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Ortho-syllables and syllables affect the dynamics of adjective handwriting in French

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Abstract. Some research on written production has focused on the role of the syllable as a processing unit. However, the precise nature of this syllable unit has yet to be elucidated. The present study examined whether the nature of this processing unit is orthographic (i.e., the ortho-syllable) or phonological. Thirty-two native French speakers were asked to copy adjectives on a digitizer, successively adding a plural and a feminine one-letter morpheme to the same adjective. The adjective agreement could modify the structure of both phonological and orthographic syllables, only ortho-syllabic structure, or leave both unchanged. When the change modified only the orthographic syllable structure, there was an increase in duration at the letter before the syllable boundary. By contrast, when adding a letter changed both orthographic and phonological structures, an increase in the duration of the inter-letter interval was observed. Importantly, the increase in duration cannot be explained exclusively by the addition of a letter because the addition of a plural inflection did not significantly influence the dynamics of handwritten production. These results are consistent with the idea that ortho-syllables serve as a processing unit during handwriting, and that this type of syllable is specific to the written code.

1. Introduction

Although many studies have investigated the nature of the units involved in processing during language activities, very few have examined the nature and format of the units that are involved in the production of written words specifically. Some recent research suggests that the syllable may be one such processing unit. Research on handwriting dynamics in adults has revealed that word writing is regulated by syllable structure (Álvarez et al., 2009; Kandel et al., 2006; Kandel et al., 2011; Lambert et al., 2008; Sausset et al., 2012). Kandel et al. (2006) provided evidence that syllable boundaries within words modulate the timing of motor programming in the production of French and Spanish words. Movement durations – i.e., inter-letter intervals, such as the time period between the letters *a* and *c* in the French words *traceur* (“tracer”) and *tractus* (“tractus”) – are longer when the two letters occur at a syllable boundary (e.g., tra.cEUR: syllable boundaries are indicated by a dot hereinafter) than when they belong to the same syllable (e.g., trac.tus). Similar syllable boundary effects have been found in word dictation and picture-naming tasks (Álvarez et al., 2009), and with keystroke intervals when typing in French (Zesiger et al., 1994), English (Kreiner, et al., 2008), Finnish (Service & Turpeinen, 2001), and German (Weingarten, et al., 2004). The impact of syllables on the dynamics of word writing has also been demonstrated by in analyses of writing latency (Lambert et al., 2008).

Although there is now a relative consensus on the role of the syllable in handwriting, the precise nature of this unit is still under debate. One view is that it is equivalent to the spoken syllable. This idea comes from phonological mediation view, according to which orthographic representations can only be accessed via prior retrieval of sound-based codes (Luria, 1970). According to this view, the processing units involved in the production of written syllables are the same as those involved in speech: letter chunks correspond to (phonological) syllables (Chetail & Mathey, 2010). An alternative approach suggests that written language production is relatively autonomous with respect to speech (Bonin, et al., 2001; Ward & Romani, 2000), and that the processing units involved in written language production do not derive exclusively from oral language.

Neuropsychologists were the first to introduce the concept of a unit which is similar to the syllable used in speech, but which based on graphemes, not phonemes: namely, the ortho-syllable (Caramazza & Miceli, 1990; Ward & Romani, 2000). In French, a mute *e* may affect the orthographic syllabification of a word and increase the number of syllables in the written form in comparison to speech segmentation. For example, the word *samedi* (“Saturday”) is a bi-syllable in speech (/sam.di/) but a three-syllable word in written language (sa.me.di). It thus provides a useful means for distinguishing between phonological and orthographic syllables. In this context, Lambert et al. (in press) asked French adults to copy three-syllable and two-syllable words with or without a mute *e* on a digitizer. In Experiment 1, the presence of a mute *e* in final position (e.g., *culture* vs. *coulour* vs. *cabinet*) increased writing latencies. In Experiment 2, which compared words with or without an internal mute *e* (*saleté* vs. *citron* vs. *salami*), latencies for three-syllable words (i.e., *salami*) did not differ from those for two-syllable words containing a schwa (i.e., *saleté*). However, writing latencies in these two conditions were longer

than for two-syllable words (i.e., *citron*). The results of the two experiments argue strongly in favour of a processing unit which is specific to written production, based on graphemic units rather than on phonological components such as spoken syllables.

Although they are very important, the results of Lambert et al. (in press) leave open the possibility that the activation of phonological representations is responsible for this effect. When processing words with an internal schwa (e.g., *saleté*) the participants might have first activated the phonological nucleus of the syllable (i.e., the mute e), which explains why such words are not processed differently from three-syllable words.

