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Brief article

The interaction between central and peripheral processes in handwriting production

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ABSTRACT

Written production studies investigating central processing have ignored research on the peripheral components of movement execution, and vice versa. This study attempts to integrate both approaches and provide evidence that central and peripheral processes interact during word production. French participants wrote regular words (e.g. FORME), irregular words (e.g. FEMME) and pseudo-words (e.g. FARNE) on a digitiser. Pseudo-words yielded longer latencies than regular words. Letter durations were greater for words at earlier letter positions and greater for pseudo-words at the later positions. Letter durations were longer for irregular than regular words. The effect was modulated by the position of the irregularity. These findings indicate that movement production can be affected by lexical and sublexical variables that regulate spelling processes. They suggest that central processing is not completely finished before movement initiation and affects peripheral writing mechanisms in a cascaded manner. Lexical and sublexical processing does not cascade to the same extent.

1. Introduction

Most research on language production focuses on speech communication, while little is known about how we write words. Written word production has been investigated by two distinct approaches. On one hand, spelling studies focused on the retrieval of orthographic codes from the mental lexicon (Caramazza, 1997). For example, the role of phonological codes during the recall of spelling was examined to investigate the central processes involved in orthographic retrieval from long-term memory (Afonso & Álvarez, 2011; Bonin, Peereman, & Fayol, 2001). These studies relied on writing latencies because they were concerned with the processes taking place before movement initiation, and, to a lesser extent, with the motor planning of the initial writing movements. Another approach examined written production from a motor perspective, as the conversion of letters into movements that produce a graphic output (Van Galen, 1991). Researchers were essentially concerned with the processes occurring at a peripheral level, so they measured kinematic variables in movement production such as stroke duration or velocity. The present study integrates these two approaches (see also Damian & Stadthagen-Gonzalez, 2009) and provides a more fine-grained measure for examining the writing dynamics involved in the interaction between central and peripheral processes. Central and peripheral processes have been shown to be dissociable. Spelling

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processes present dysfunctions in central dysgraphias irrespective of output modality (Baxter & Warrington, 1986). In peripheral dysgraphias, the difficulties concern the mechanics of motor production but the patients spell correctly in all the output modalities. This distinction is also supported by fMRI studies showing that these processes are sustained by distinct neural substrates (Purcell, Turkeltaub, Eden, & Rapp, 2011). If central and peripheral processes interact, movement production can be affected by higher order variables that regulate spelling processes. This implies that the movement to write a letter will depend on its shape and the motor program that is activated to produce it but also on the kind of word it is embedded in. For example, an F will be produced differently in the orthographically irregular French word FEMME (/fam/, woman) than the regular word FORME (/foRm/, shape). Orthographic regularity refers to the possibility of spelling a word correctly by applying the most frequent phoneme–grapheme conversion rules. The rule is /a/ = A, so we would incorrectly write FAME instead of FEMME. FORME is regular because rule application leads to correct spelling. The present study examined how central sublexical and lexical processing affects movement production. Orthographic regularity taps into central processes at a sublexical level. At a lexical level, we manipulated the presence/absence of a letter string in the mental lexicon (i.e., lexicality: regular words vs. pseudo-words). We used a copying task and measured latency as well as movement duration recorded on a digitiser.

