26 Syllables as Representational Units in English Handwritten Production?

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When individuals write words, does syllable structure influence the preparation and execution of the responses? Recent studies conducted with French and Spanish participants have suggested that this is the case; specifically, interletter pauses when writing in uppercase tend to be prolonged when the critical bigram straddles a syllable boundary, compared to when the same bigram occurs within a syllable. This implies that higher-level abstract linguistic properties such as syllable structure emerge in the motoric properties of the written response. The current work investigated whether similar syllabic effects are found in English, a language in which syllable boundaries are oftentimes vague and ambiguous, and due to less perceptual salience syllables might be less relevant as organizational principles in orthographic output tasks.

La structure syllabique influence-t-elle la préparation et l'exécution de l'acte graphique ? C'est ce que suggèrent des études récentes menées en francais et en espagnol, où il a été montré qu'un scripteur qui écrit en majuscules tend à effectuer une pause plus longue entre deux lettres lorsque ces dernières appartiennent à des syllabes différentes plutôt que lorsqu'elles appartiennent à une même syllabe. Il y aurait donc un niveau de traitement supérieur, à partir duquel la structure syllabique guiderait les aspects moteurs de l'écriture. La présente étude a examiné si des effets similaires sont visibles en anglais. Dans cette langue, les frontières syllabiques sont plus ambigües et moins marquées qu'en francais ou en espagnol, et donc on

DOI: https://doi.org/10.37514/INT-B.2017.0919.2.26

pourrait s'attendre à ce que la syllabe y joue un role organisateur moins important. Des participants de langue anglaise avaient pour tâche de copier, à l'aide d'une tablette graphique et en majuscules, des mots deux syllabes présentés visuellement. Les stimuli consistaient en des paires de mots partageant les trois premières lettres, de sorte que le bigramme cible soit était à cheval sur la première et la deuxième syllabe (BA.SIS), soit terminait la première syllabe (BAS.KET). La durée d'exécution des première et troisième lettres était aussi mesurée. Nous n'avons trouvé aucun effet de frontière syllabique, que ce soit dans la durée des pauses ou dans celle d'exécution des lettres. Dans les langues à frontières syllabiques peu marquées, les sujets ne semblent donc ni planifier ni exécuter leurs actes graphiques en termes syllabiques. Nous donnons plusieurs explications à cela.

1. Syllables as representational units in English handwritten production?

The act of writing can be characterized as the (sometimes creative) act of composing a text. However, writing can also be considered in a more technical sense, namely as a specific form of cognitive generation of output codes. Within such a definition from the cognitive sciences, writing is a form of non-oral, orthographic language production skill. According to this view, just as the speaker intends to express thought via spoken words, the writer expresses thought in written form, and in the process of a transformation from meaning to orthography the mind/brain carries out a number of stages of information processing. From this standpoint, the content of the written output is of lesser interest, whereas the main emphasis is on mental representations and transformations which are involved in writing. An insight into how writing is accomplished from a cognitive perspective is by itself of great interest to psychologists, but it also holds potential relevance for educational settings because acquisition of handwriting skills represents a key educational achievement for language learners.

When individuals prepare and execute written words, which types of mental representations and processing units are involved? Compared to other areas of research in the psychology of language such as speech comprehension, production, and reading, relatively less work has been conducted to explore the cognitive mechanisms underlying orthographic output tasks such as handwriting, typing, and spelling. For some while, researchers have examined spelling errors generated by individuals with acquired brain damage, but only relatively recently have psychologists begun to explore orthographic production in unimpaired individuals via experimental tasks. Recent reports have demonstrated that in languages such as French and Spanish, syllable boundaries emerge in the timing of handwritten word production. The study reported below investigated whether this is also the case in English, a language with relatively ambiguous syllabic structure.