We thus sought to gather further evidence on the existence of orthosyllables in a new experiment. We asked undergraduate students to perform a copying task, in which they had to copy French adjectives on a digitizer. Their singular masculine form was presented on a computer screen (e.g., *noir*, “black”). Participants had to copy them first exactly and then with the addition, successively, of a plural and a feminine morpheme to the same adjective (e.g., *noir* – *noirs* – *noire*). Three different types of adjectives were used. In the first condition, feminine agreement did not modify the phonological or the orthographic syllable (e.g., *bleu* – *bleus* – *bleue*). In the second condition, feminine agreement changed the orthographic structure of the syllable but not the phonological structure (e.g., *noir* – *noirs* – *noire*). And finally, in the third condition, feminine agreement changed both the phonological and the orthographic structure of the syllable (e.g., *vert* – *verts* – *verte*). Note that in all three conditions, plural agreement requires the addition of a final -s but does not modify the phonological or orthographic structure of the syllable. Comparison of these three conditions will shed light on the type of unit (phonological syllable vs. orthosyllable) that is activated when handwriting.

2. Method

2.1 Participants. Thirty-two undergraduate students participated in the experiment. They were all native French speakers with normal or corrected-to-normal vision.

2.2 Material. The corpus consisted of a total of 36 adjectives that were divided into three conditions: 1) Feminine agreement did not change the syllabic structure of the adjective: e.g., BLEU /bIE/ vs. BLEUE / bIE /. 2) Feminine agreement changed the orthographic structure of the syllable only (e.g., NOIR /nwaR/ vs. NOIRE /nwaR/. 3) Feminine agreement changed both the phonological and orthographic structure of the syllable e.g., VERT /vèR/ vs. VER.TE /vèR.t/.

2.3 Procedure. The experiment was run on a PC computer with a Wacom Intuos® 4 digitizer. Data were collected using the real time analysis software Eye and Pen© (Alamargot, et al., 2006). The adjective (in singular - masculine) appeared at the center of the screen, and the participants had to copy it in uppercase letters four times in a row (see Figure 1): 1) singular - masculine, 2) singular - feminine, 3) singular - masculine, 4) plural - masculine. All the conditions were counterbalanced across participants. Only the second, third and fourth copies were analyzed.

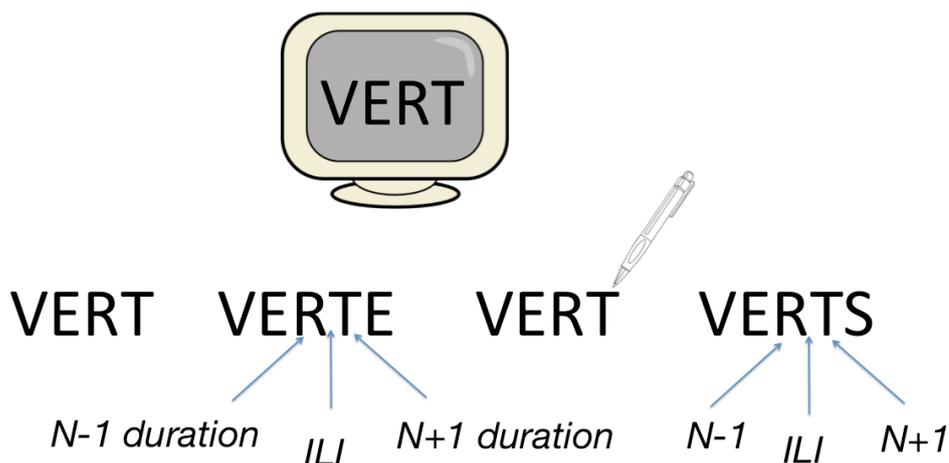


Figure 1. Each adjective was written four times: two times in masculine singular form, once in feminine singular form, and once in masculine plural form. The duration of the letter preceding (N-1) and following (N+1) the syllable boundary was analyzed, as well as the inter-letter interval (ILI)

2.4 Data analysis. Data were analyzed using a linear mixed-effect model with two fixed-effect factors (condition and type of agreement) and two random-effect factors (items and participants) for each dependent variable: letter duration before the syllabic boundary (N-1 duration), letter duration after the syllabic boundary (N+1 duration), and inter-letter interval (ILI).

3. Results and Discussion.

Table 1. Mean N-1 and N+1 durations and inter-letter interval (in ms)

| Condition | Dependent variable | Masculine | Feminine | Plural |
|--------------------------------------|--------------------|-----------|-----------|-----------|
| No change | N-1 duration | 393 (138) | 386 (153) | 394 (146) |
| | N+1 duration | 350 (194) | 352 (191) | 347 (176) |
| | ILI | 144 (78) | 154 (86) | 152 (78) |
| Orthographic change | N-1 duration | 295 (142) | 317 (171) | 299 (150) |
| | N+1 duration | 399 (159) | 378 (135) | 392 (140) |
| | ILI | 149 (72) | 157 (71) | 153 (65) |
| Orthographic and phonological change | N-1 duration | 367 (138) | 361 (153) | 367 (146) |
| | N+1 duration | 378 (122) | 368 (85) | 374 (93) |
| | ILI | 147 (71) | 168 (87) | 152 (77) |

In the condition with no change (Condition 1) there was no effect of the type of agreement (singular vs. masculine, feminine, plural) on the duration of the letter preceding the boundary, $F(2, 2461) = 1.19, p = .31$, the letter following the boundary, $F(2, 2461) = 0.27, p = .76$, or the ILI, $F(2, 2461) = 1.27, p = .28$.