Functional models assume that the processes underlying written production operate in a cascaded fashion. This means that the processes that occur higher in the hierarchy of the cognitive architecture are still active during lower level processing and can therefore modulate them (Bonin, Roux, Barry, & Canell, 2012; Roux & Bonin, 2012). A critical issue is whether writing movements are initiated before the word's spelling is entirely retrieved. To our knowledge, the only study investigating the way central processing cascades into the peripheral aspects of graphomotor production was conducted by Delattre, Bonin, and Barry (2006) with a spelling-to-dictation task. They examined whether writing latencies and durations were affected by central processes at the lexical (word frequency) and sublexical levels (orthographic regularity). The cascaded view predicts that durations – which reflect peripheral processing – will be affected by these variables because orthographic retrieval should still operate after the initiation of the writing movements. In contrast, if word retrieval is fully achieved before peripheral processes come into play, then durations should not be affected by central variables. The authors reported an interaction between the two variables on latencies. They also observed that words with irregular spellings yielded longer movement durations than words with regular spellings, suggesting that handwriting movements are affected by central processes. Spelling-to-dictation recruits two routes that operate in parallel (Rapp, Epstein, & Tainturier, 2002). The semantic-lexical pathway retrieves an orthographic representation stored in the mental lexicon while a sublexical conversion mechanism computes an orthographic output by applying phoneme-to-grapheme correspondences. The outputs are integrated either at the graphemic buffer, or at the grapheme level as claimed by recent implementations (Martin & Barry, 2012). With irregular words, they do not match and a conflict occurs: For /fam/ the lexical route retrieves FEMME and the sublexical route FAME. This conflict increases latencies and if it is still not entirely solved when writing begins, it continues to be processed on-line. This slows down the processing of the whole movement, increasing durations of irregular words with respect to regular ones. This indicates that central sublexical processing cascades over peripheral processing. What we do not know is how and when the cascade spreads into writing because the authors measured the duration of the whole word.

In the present study we measured the duration of each letter to gain understanding on how the activation spreads from the central processing of spelling to letter production. In French, the duration of A in CLAVIER (A = /a/; keyboard) is shorter than in PRAIRIE (AI = /ɛ/; meadow). The duration of the letter that precedes A is also shorter because the writing system anticipates grapheme complexity (Kandel & Spinelli, 2010). For orthographically irregular words, we predict that the conflict between the lexical and sublexical levels will spread over the production of the initial letters. This should result in longer letter durations with respect to regular words until the conflict is solved. This methodology should allow us to determine the locus of the cascade for *sublexical* processing in word writing.

Regarding *lexical* processing, Delattre et al. (2006) failed to find word frequency effects on writing duration. Does this mean, as the authors speculated, that frequency processing is already achieved when writing begins? We believe that lexical processing cascades into peripheral processing, but it is confined to the very beginning of the word. This should affect the duration of the initial letters but not the final ones. Note that Delattre et al. (2006) measured the duration of the whole word and not letter by letter. In our study, we preferred to rely on another variable to index lexical processing, so we compared words to pseudo-words. Lexicality is known to affect handwriting production so that copying latencies are shorter for words than pseudo-words (Kandel, Alvarez, & Vallée, 2006).

In sum, central processes should cascade into the peripheral levels of writing but sublexical and lexical processes should not spread in the same way. French participants copied orthographically irregular words (FEMME), regular words (FORME) and pseudo-words (FARNE) words on a digitiser. Irregular words should yield longer durations than regular ones. The analysis by letter should reveal the locus of this kind of sublexical processing during writing. If lexical retrieval is still operating when writing begins, the duration of the initial letters should be longer for words than pseudo-words.

2. Method

2.1. Participants

The participants were 39 right-handed students from Université Pierre Mendès-France. They were native French speakers and had a normal or corrected-to-normal vision.

2.2. Material

We selected 28 orthographically irregular words that are exception words or have very low sound-to-spelling consistency (Appendix A). We matched them to 28 orthographically regular words that have highly-consistent sound-to-spelling correspondences (Appendix B). Twenty-eight pseudo-words were generated to match the regular words on several variables and on syllable structure. Appendix B presents all the factors for which the items were controlled. Since we had to compare letter duration among the different conditions we tried to choose items that shared the most initial letters as possible. Irregular and regular words shared at least the initial letter and up to the first three letters (e.g., PARFUM/PARDON). Pseudo-words and regular words shared at least the initial letter and up to the first four letters. Overall, the mean initial letter overlap was greater between pseudo-words and regular words (2.1) than between irregular and regular words (1.4), since the selection of words is always more constrained than the generation of pseudo-words.