Written production involves a series of processing stages: conceptual activation, semantic retrieval, orthographic encoding, access to the graphemic buffer, to the allographic store, retrieval of graphemic motor patterns, and neuromuscular execution (Rapp & Caramazza, 1997). One of the most fundamental issues concerns the structure of orthographic representations underlying written production. Neuropsychological case studies have broadly supported the view that written word production does not merely involve linearly-ordered strings of letter identities, but is also constrained by more complex high-level linguistic units of orthographic representations (see Tainturier & Rapp, 2001, for an overview). In a seminal neuropsychological case study, Caramazza and Miceli (1990) observed that the spelling errors produced by an Italian dysgraphic patient were constrained by some sublexical units. For example, the patient's spelling showed a tendency to simplify the syllabic structure of words. Letter omissions frequently took place in letter clusters, leading to simpler syllabic structures (e.g., creatura → retura), whereas omissions never occurred in the context of simple consonant-vowel (CV) structure which would cause more complex syllabic structures. Better performance was shown for words with simple syllable structure (e.g., CV-CV-CV) than for those with more complex syllable structure (e.g., CCV-CVC). Moreover, substitution errors always involved the substitution of a consonant for a consonant or a vowel for a vowel, i.e., substituted letters preserved CV status (e.g., fanale → farale, tesoro → tesera). Also, exchange errors involving geminate consonants always respected the geminate features (e.g., sorella → solerra, but not sorella → solerla). Based on these findings, Caramazza and Miceli proposed that orthographic representations involve multiple dimensions which contain syllable structure, CV status, geminate clusters and abstract graphemes (see also Buchwald & Rapp, 2006, for a similar view).

Experiments conducted with unimpaired individuals have broadly supported the notion that higher-level linguistic variables such as syllable structure and grapheme status constitute important processing units. Studies of this type generally either involve individuals writing responses on a digital graphic tablet, which allows the measurement of detailed properties of movement execution, or the typing of responses on a computer keyboard. Substantial evidence now suggests that written production is characterized by "cascaded" information flow between central response selection and peripheral response execution stages, i.e., higher-level linguistic properties emerge in the low-level characteristics of written output (e.g., Bogaerts, Meulenbroek, & Thomassen, 1996; Delattre, Bonin & Barry, 2006; Gentner, Larochelle, & Grudin, 1988; Zesiger, Mounoud, & Hauert, 1993). For instance, Zesiger et al. (1993) revealed the influence of lexicality in handwriting execution duration: movement duration and trajectory length of the first trigrams were shorter when the sequence was embedded in words than in pseudowords. Apart from lexicality, it was found that word frequency also affected movement duration, that is, duration for typing (or writing) high-frequency words was shorter than for low-frequency words, which in turn was shorter than for non-words (e.g., West & Sabban, 1982; Sovik, Arntzen, Samuelstuen, & Heggberget, 1994). In addition to letter movement durations, previous research has also examined interletter intervals (or inter-keypress intervals) as dependent measures to identify processing units in orthographic production. For example, Gentner et al. (1988) observed that inter-keypress intervals were affected by word frequency; e.g., the interval between "s" and "t" was shorter when the sequence was embedded in the high-frequency word "system" than in the low-frequency word "oyster." These findings suggest that if one is interested in exactly how individuals generate written responses, then the temporal characteristics of response execution (as revealed by the measurement of properties of writing execution) can provide a window into high-level cognitive processes (i.e., which mental codes the writer manipulates in order to generate the orthographic response).