In the condition with orthographic change only (Condition 2) there was no effect of the type of agreement on the ILI, $F(2, 2461) = 0.97, p = .38$, or on the letter following the boundary, $F(2, 2461) = 1.17, p = .31$. However, there was a significant effect of type of agreement on the letter preceding the boundary, $F(2, 2461) = 3.44, p = .032$. The mean production time of the letter preceding the boundary was longer when writing feminine adjectives (NOI.RE) than masculine adjectives (NOI.R), $t(2461) = 2.42, p = .016$, and plural adjectives, (NOI.RS), $t(2461) = 2.10, p = .036$. The two last conditions did not differ from each other, $t(2461) = 0.31, p = .75$.

In the condition with both phonological and orthographic change (Condition 3) there was no effect of the type of agreement on the letter preceding the boundary, $F(2, 2461) = 0.04, p = .97$, or on the letter following the boundary, $F(2, 2461) = 0.78, p = .46$. However, although there was also no significant effect of type of agreement on the ILI, $F(2, 2461) = 2.13, p < .12$, ILIs at the critical boundaries were longer for feminine adjectives (VER/TE) than for masculine adjectives (VER/T), $t(2461) = 2.00, p = .045$, or plural adjectives (VER/TS), $t(2461) = 1.97, p = .051$. The two last conditions did not differ from each other, $t(2461) = 0.56, p = .57$.

These results show that the impact of feminine agreement, with its addition of a mute e, on the dynamics of the handwritten production of adjectives depends on the type of syllabic modification created by letter addition. When the addition of a mute e changed only the orthographic syllable structure – NOIR vs. NOI.RE – there was an increase in duration at the letter before the syllable boundary. By contrast, when adding a letter changed both the orthographic and phonological structures – VERT /vèr/ vs. VER.TE /vèr.t/ – an increase in the duration of the inter-letter interval was observed. Finally, when adding a letter did not change the syllabic structure – BLEU / BLEUE – there was no effect of agreement. Importantly, the increase in duration cannot be explained simply by the addition of a letter, because the addition of a plural inflection did not significantly influence the dynamics of handwritten production: the difference between the masculine singular and masculine plural was never significant despite the addition of the plural marker –s. It is also important to note that the results are not related to letter differences (in terms of frequency or number of strokes for example): the letters compared were always exactly the same (eg. NOI.R / NOI.RE / NOI.RS).

These results are consistent with the idea that the ortho-syllable serves as a processing unit during handwriting, and that this type of syllable is specific to the written code. If the dynamics of handwriting were influenced by phonological representations, then we should have observed an impact of the addition of the feminine only when it modified the phonological syllable. To the contrary, our results show that the effect of the addition of the feminine is also significant when it affects only the orthographic syllable structure of the words. Thus, the modification of the syllabic structure by the addition of a feminine marker occurs at the orthographic level rather than at the phonological level.

Importantly, the addition of feminine agreement influenced handwriting dynamics at different points of word production. The effect occurs earlier when only orthographic structure is modified than when both orthographic and phonological structures are modified. This result might be explained by the greater complexity of the modification of the syllabic structure in the latter condition. This process is more complex and might therefore not be managed as early in processing. The modification of the syllabic structure involved in the

orthographic condition might be easier to process and thus be managed during the production of the letter preceding the boundary rather than afterward. More research is needed to further explore this issue.

The influence of phonological representations on written word writing is highly debated. According to the phonological mediation hypothesis (Luria, 1970), the activation of orthographic representations requires the activation of phonological representations. Evidence for such mediation has been found with a cross-modal repetition priming task: Participants were shown to systematically activate phonological representations (Damian et al., 2011). According to the orthographic autonomy hypothesis (Rapp et al., 1997), on the other hand, orthographic codes are activated directly from meaning, although phonological codes can also be activated in parallel. Our results are consistent with the existence of the ortho-syllable, and therefore favor the orthographic autonomy hypothesis. If orthographic processing occurs at least partly independently of phonological constraints, then this shows that orthographic codes can be activated directly from meaning. Further research is needed to establish a more precise model of the role of the ortho-syllable in handwriting.

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