2.3. Procedure and data processing

Stimulus presentation and movement analysis were controlled by Ductus (Guinet & Kandel, 2010). Each trial began with a fixation point. Then, the words appeared in the center of the screen in a random order. The participants wrote the words in upper-case letters on a lined paper attached to the digitiser (Wacom Intuos2, 200 Hz) with a special pen (Inking pen). They were instructed to lift the pen between letters so we could determine unambiguously the beginning and end of each letter. The experiment consisted of 84 trials presented in four blocks of words and two blocks of pseudo-words.

We segmented the words and pseudo-words into letters and measured the duration of the five initial letters so we could observe the evolution of the cascade throughout the writing of the word. We had to compare durations of letters that vary in number of strokes (see Kandel & Spinelli, 2010 for an illustration of how letters are segmented into strokes on the basis of their velocity profile). For the pair FEMME/FORME, for example, we had to compare the two initial Fs, but also E and O, M and R, etc. Since E has four strokes and O has 2 (see Spinelli, Kandel, Guerassimovitch, & Ferrand, 2012 for information on stroke composition for each letter of the alphabet), the absolute duration of E will be longer than O because E has more strokes than O, and not because of differences in orthographic regularity. So to render all letter durations in all the items comparable, we divided the absolute duration of each letter by the number of strokes it is composed of. Our measure thus concerns stroke duration and allows for a direct comparison between letters at a given letter position. Finally, latency concerned the time between target presentation and the moment that the participant started to write (pressure > 0).

3. Results

The statistical analyses were performed on latencies and stroke duration at each letter position. Latencies higher than 3000 ms or below 300 ms were excluded (1.4%). The remaining latencies and stroke durations that exceeded 2 standard deviations were also discarded (1.2%). The results were analysed using linear mixed models (Baayen, Davidson, & Bates, 2008; software R, package lme4, Bates & Maechler, 2009).[1] Fig. 1 presents the results for stroke duration as a function of letter position.

3.1. Lexicality

Latencies were longer for pseudo-words (1428 ms; SD = 433 ms) than regular words (1201 ms; SD = 304 ms), $t(2042) = 10.58$, $p < .001$. The durations for pseudo-words were longer than regular words, $t(10{,}622) = 2.58$, $p < .01$. The lexicality $\times$ letter position interaction was significant, $t(10{,}621) = 3.18$, $p < .005$. Stroke durations were longer for regular words than pseudo-words at L1, $t(2127) = 2.37$, $p < .05$, and L2, $t(2125) = 2.04$, $p < .05$. The inverse pattern was observed at L5, $t(2111) = 2.79$, $p < .01$.

3.2. Orthographic regularity

Latencies were equivalent for irregular (1294 ms; SD = 313 ms) and regular words (1291 ms; SD = 304 ms), $t(2023) < 1$. Stroke durations were longer for irregular than regular words, $t(10{,}488) = 4.88$, $p < .001$. There was a letter position effect, $t(10{,}484) = 5.8$, $p < .001$, and a regularity $\times$ letter position interaction, $t(10{,}479) = 2.69$, $p < .01$. Stroke durations were longer for irregular than regular words at L1, $t_1(2108) = 8.58$, $p < .001$; L4, $t_1(2104) = 3.7$, $p < .005$; and L5, $t_1(2071) = 3.33$, $p < .001$. Stroke durations were shorter for irregular than regular words at L3, $t(2104) = -2.58$, $p < .01$.

Orthographic irregularity affected durations over the entire word. Further analyses revealed that the way the activation spread throughout the word differed according to the position of the irregularity. In 11 words the irregularity was located at the beginning (MONSIEUR, mister) and 17 at the end (INSTINCT, instinct). The analysis included the position of the irregularity (initial, final) as factor. The interaction regularity $\times$ position of irregularity $\times$ letter position was significant, $t(10{,}486) = 2.01$, $p < .05$ (Figs. 2a and 2b).