More recent studies on handwriting have highlighted the role of abstract graphemes (e.g., Kandel & Spinelli, 2010; Kandel, Soler, Valdois & Gros, 2006), as well as suggesting a possible role of morphological structure (e.g., Kandel, Álvarez, & Vallée, 2008). Particularly critical for present purposes, a number of recent studies have examined temporal features of writing execution (e.g., letter movement duration or interletter intervals) to explore whether written production of French and Spanish is constrained by syllabic structure. Kandel, Álvarez and Vallée (2006) asked French participants to copy words in uppercase letters on a digitizer. Response words, selected in pairs, shared the initial letters but had different syllable boundaries (TRA.CEUR—TRAC.TUS; the dot marking syllable boundary was not shown in the experiment). In this example, the bigram (i.e., two-letter sequence) AC is inter-syllabic in TRA.CEUR but intra-syllabic in TRAC.TUS. Kandel et al. observed that interletter intervals were longer between than within syllables. This pattern was only significant when words consisted of relatively complex syllabic structures (e.g., CCV vs. CCVC), but it was not reliably significant for words with simple syllabic structures (e.g., CV, "PA.RENT" vs. CVC, "PAR.DON"). In a second experiment, Kandel et al. asked French and Spanish participants to copy cognate words with an embedded bigram (GN) which was always intra-syllabic in French but inter-syllabic in Spanish, and words with an embedded bigram (GM) which was always inter-syllabic in both languages. They found that the GN interletter intervals (within syllables) were shorter than the GM ones (between syllables) in French; by contrast, GN (between syllables) and GM (between syllables) intervals were equivalent in Spanish.

The general finding that interletter intervals were modulated by syllabic structure (see also Kandel, Peereman, Grosjaques & Fayol, 2011; Sausset, Lambert, Olive & Larocque, 2012, for related evidence with French participants) was subsequently replicated in other tasks such as writing-to-dictation and written picture naming with Spanish writers (Álvarez, Cottrell, & Afonso, 2009). Further studies revealed that the relevant processing unit in handwriting appears to be orthographic, rather than phonological, syllable structure. Kandel, Hérault, Grosjacques et al. (2009) asked 4th and 5th graders to write words (e.g., "barque") that were phonologically monosyllabic but orthographically bisyllabic ("bar.que"), and performance was compared to words which were both phonologically and orthographically bisyllabic (e.g. "balcon"). Handwriting measures indicated that children used orthographic rather than phonological syllables to program the words they wrote. It should be noted that similar findings have also been observed in other modalities of orthographic production such as typing (Nottbusch, Grimm, Weingarten, & Will, 2005; see Weingarten, Nottbusch, & Will, 2004 for a review). Nottbusch et al. conducted a typing task with German deaf participants and found that, as was the case for unimpaired individuals, interkey intervals were longer at syllable boundaries than at common letter boundaries. This suggests that syllabification in orthographic production is largely independent of experience with spoken language, and highlights the relevance of orthographic rather than phonological syllables.

Effects of syllabic structure manifest themselves not only in interletter intervals, but also in the time it takes to write individual letters. In a developmental study with French children, Kandel and Valdois (2006) asked first- to fifth-graders to copy French words and pseudo-words, and letter movement duration was measured. It was found that for children at different school levels, letter movement duration systematically peaked at the first letter of the second syllable of words, suggesting a cognitive load associated with processing the second syllable during writing its first letter. This finding suggests that French children use syllable-by-syllable processing to prepare writing, and thus further highlights the critical role of syllables as processing units underlying written production, at least in languages with relatively clear syllable boundaries (see below).

