



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.

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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 graph-

eme 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 = /ε/; 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.

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