When the irregularity was in initial, the durations were longer for irregular than regular words at L1, $t_1(826) = 8.01$, $p < .001$ (Fig. 2a). The opposite pattern was found at L2, $t(826) = -2.44$, $p < .05$, and L3, $t(827) = -5.14$, $p < .001$. At L4 the durations for irregular words were longer than for regular ones, $t(827) = 2.4$, $p < .05$. When the irregularity was in the final position, the durations for irregular words were longer than for regular words at all letter positions except for L3: L1, $t(1281) = 4.86$, $p < .001$; L2, $t(1270) = 3$, $p < .005$; L4, $t(1277) = 2.81$, $p < .01$; L5, $t(1260) = 3.76$, $p < .001$.

Finally, almost all latency values were positively and significantly correlated with stroke duration (see Table 1).

[1] Linear mixed models simultaneously take participant and item variability into account. Also, the analysis considers directly each individual data rather than being based on averages. Latencies and stroke durations were processed as outcome variables; orthographic regularity and lexicality as fixed effects. The number in brackets concerns the number of observations minus the number of variables.

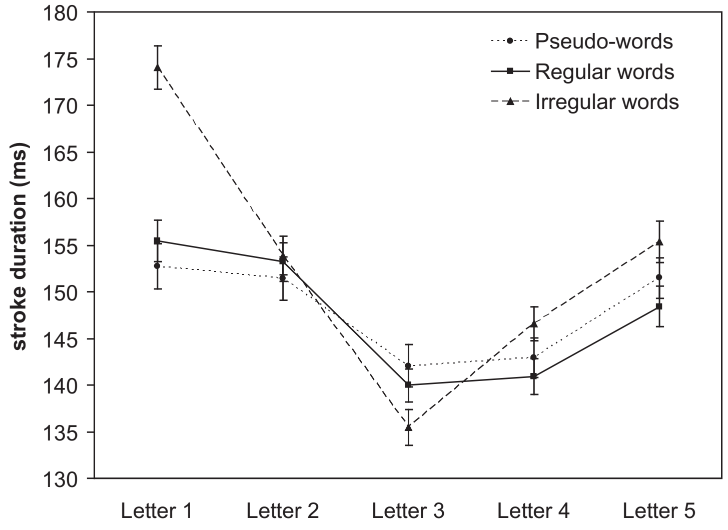

Fig. 1. Stroke durations (ms) for regular words (FORME), irregular words (FEMME) and pseudo-words (FARNE) as a function of letter positions 1–5 (L1, L2, L3, L4, L5).

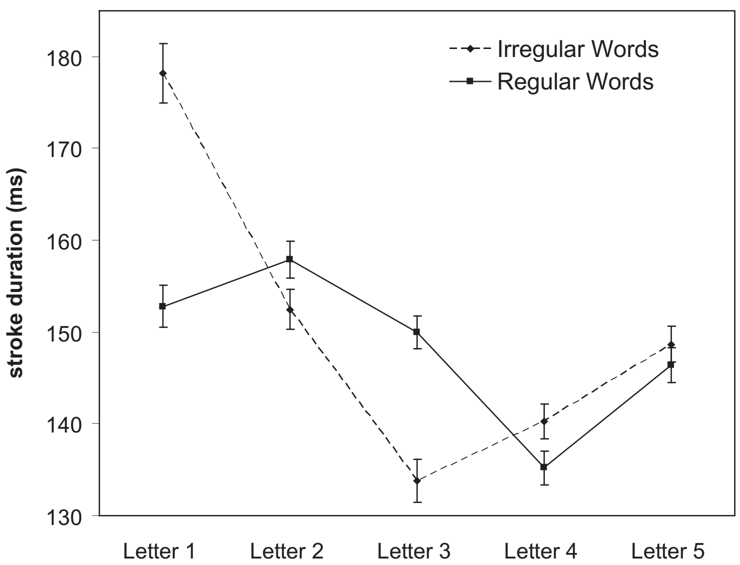

Fig. 2a. Stroke durations (ms) for irregular words presenting the irregularity at the beginning of the word (MONSIEUR) and regular words (MEILLEUR) as a function of letter positions 1–5 (L1, L2, L3, L4, L5).