In summary, existing results have highlighted the importance of syllabic representations in handwritten word production. However, the evidence mainly stems from experiments conducted in French and Spanish. In these languages, syllabic boundaries are generally well-defined and clear, and individuals agree to a large extent when asked to define where syllables begin and end. In other languages such as English, syllabic boundaries are overall less clearly defined; for instance, intervocalic consonants (such as the "m" in "camel") are difficult to assign clearly to either the first or the second syllable. This has led to the common linguistic proposal that they are "ambisyllabic," i.e., governed by both syllables simultaneously. Hence, it is not impossible that systematic differences among languages with regard to certain properties (in this case, syllabic structure) could impact on language use (here, the issue whether syllable boundaries are relevant in handwriting). Indeed, in the extensive literature on spoken language processing, early experimental work conducted with French individuals (Mehler, Dommergues, Frauenfelder & Segui, 1981) suggested a clear role of syllables, which subsequently did not replicate in equivalent experiments conducted with English individuals (Cutler, Mehler, Norris & Segui, 1986). Cutler et al. postulated that the discrepant results from French and English participants might result from systematic differences between languages: "French speakers consistently make use of syllabification in segmentation; English speakers do not . . . this difference reflects the phonological differences between French and English . . . speakers of any language with clearly bounded regular syllables should show syllabification effect, while speakers of any language with irregular, hard-to-segment syllables should not" (p. 397). In this way, effects might mirror the distinction originally proposed by Pike (1945) between "syllable-timed" languages in which every syllable is perceived as taking up roughly the same amount of time (e.g., French, Spanish, Italian, Mandarin), and "stress-timed" languages in which syllables are perceived to occupy a fairly constant average amount of time between consecutive stressed syllables (e.g., English, German, Dutch, Russian, Portuguese). Although such a strict division into syllable- and stress-timed languages is no longer tenable, it is clear that languages do indeed differ in the relative prominence of the syllable.

However, since the seminal work by Mehler et al. and Cutler et al. on this topic, syllabic effects have been documented in Dutch, a syllable-timed language (Zwitserlood, Schriefers, Lahiri & Van Donselaar, 1993). And in fact, syllabic effects can be found even with English participants, at least in some experimental tasks (such as the "migration paradigm"; Mattys & Melhorn, 2005). Overall, as argued by Kolinsky (1998), it appears to depend on a complex interaction between specific task demands and properties of the target language whether or not syllabic effects arise in speech segmentation.

In the literature on neuropsychological impairments of handwriting, the possibility has also been raised that "languages differ in the organization of the graphemic buffer just as they differ with respect to the perceptual salience of the syllable. Spellers of Italian and English might differ in the number of tiers in the graphemic buffer" (Jónsdóttir, Shallice, & Wise, 1996, p. 190; see also Kay & Hanley, 1994, but see Ward & Romani, 2000, for contradictory evidence). Given this possibility, the experiment below investigated whether syllables constitute processing units in handwriting for unimpaired writers of English, a language with vague syllable boundaries. As in Kandel et al. (2006), a task was used in which individuals copied words in uppercase letters onto a digitizer. These words, selected in pairs, shared the first trigram but had different syllable boundaries (e.g., BA.SIS—BAS.KET). Interletter intervals between the critical bigram (AS in this example) and letter movement durations of first (B) and third letter (S) were measured. If these are modulated by syllabic structure, we would predict: a) longer interletter intervals if the critical bigram straddles a syllable boundary (AS in BA.SIS) than when it does not (AS in BAS.KET), b) longer durations for the initial letter (B) if it is embedded within a complex syllable (BAS) than when embedded within a simple syllable (BA) due to higher processing load associated with the first, compared to the second, case, c) longer durations for the third letter (S) if it occurs at the beginning of the second syllable (BA.SIS) than when at the end of the first syllable (BAS.KET). If interletter intervals and letter movement durations in English are modulated in the same way as they have been previously shown in French and Spanish, the results would highlight an important, cross-linguistically invariant principle of the organisation of handwritten word production.

2. Method

2.1. Participants

Twenty right-handed undergraduate students at the University of Bristol, all of whom had grown up with English as their first language, took part in the experiment and were given course credit for their participation. All participants had normal or corrected-to-normal vision and no dysgraphia.

