(1,40)=6.16, p < .01$; $F^2 < 1$. All the F^1 differences were still significant after a Bonferroni correction. The fact that most F^2 do not reach significance is due to the limited number of items.

21 For the Catalan children the pattern of results was different, with only one peak at letter 5 (second syllable boundary). Letter duration percentages increased from letter 1 to 2, $F^1(1,40)=54.96, p < .001$; $F^2(1,8)=23.82, p < .001$. They remained stable from letter 2 to 3 and from letter 3 to 4, all F^1 and $F^2 < 1$. Then, there was a significant increase from letter 4 to 5, $F^1(1,40)=18.43, p < .001$; $F^2(1,8)=4.65, p < .05$. Durations decreased from letter 5 to 6, $F^1(1,40)=31.78, p < .001$; $F^2(1,8)=9.50, p < .01$. They were equivalent from letter 6 to 7, both F^1 and $F^2 < 1$. All the F^1 differences were still significant after a Bonferroni correction. The fact that most F^2 do not reach significance is due to the limited number of items.

Discussion

- 22 This experiment investigated whether the syllable structure of words modulates French and Catalan first graders' handwriting production. For this purpose, we calculated the movement time distribution throughout the word. The results suggest that the syllable structure of the words influenced the time course of handwriting, both for French and Catalan children. We would like to note, however, that the outcome of this study is somewhat limited by the number of items and the difficulty of interpreting the results. The following paragraphs try to explain the observed data but more research definitely needs to be done in order to confirm these interpretations.
- 23 For the French children, the two movement time peaks (at letters 2 and 4) occurred at the syllable boundaries. They correspond to the last letter of the first and second syllables. This pattern of results suggests that the French children prepared the movement to produce the first syllable before starting to write. The gesture to write the second syllable could be processed during the execution of letter 2; i.e. while finishing the production of the first syllable. Then, in parallel to the production of the last letter of the second syllable (letter 4), the children apparently anticipated the production of third syllable. This idea seems to be reinforced by the fact that duration percentages decreased progressively until the end of the word (from letters 5 to 7). We would like to point out that three out of the nine French words had an orthographic accent at the locations where the duration peaks appeared. Although the normalization procedure should have annulled any bias due the presence of accents, we believe further research should be done to determine whether the accents could account for the duration peaks.
- 24 These results shed some light on how the children anticipate subsequent syllables when writing French words. When they have to write bi-syllabic words (Kandel & Valdois, 2006a, 2006b; Kandel et al., 2009), they prepare the production of the first syllable before starting to write and then anticipate the gesture to write the second syllable during the production of its first letter. After the peak at the first letter of the second syllable, the duration decreases progressively until the end of the word. The results of the present experiment suggest that when the children have to write three syllable words, the anticipation of the following syllable apparently shifts to the other side of the syllable boundary. The children could anticipate the following syllable while writing the last letter of the current syllable.
- 25 For the Catalan children, the pattern of results was different, but it could also point to the presence of a syllable oriented writing strategy. The significant movement time increase from letters 1 to 2 suggest that the first syllable was prepared before starting to write, at least its first letter. From letters 2 to 4, the durations remained stable. The second syllable could be prepared on-line during the last letter of the first syllable and throughout its production. In other words, the anticipation seems to be very limited. Maybe some processing of the gesture to produce the second syllable was done before movement initiation. Regarding the third syllable, there was a peak at its first letter (letter 5). The duration then decreased until the end of the word. This result suggests that the third syllable was processed as a whole unit during the production of its first letter. Although this pattern is in agreement with Soler and Kandel (2009) who observed a letter duration peak at the first letter of the first syllable followed by a progressive decrease towards the end of the word, more studies need to be conducted to investigate more thoroughly the nature of syllable effects of handwriting acquisition in Catalan.
- 26 To summarize, although the data present potential problems, it seems to be in line with previous studies showing that writing strategies in French acquisition are regulated by the word's syllable structure (Kandel & Valdois, 2006a, 2006b; Kandel et al., 2009). When the words have more than two syllables, the syllables seem to be anticipated by the handwriting system at the last letter of the current syllable instead of the first letter of the following syllable. In Catalan, the children apparently prepared the movement to produce the first syllable before

starting to write, as in French, but the second syllable could have been produced without hardly any anticipation. It is also possible that some of the processing of the third syllable was done during the production of the second syllable but this is quite unlikely because the duration peak was rather high. The results also suggest that the children programmed the movement to write the third syllable during the production of its first letter, as other Catalan children did when writing bisyllabic words. Further research should be done to understand better the syllable effect in Catalan. It is noteworthy that in Kandel and Valdois (2006b), there was a clear syllable effect for the French children but not for the Spanish-speaking ones. The latter prepared the movement to produce the syllables either before starting to write and/or during the production of the first letters of the word. In other words, they grouped letters into chunks that were larger than the syllable. It is thus likely that Catalan children in our experiment chunked the two first syllables, programmed them before starting to write or maybe the second one on-line, and then prepared the third syllable in parallel to the production of its first letter. Therefore, the orthographic shallowness/deepness of a language has an influence on the strategies the children use when learning how to write. In French and Catalan, the children could privilege the syllable as a processing unit, but the location within the word at which they process it would be quite different. Of course, the data presented in this study are not strong enough to make conclusions of this issue. We admit our argumentation is quite speculative. More cross-linguistic studies need to be conducted to validate our hypothesis.

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Annex

Appendix 1. The orthographic cognates used in the experiment.

French words	Catalan words
radical	radical
malabar	malabar
minéral	mineral
musical	musical
récital	recital
retirer	retirar
tabuler	tabular
tolérer	tolerar
nudisme	nudismo

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Résumé / Abstract

Cette étude inter-langues français-catalan porte sur l'acquisition de l'écriture de mots de trois syllabes. Des enfants de CP écrivaient des mots cognates sur une tablette digitalisante. La distribution de la durée du mouvement fournit des informations sur la programmation du geste d'écriture. En français, on observe des pics de durée aux deux frontières syllabiques, indiquant que la préparation de la syllabe suivante se fait au cours de la réalisation de la dernière lettre de la syllabe en cours. En catalan, les résultats suggèrent une production modulée par la structure syllabique mais le pattern est différent du français. Les deux premières syllabes sont activées avant l'initiation de l'écriture du mot. La troisième syllabe est programmée au cours de la réalisation de sa première lettre. Cette étude suggère que les différences orthographiques du français et du catalan ont des effets dans la manière dont les enfants utilisent la syllabe pour moduler le mouvement d'écriture.

Mots clés : français, enfants, catalan, durée, écriture

This cross-linguistic study examined how French and Catalan 1st graders (age 6) learn to write. The children wrote three-syllable French-Catalan cognate words on a digitiser. The analysis of movement time distribution provided information on the timing of handwriting production. In French, we observed duration peaks at the two syllable boundaries, indicating that the movement to produce the following syllable is prepared while executing the last letter of the current syllable. In Catalan, the pattern of results also indicates that the children's gestures are modulated by the syllabic structure of the word, but the pattern of results is different than in French. The first two syllables are prepared before starting to write. The third syllable is processed in parallel to the production of its first letter. The results suggest that the differences in the orthographic characteristics of French and Catalan lead to differences in the way syllables modulate the timing of handwriting production.

Keywords : duration, Catalan, children, French, writing