4. Discussion

This study investigated whether lexical and sublexical central activation spreads to peripheral processes during writing. The results revealed that the item's lexical status and its orthographic regularity affected the kinematics of letter production. Participants were slower to initiate writing for pseudo-words (FARNE) compared to regular words (FORME). Interestingly, the lexicality effect on letter duration was largely dependent on letter position, in that durations were greater for regular words at earlier letter positions, and greater for pseudo-words at the later positions. Letter durations were longer for irregular words (FEMME) compared to regular words. They were modulated by the position of the irregularity. The correlations between latency and stroke duration indicate that the items for which movement preparation was more time consuming were also the ones in which letter duration was longer. This supports the idea that the effects arising at a central level affect movement processing. In addition, it provides evidence that lexical and sublexical processing do not cascade to the same extent during handwriting production.

Further analysis allowed us to get insight into the locus of these effects. For lexicality, we observed that stroke durations were longer for words than pseudo-words only

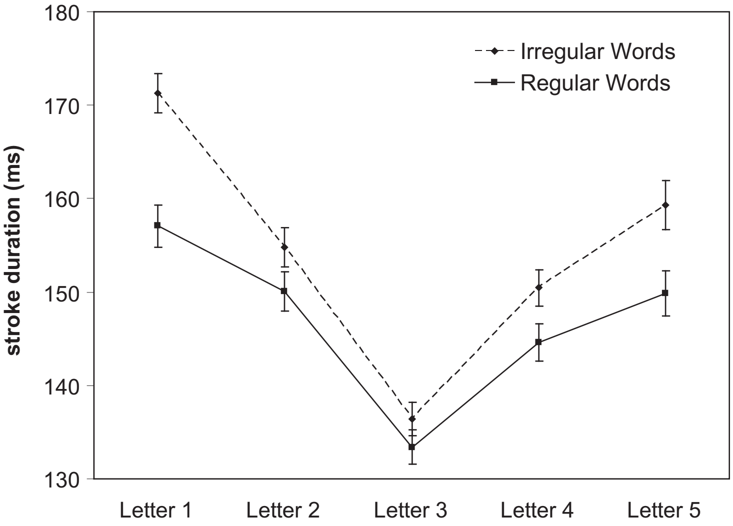

Fig. 2b. Stroke durations (ms) for irregular words presenting the irregularity at the end of the word (INSTINCT) and regular words (INDEX) as a function of letter positions 1–5 (L1, L2, L3, L4, L5).

Table 1
Correlation analysis between latency values and stroke duration for letter positions 1 through 5 (L1, L2, L3, L4, L5) in irregular and regular words as well as pseudo-words.

	Irregular words	Regular words	Pseudo-words
L1	$r(997) = .063$, $p < .05$	$r(1014) = .155$, $p < .001$	$r(1014) = .13$, $p < .001$
L2	$r(989) = .143$, $p < .001$	$r(1010) = .212$, $p < .001$	$r(1011) = .20$, $p < .001$
L3	$r(995) = .098$, $p < .01$	$r(1009) = .159$, $p < .001$	$r(1010) = .19$, $p < .001$
L4	$r(990) = .083$, $p < .01$	$r(1014) = .154$, $p < .001$	$r(1012) = .20$, $p < .001$
L5	$r(966) = .028$, $p > .1$	$r(1004) = .2$, $p < .001$	$r(1003) = .18$, $p < .001$