2.2 Materials

Stimuli were adapted from work by Schiller (2000) on the role of syllables in spoken word production. 21 pairs of bisyllabic, monomorphemic words with clear syllable boundaries were used; three pairs with polymorphemic response words were removed from the original materials. Of each pair, one word had an initial CV syllable (henceforth referred to as "CV words") while the other had an initial CVC syllable (referred to as "CVC words"). Word pairs shared the first trigram but differed with regard to syllable boundaries (e.g., BA.SIS vs. BAS.KET). For both types of words, critical interletter intervals were located between the second and the third letter (in the above example, the interval between A and S) so that they straddled syllabic boundaries for CV words (intersyllabic condition) but occurred within syllables for CVC words (intrasyllabic condition). The lexical properties for both types of words are shown in Table 26.1. They were statistically matched on logarithmically transformed data (log), which is commonly used in psycholinguistic studies to reduce skewness in frequency measures, Kučera-Francis (1967) frequency, log CELEX (Baayen, Piepenbrock & van Rijn, 1993) written and spoken word frequency, log overall token bigram frequency, and orthographic neighborhood, with the latter two measures obtained from N-Watch (Davis, 2005). However, CVC words were statistically longer (in terms of mean number of letters) than CV words ($t(20) = 5.876$, $p < .001$), a confound which is difficult to avoid because differences in syllabic complexity necessarily imply differences in length. See Appendix A for a full list of materials.

Table 26.1. Mean lexical properties of words used in the experiment

	CV words	**CVC words**
Kučera-Francis frequency (log)	1.4	1.5
CELEX: written frequency (log)	1.2	1.4
CELEX: spoken frequency (log)	0.8	1.2
Bigram frequency: token (log)*	2.9	3.0
Orthographic neighborhood	1.9	1.5
Number of letters	5.1	6.2

** Bigram frequencies were taken from N-Watch (Davis, 2005) and based on the COBUILD corpus.*

2.3 Procedure

Participants were tested individually. The experiment was conducted with the software package Ductus (Guinet & Kandel, 2010). Each word was presented in uppercase Times New Roman size 18 in the centre of a 17-in screen of an IBM-compatible computer. Participants were asked to copy the words in uppercase letters on a WACOM Intuos A4 graphic tablet, using a WACOM inking pen. They were instructed to lift the pen slightly above the answering sheet to get ready to copy words, and to write the words at a natural speed. As in previous studies (e.g., Bogaerts et al., 1996; Kandel et al., 2006), participants were required to carry out an articulatory suppression task while they were writing their responses: they were instructed to count out aloud, starting from one, as soon as a target stimulus appeared on the screen, and to continue counting until they had written their response. This was done to diminish the influence of phonological encoding and associated potential syllabification during visual word recognition.

Participants first practiced lifting the pen naturally between letters by writing their names in uppercase letters several times. After the practice phase, participants were presented with two blocks of 42 trials with each word appearing once in each block. In each trial, participants first saw a fixation point at the centre of the screen (1,500 ms) prior to a visual word. Once a participant completed writing the word, the experimenter clicked on a button located at the bottom right of the screen to initiate the next trial. The order of trials was randomized within a block. The entire experiment lasted approximately 30 min per participant.

3. Results

The data were smoothed with a Finite Impulse Response filter (Rabiner & Gold, 1975) with a 12-Hz cutoff frequency. The critical interletter intervals between the second letter and the third letter (intersyllabic in CV words but intrasyllabic in CVC words) and movement durations for first and third letter of the shared word-initial trigrams were measured. The interletter interval was defined as the period from the end of the letter, which corresponded to pressure = 0, to the onset of the next letter, which corresponded to the initial pressure > 0. Letter movement duration was defined as the period from the movement initiation point, corresponding to pressure > 0, to the movement ending point, corresponding to pressure = 0.

Results from two participants were excluded from the following analysis, one due to the failure of the technical device and the other due to generating too frequent connected letters (more than 30%). For the remaining responses, trials with copying errors or connected letters in the critical interletter intervals (4.3%) were excluded from the analysis. Additionally, interletter intervals more than two standard deviations above or below the mean for a participant

(4.3%) were excluded from the analysis. There was no significant difference in error rates between the two types of words (4.8 vs. 3.7%; $t(17) = 0.968$, $p = .346$). Table 26.2 presents means and standard deviations of the interletter intervals and letter movement durations for CV words and CVC words.