at letter positions 1 and 2. Lexical processing was still active while the participants were writing the first letters and the cascade ended at L3. The durations for words resulted from the simultaneous processing of the lexical components that were activated during movement preparation and the peripheral processes that determine local parameters such as movement direction. It is likely that for pseudo-words the writing system processed L1 and L2 letter-by-letter. At L3, L4 and L5 the durations for words were shorter than pseudo-words. The spelling of the words was processed before movement initiation and during the production of the initial letters. So when the participant had to actually write the final letters, the processing only concerned the local aspects of the movements. This was less time consuming than the more analytic processes needed to write the end of pseudo-words. So lexical processing cascades into peripheral processing, but it is limited to the very beginning of the word.

We also investigated the locus of orthographic regularity effects. Durations were longer for irregular than regular words at L1 (MONSIEUR and MEILLEUR, respectively). This difference was systematic, irrespective of the position of the irregularity, indicating that the processing of an irregular spelling is still active during the production of the first letter, which is equivalent for regular and irregular words. Despite the activation of the same motor program (i.e., M), the kinematics of movement production was affected by central, sublexical, processing. The conflict arising from orthographic irregularity affected differently the words that have the irregularity at the beginning of the word (MONSIEUR) than those with the irregularity at the end (INSTINCT). We found that orthographic irregularity in word initial was solved during the production of L1. For the words with irregularity in final position, letter duration was systematically higher for irregular than regular words throughout the word. Thus, the processing of an irregularity at the end of a word is anticipated from the beginning of the movement and spreads until the end the word. What may seem puzzling in our results is that latencies were unaffected by regularity. Regularity effects on latencies in French have only been reported in a few word production studies, most of them involving spelling-to-dictation (Bonin, Collay, Fayol, & Méot, 2005; Bonin & Méot, 2002; Delattre et al., 2006). The differences in the nature of a dictation and copying tasks may account for this discrepancy. Dictation stems on a phonological input, so the conflict between sublexical and lexical pathways during orthographic encoding should be stronger than in copying. Thus, regularity effects on latencies could emerge under dictation and not in copying. Crucially however, the sublexical route remains sufficiently active in the copying task so that sound-to-spelling irregularity affects writing, even several seconds after movement initiation. The lack of regularity effects on latencies may also have occurred because some participants slowed their responses to avoid errors. If so, a regularity effect would be more likely to emerge on short latencies. To test this hypothesis, we split the participants into "fast" ($n = 19$; latency = 1145 ms) and "slow" ($n = 20$; latency = 1432 ms). Since the interaction was not significant, a response-speed trade-off strategy was ruled out, $t(2022) = 1.6$, $p > .1$.

As Delattre et al. (2006), our data revealed that sublexical central processing cascades into peripheral processing. However, the present study goes a step further since it provides information about the way the position of the irregularity modulates the cascade. Orthographic irregularity in word initial is processed on-line during the production of the first letters, whereas the processing of final irregularity is distributed over the entire word. Finally, the correlations between latency and stroke duration indicate that the letter strings that required more processing before starting to write were also the ones for which letter production was more time consuming. Then, if lexical processing constituted a supplementary load for words with respect to pseudo-words before starting to write, this load spread throughout letter production. This provides further support for the view that central processing cascaded over peripheral processing during movement production.

To conclude, our data suggest that both lexical and sublexical processes were still operating during the execution of the handwriting movements. This supports the idea that central processes cascade over peripheral processes during handwriting (Delattre et al., 2006; Roux & Bonin, 2012; Álvarez, Cottrell, & Afonso, 2009). More precisely, lexical processing started before movement initiation and was still active during the execution of the first letters in the word. In contrast, sublexical processing affected the execution of handwriting movements throughout the entire word, indicating that lexical and sublexical central processing do not cascade on peripheral processing to the same extent. Furthermore, it is important to stress that Delattre et al. (2006) failed to show an effect of a lexical variable such as word frequency on whole-word durations. This could lead to the erroneous conclusion that lexical processing is already over when peripheral processes are engaged. In our study, a lexicality effect emerged when we considered the durations at letters 1 and 2, suggesting that lexical processing does cascade over peripheral processing during handwriting but only in word initial and not on the whole word as Delattre and colleagues expected. It is therefore likely that word frequency processing cascades into peripheral processes but only on the production of the initial letters. Our research therefore shows the importance of measuring duration letter-by-letter and not the whole word. This methodological detail changes the theoretical outcome of the interaction between central and peripheral processes.