Table 26.2. Interletter interval for critical bigram (in milliseconds), mean letter duration for first and third letter (in millisecond), and difference between the CV and CVC condition. Standard deviation in parentheses.

	CV words	CVC words	Difference
Interletter interval	151 (31)	152 (31)	1
First letter duration	626 (75)	627 (83)	1
Third letter duration	546 (87)	550 (92)	4

Interletter intervals were analyzed using a linear mixed effects model (Baayen, Davidson & Bates, 2008; Bates, 2005) that included fixed effects of Block (Block 1 vs. Block 2) and Condition (intersyllabic vs. intrasyllabic), and by-participant and by-item random intercepts. An analysis of variance showed an effect of Block, $F(1377) = 10.82$, $MSE = 9514$, $p = .001$, arising from the fact that intervals were 6 ms faster in the second block than in the first one (154 ms vs. 148 ms), no effect of Condition, $F(1377) < 1$, $MSE = 1$, $p = .970$, and no interaction between Block and Condition, $F(1377) < 1$, $MSE = 32$, $p = .848$.

For the analysis of movement duration of the first letter, trials in which participants produced copying errors or did not lift the pen between the first and the second letters (6.9%) were excluded. The pattern of results was similar to the interletter intervals. An analysis of variance showed an effect of Block, $F(1404) = 28.43$, $MSE = 206.249$, $p < .001$, arising from the fact that participants wrote the first letter 22 ms faster in the second block than in the first one (637 ms vs. 612 ms). There was no effect of Condition, $F(1404) < 1$, $MSE = 11$, $p = .969$, and no interaction between Block and Condition, $F(1404) < 1$, $MSE = 5842$, $p = .370$.

For the analysis of movement duration of the third letter, trials in which participants produced copying errors or did not lift the pen between the second and the third letter or between the third and the fourth letter (5.2%) were excluded. An analysis of variance showed an effect of Block, $F(1429) = 7.02$, $MSE = 364.618$, $p = .008$, arising from the fact that average durations in the second block were 32 ms shorter than the first block (564 ms vs. 532 ms). There was no effect of Condition, $F(1429) < 1$, $MSE = 398$, $p = .930$, and no interaction between Block and Condition, $F(1429) < 1$, $MSE = 9692$, $p = .666$.

4. Discussion

A few recent studies have shown that the syllable constitutes an important processing unit in written word production. However, existing studies have focused on languages with relatively clear syllable boundaries. The main purpose of the present experiment was to test whether syllables also constitute processing units in languages with ambiguous syllable boundaries. With this aim, we investigated handwriting in English, a language with oftentimes ambiguous syllable boundaries. We used a task in which English-speaking participants were asked to copy visually presented words onto a digitizer; response words, in pairs, shared the word-initial trigram but had different syllabic boundaries. Contrasting from previous findings in equivalent experiments with French and Spanish writers, we observed that in English, the critical interletter intervals and letter movement durations were not affected by the syllabic structure of words. At face value, these results suggest that English-speaking individuals do not use syllabic structure to prepare and execute handwritten word production. A possible explanation might be in terms of systematic cross-linguistic differences between French/Spanish and English: because syllabic boundaries are typically clear in the former languages, writers use syllable-sized mental representations to prepare and execute orthographic output; by contrast, because syllable boundaries in English are oftentimes ambiguous and vague, writers do not use such mental planning units. In this sense, the results would support Jónsdóttir et al.'s (1996) conjecture that the organisation of the graphemic buffer differs between languages regarding the perceptual salience of the syllable.

Of course, it is generally problematic to derive inferences from a null finding (in this case, our observation that interletter intervals and letter durations are not affected by syllabic boundaries). Hence it is worth considering alternative explanations for the discrepancy between our results and the earlier ones obtained with French and Spanish individuals. One possibility is that the syllabic structures of the stimuli used in the present experiment (CV vs. CVC) were relatively simple, hence genuine syllabic effects might have been masked. Recall that Kandel et al. (2006) found reliably significant effects of syllabic structure on interletter intervals only with relatively complex syllable structures (i.e., CCV vs. CCVC), but syllabic effects were significant only by participants for words with simple syllable structures (i.e., CV vs. CVC). Kandel et al. attributed this pattern to the possibility that simple syllables can be processed automatically and only more complex syllables are associated with an increased processing load which subsequently emerges in interletter intervals. However, Afonso et al. (2009) reported syllabic effects on interletter intervals with Spanish writers even with simple syllable structures, although in writing-to-dictation and written picture naming, rather than in visual copying.

Moreover, it is noteworthy that if the null effect in our study was partially due to overly simple word-initial syllable structure, we should still observe a trend in the predicted direction, as Kandel et al. (2006) did (6 ms longer interletter intervals for between- than within-syllable bigrams). In the present experiment, we observed a 1 ms effect in the opposite direction, which suggests that the statistical null finding is probably not due to overly simple syllable structure. Nevertheless, it would clearly be informative to repeat our experiment with more complex word-initial syllables such as CCV vs. CCVC (e.g., TRI.POD vs. TRIP.LET). Unfortunately, it turns out to be very difficult (if not impossible) to identify suitable stimulus pairs with sufficiently clear syllable boundaries.

We adopted the materials from a study by Schiller (2000) on the role of syllables in spoken word production. In languages with sometimes vague syllable boundaries, individuals don't always agree on where syllable boundary should be drawn, and linguistic theories also make partially contradictory predictions (Goslin & Frauenfelder, 2000). Despite the difficulties in identifying syllable boundaries in many English words, Schiller (2000) argued that all stimuli in his study had unambiguous syllabic boundaries. To further examine this issue, we conducted a metalinguistic syllable repetition task adopted from work by Goslin and Frauenfelder (2000). Five postgraduate students who had grown up with English as their first language, and with no hearing and language problems, volunteered for this task. Materials for the main experiment were presented in spoken form, and participants were asked to repeat either the first or second "part" of the words they heard (we avoided using the term "syllable" in the instruction in order to prevent participants from responding strategically). Stimuli were produced by a monolingual English speaker and were recorded at a sampling rate of 44100 kHz, and digitized at 16 bits per sample. The syllable repetition task was run using DMDX (Forster & Forster, 2003). Each participant was presented with two blocks of 42 trials each with 21 CV words and 21 CVC words appearing once in each block. The order of trials within each block was randomized and the order of the two blocks was counterbalanced among participants. Participants first received 10 practice trials before two experimental blocks were presented. Each trial started with the prompt "*" (500 ms), followed by a blank screen (500 ms), the target word presented over headphones, and an inter-trial interval (1,000 ms). Participants were asked to give responses as quickly as possible within a timeout interval of 2,000 ms.

Responses were analyzed separately according to whether instructions asked to repeat the first or second part of the word. Results showed that syllabification consistency across participants was higher for the second than the first syllable repetition condition. Specifically, responses were consistent across all five participants for all words when they were asked to repeat the second syllables, whereas responses for some words were less consistent in the first syllable repetition condition (e.g., prestige—pres.tige/prest.ige). This disparity in syllabification repetition consistency between the first and the second syllable accords with Goslin and Frauenfelder's (2000) findings, a pattern which led them to argue that repeating the second syllable is a more reliable way of defining syllable boundaries of words than repeating the first syllable.