Appendix A

Orthographically irregular and regular words (with their english translation) and pseudo-words.

Irregular words	Regular words	Pseudo-words
ACCROC (snag)	AIGLON (eaglet)	AIGRIN
ALBUM (album)	AIGLE (eagle)	ANGUI
ALCOOL (alcohol)	AUTRUI (others)	AUTRIT
APLOMB (aplomb)	AGNEAU (lamb)	AGNOIN
ASPECT (aspect)	AUTEUR (author)	AUTOIR
ASTHME (asthma)	ARCEAU (hoop)	ARCEIN
CAMPING (camping)	CANDEUR (candor)	COITAIR
CANYON (canyon)	CASTOR (beaver)	CASTAL
COMPTE (account)	CHACUN (each)	CHIPEN
COMPTEUR (counter)	CHAUDRON (cauldron)	CHOIDRAN
DOLMEN (dolmen)	DICTON (saying)	DIRTAL
FAISAN (pheasant)	FLOCON (flake)	FLESAN
FEMME (woman)	FORME (form)	FARNE
FOETUS (fetus)	FOURMI (ant)	FOIRTA
FUSIL (rifle)	FUTUR (future)	FURUT
GADGET (gadget)	GADOUE (slush)	GADORD
GALOP (gallop)	GAZON (turf)	GOBIN
GENTIL (nice)	GOUTTE (drop)	GEUMME
INSTINCT (instinct)	INDEX (index)	INDOM
MONSIEUR (mister)	MEILLEUR (best)	MEISSOIN
MOYEN (average)	MATIN (morning)	MATOL
OIGNON (onion)	ORTEIL (toe)	ORDEIR
PARFUM (perfume)	PARDON (forgiveness)	PIRTIN
RESPECT (respect)	RECOURS (recourse)	RECEURT
SECOND (second)	SORTIR (exit)	SIRTAR
SIROP (syrup)	SATIN (satin)	SORON
TABAC (tobacco)	TISSU (tissue)	TASSO
WAGON (wagon)	VIGNE (vine)	VAGLI

Appendix B

Characteristics of regular words, irregular words and pseudo-words, provided by Lexique 2 (New, Pallier, Brysbaert, & Ferrand, 2004) and LEXOP (Peereman & Content, 1999).

	Words		Pseudo-words	p-Value
	Irregular	Regular		
PG L[a]	2.21	49.5	_	<.001
Word frequency	51.1	39.5	–	ns
Number of letters	6	5.9	5.9	ns
Number of phonemes	4.39	4.5	4.64	ns
Number of syllables	1.89	1.86	1.93	ns
Orthographic uniqueness point	6.33	6.63	_	ns
Bigram syll[b]	476.07	493.32	508.42	ns
Bigram frequency	3857.6	4120	–	ns
Trigram frequency	813.55	774.94	–	ns

[a] PG L = mean consistency (by Type) of the Lowest Phoneme–Grapheme association of each word provided by LEXOP.
[b] Bigram Syll = Bigram frequency at the syllable boundary; ns = non significant.

References

Afonso, O., & Álvarez, C. J. (2011). Phonological effects in handwriting production: Evidence from the implicit priming paradigm. *Journal of Experimental Psychology: Learning, Memory, and Cognition., 37*(6), 1474–1483.