Hence, according to our results from the second syllable repetition condition, the 42 words used in the present study had clear syllable boundaries. Of course, the repetition task was based on spoken presentations of the target word, whereas our main experiment investigated written syllables. Whether this is relevant depends on one's theoretical view of syllables: if they are seen as ultimately phonological principles of organisation, then there is no reason to assume that phonological and orthographic syllable structure should not always be the same. However, if it is assumed that orthographic representations are independently organized according to syllabic principles, then syllables constitute rather abstract entities. As outlined in the Introduction, the currently available evidence favors the second possibility (e.g., Kandel et al., 2009; Nottbusch et al., 2005; Ward & Romani, 2000). This leaves open the possibility that orthographic syllable boundaries in our materials differed from phonological ones, such that genuine (orthographic) syllable effects could have been obscured by our choice of materials. Further research is required to resolve this issue.

Perhaps an additional informative experiment might be to replicate the current design, but with typed, rather than handwritten, responses (e.g., Weingarten, Nottbusch, & Will, 2004). The advantage of typing over handwriting is that results render clear and precise interkeystroke intervals, and that responses tend to be executed more rapidly (at least by skilled typists) than the uppercase writing required in the current study, and hence might more adequately reveal automatic and fast planning of orthographic output codes. Of course, ideally one might also want to replace the current visual copying task with one based on the written naming of pictures (as in Afonso et al., 2009) in order to eliminate potential effects of input processing of the visually presented to-be-copied word. Unfortunately, it will probably be impossible to find enough stimuli in English which could be elicited by pictorial materials.

It is worth highlighting that identifying the role of syllables in handwriting English words is not merely of theoretical interest, but also potentially has impact in educational contexts. For instance, the "National Curriculum in England" specifies guidelines for competency in various areas (numeracy, literacy, etc.) that pupils are expected to meet at various stages. For the acquisition of handwriting, the curriculum requires the demonstration of "good handwriting habits" such as writing words with lowercase letters of the appropriate size, with adequate spacing between words, etc. But very little reference is made to psycholinguistic research which could inform educational strategies. For instance, one of the "statutory requirements" in spelling for Year 1 pupils is the correct "division of words into syllables." However, being able to divide words into syllables is a "meta-linguistic" skill and as far as we are aware, there is little empirical evidence to determine whether English-speaking children do indeed mentally manipulate syllable-sized codes when writing words. Hence, results from future studies similar to those by Kandel and colleagues summarized in the Introduction, but carried out on English-speaking (rather than French or Spanish) children, might directly inform educational strategies which aim to maximize the "match" between learning strategies and children's preferred mental codes and structures.

To conclude, the results of our study did not show an indication for the involvement of syllabic processing in English writing. Based on these findings, we tentatively propose that the role of syllables in English written production is relatively limited, or at least not as important as in languages with clear syllable boundaries such as French and Spanish. Given substantial differences in syllabic characteristics across languages, the role of syllables in written production might likewise be subject to cross-linguistic differences. More work is needed to further investigate this possibility. As far as the methodology is concerned, so far most existing studies on the influence of syllables in written production focused on measuring and analyzing the time course of written response execution, as was done in the current study. There is no doubt that this approach has provided a range of informative findings, but ideally converging evidence should be generated from studies in which response latencies of written responses are measured (hence assessing preparation rather than, or in addition to, execution; e.g., Lambert, Kandel, Fayol & Espéret, 2008). For instance, one could conduct masked priming studies with written responses, along the lines of the work conducted by Schiller (1998, 1999, 2000) with spoken responses. Overall, we conclude that further work is required to validate the possibility that the influence of syllables in the written production of languages with unclear syllable boundaries is limited.

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Appendix. Materials used in the experiment

CV targets	**CVC targets**
basis	basket
basil	bastard
bison	biscuit
caper	captain
coma	combat
cosine	cosmos
Danish	danger
donor	donkey
halo	halter

CV targets	**CVC targets**
humour	humbug
napalm	napkin
pilot	pilgrim
polo	polka
pony	pontiff
rumour	rumble
secret	section
serum	sermon
silence	silver
sinus	single
tumour	tumble
tuna	tundra