Álvarez, C. J., Cottrell, D., & Afonso, O. (2009). Writing dictated words and picture names: Syllabic boundaries affect execution in Spanish. *Applied Psycholinguistics, 30*, 205–223.

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language, 59*, 390–412.

Bates, D., & Maechler, M. (2009). lme4: Linear mixed-effects models using S4 classes. <http://CRAN.R-project.org/package=lme4>.

Baxter, D. M., & Warrington, E. K. (1986). Ideational agraphia: A single case study. *Journal of Neurology, Neurosurgery, and Psychiatry, 49*, 369–374.

Bonin, P., Collay, S., Fayol, M., & Méot, A. (2005). Attentional strategic control over sublexical and lexical processing in written spelling to dictation in adults. *Memory and Cognition, 33*, 59–75.

Bonin, P., & Méot, A. (2002). Writing to dictation in real time in adults: What are the determinants of written latencies? In *Advances in psychology research* (pp. 131–165). NY: Nova Science Publishers.

Bonin, P., Peereman, R., & Fayol, M. (2001). Do phonological codes constrain the selection of orthographic codes in written picture naming? *Journal of Memory and Language, 45*, 688–720.

Bonin, P., Roux, S., Barry, C., & Canell, L. (2012). Evidence for a limited-cascading account of written word naming. *Journal of Experimental Psychology: Learning, Memory and Cognition*.

Caramazza, A. (1997). How many levels of processing are there in lexical access? *Cognitive Neuropsychology, 14*, 177–208.

Damian, M. F., & Stadthagen-Gonzalez, H. (2009). Advance planning of form properties in the written production of single and multiple words. *Language and Cognitive Processes, 24*, 555–579.

Delattre, M., Bonin, P., & Barry, C. (2006). Written spelling to dictation: Do irregularity effects persist on writing durations? *Journal of Experimental Psychology: Learning, Memory and Cognition, 32*, 1330–1340.

Guinet, E., & Kandel, S. (2010). Ductus: A software package for the study of handwriting production. *Behavior Research Methods, 42*, 326–332.

Kandel, S., Alvarez, C., & Vallée, N. (2006). Syllables as processing units in handwriting production. *Journal of Experimental Psychology: Human Perception and Performance, 32*(1), 18–31.

Kandel, S., & Spinelli, E. (2010). Processing complex graphemes in handwriting production. *Memory and Cognition, 38*(6), 762–770.

Martin, D. H., & Barry, C. (2012). Writing nonsense: The interaction between lexical and sublexical knowledge in the priming of nonword spelling. *Psychonomic Bulletin and Review, 19*(4), 691–698.

New, B., Pallier, C., Brysbaert, M., & Ferrand, L. (2004). LEXIQUE 2: A new French lexical database. *Behavior Research Methods, Instruments, and Computers, 36*, 516–524.

Peereman, R., & Content, A. (1999). LexOP: A lexical database with orthography–phonology statistics for French monosyllabic words. *Behavior Research Methods, Instruments, and Computers, 31*, 376–379.

Purcell, J. J., Turkeltaub, P. E., Eden, G. F., & Rapp, B. (2011). Examining the central and peripheral processes of written word production through a meta-analysis. *Frontiers in Psychology, 2*, 239.

Rapp, B., Epstein, C., & Tainturier, M.-J. (2002). The integration of information across lexical and sublexical processes in spelling. *Cognitive Neuropsychology, 19*, 1–29.

Roux, S., & Bonin, P. (2012). Cascaded processing in written naming: Evidence from the picture–picture interference paradigm. *Language and Cognitive Processes, 27*, 734–769.

Spinelli, E., Kandel, S., Guerassimovitch, H., & Ferrand, L. (2012). Graphemic cohesion effect in reading and writing complex graphemes. *Language and Cognitive Processes, 27*(5), 770–791.

Van Galen, G. P. (1991). Handwriting: Issues for a psychomotor theory. *Human Movement Science, 10*, 165–191.