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RESEARCH REPORT

Locus of Word Frequency Effects in Spelling to Dictation: Still at the Orthographic Level!

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The present study was aimed at testing the locus of word frequency effects in spelling to dictation: Are they located at the level of spoken word recognition (Chua & Rickard Liow, 2014) or at the level of the orthographic output lexicon (Delattre, Bonin, & Barry, 2006)? Words that varied on objective word frequency and on phonological neighborhood density were orally presented to adults who had to write them down. Following the additive factors logic (Sternberg, 1969, 2001), if word frequency in spelling to dictation influences a processing level, that is, the orthographic output level, different from that influenced by phonological neighborhood density, that is, spoken word recognition, the impact of the 2 factors should be additive. In contrast, their influence should be overadditive if they act at the same processing level in spelling to dictation, namely the spoken word recognition level. We found that both factors had a reliable influence on the spelling latencies but did not interact. This finding is in line with an orthographic output locus hypothesis of word frequency effects in spelling to dictation.

Keywords: objective word frequency, spelling to dictation, spoken word recognition

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Among the factors that account for the speed with which words are retrieved from memory when people hear, read, speak, or write them down is their frequency of occurrence in the language. In psycholinguistics, word frequency effects are well-documented (Brysbaert et al., 2011). However, a critical issue is how exactly, and where in the cognitive architecture of lexical processing, word frequency exerts its influence. In the present study, we are concerned with the locus of word frequency in handwritten spelling to dictation. To make clear the rationale of our study, we begin by describing the most prevalent view of spelling to dictation in adults: the dual-route view (Tainturier & Rapp, 2001). We then briefly report the recent study of Chua and Rickard Liow (2014) that has challenged the classical view of the locus of word frequency effects in spelling to dictation, namely that word frequency influences the orthographic output word-form level. Finally, we explain the rationale of our study, which was aimed at addressing the "input" versus "output" locus of word frequency effects in spelling to dictation.

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As described by Bonin, Méot, Lagarrigue, and Roux (2015) and as illustrated in Figure 1, three main components are involved when writing down the spellings of words from their auditory presentation.

The dual-route view of spelling assumes that two processing pathways, or routes, are available and interact when producing the spellings of familiar words. First of all, the auditory string is analyzed at the perceptual level thus making available sublexical units such as phonemes. This level is common to both the nonlexical and lexical routes. Then, within the nonlexical route, the activated sublexical units are converted into orthographic sublexical units, most probably graphemes. Within the lexical route, the output of the perceptual stage (spoken word recognition) is the activation of phonological (input) word-forms which are used to access semantic codes. These codes permit the activation of several orthographic word-forms in the orthographic (output) lexicon from which a target is selected. The outputs of the lexical and nonlexical routes converge at a common grapheme level (orthographic working memory). Finally, several peripheral processes are then involved in deriving a written trace from the grapheme level.

Word frequency effects in spelling to dictation in adults have been reported several times on both written latencies and spelling errors (Bonin & Méot, 2002; Bonin et al., 2015; Delattre et al., 2006). It has long been assumed that these effects take place within the lexical route, and more precisely, at the level of the orthographic output lexicon (see Figure 1). As mentioned above, a recent study (Chua & Rickard Liow, 2014) has challenged this hypothesis and put forward the interesting alternative that word frequency influences the stage of spoken word recognition that is involved in spelling to dictation (see Figure 1). Chua and Rickard Liow (2014) have argued for such an hypothesis on the basis of findings observed in immediate-delayed/uncertain tasks. The rationale was to isolate the orthographic retrieval level from the spoken word recognition level, and in this way assess the influence of word frequency on these two independent levels. Participants were presented with spoken words and had to perform either an imageability rating task or a spelling task on the basis of these items. In the delayed/uncertain task, they were informed about the nature of the task to perform when a cue was given 1,200 ms after the offset of the spoken word. Chua and Rickard Liow (2014) assumed that the latencies in the spelling task (measured from the onset of the task cue until the first keystroke) capture task cue decision, orthographic retrieval, and response execution. In the immediate/uncertain task, the same procedure was used except that there was no delay during which spoken word recognition could be completed. Indeed, the cue indicating the type of task to perform was given at the offset of the spoken word instead of 1,200 ms after it. The idea was that in this situation, the latencies measured not only the stage of spoken word recognition, but also task cue decision, orthographic retrieval, and response execution. The experimental logic was then to compare word frequency effects in the immediate/uncertain task with these effects in the delayed/uncertain task in order to localize word frequency effects in spelling to dictation. Given that word frequency effects were reliable in the immediate/uncertain task but not in the delayed/uncertain task, the implication was that the locus of word frequency in spelling to dictation is an "input level," namely the level of spoken word recognition.

In our view, the design used by Chua and Rickard Liow (2014) is complex since it combines two different tasks and decisional processes. As a result, we think that the issue of the locus of word frequency effects in spelling to dictation is not settled and requires further examination. This was precisely the aim of the present study that made use of the additive factors logic of Sternberg (1969, 2001) to investigate this particular research question. The additive factors logic is based on the idea that when two factors affect theoretically independent stages within a cognitive architecture, this should result in additivity in mean RTs, that is, there should be two main effects for each factor, but no interaction.[1]

In the present study, adults had to write down French words from their auditory word presentation. The words had either sparse or dense phonological neighborhoods and they were of high or low-frequency in the language. Phonological neighborhood effects have been found in auditory lexical tasks and indicate that words with dense neighborhoods take more time to be recognized than words with sparse neighborhoods (e.g., Dufour & Peereman, 2003; Ziegler, Muneaux, & Grainger, 2003). Phonological neighborhood density has also an early influence in auditory word recognition as shown by EEG data (Dufour, Brunellière, & Frauenfelder, 2013). In the architecture of spelling to dictation, the locus of this latter variable is at a perceptual stage. Word frequency effects have been found in spoken word recognition, with high-frequency words being processed faster and more accurately than low-frequency words (e.g., Connine, Mullennix, Shernoff, & Yelen, 1990; Dahan, Magnuson, & Tanenhaus, 2001; Luce & Pisoni, 1998). If we assume that, in spelling to dictation, phonological neighborhood density affects the stage of spoken word recognition, whereas word frequency effects occur at the level of the orthographic output lexicon, we can predict additivity of the two factors, that is to say, we should observe main effects of phonological neighborhood density and word frequency, but no interaction. In contrast, following Chua and Rickard Liow's (2014) claim that word frequency in spelling to dictation affects spoken word recognition, we should predict an interaction similar to that found in spoken word recognition studies (Goh, Suarez, Yap, & Tan, 2009; Luce & Pisoni, 1998), in which the frequency effect is larger for words having a sparse neighborhood compared to words having a dense neighborhood.

Method

Participants

Forty-five undergraduate students (36 females, mean age = 19 years old, range 17–22 years) from either the University of Bourgogne or the University of Poitiers took part. They were all right-handed, native French-speakers, volunteers, and had normal or corrected-to-normal vision and no known hearing deficit.

Materials

Eighty-five mono- and bisyllabic words were selected (the list of words is available in the Supplementary material). The 80 experimental items consisted of two sets of 40 words: Half had few phonological neighbors ($M = 4.95$, $SD = 2.61$), and the remaining half had many phonological neighbors ($M = 16.13$, $SD = 4.66$). In addition, the words were divided into high-frequency words (book frequency: $M = 49.63$, $SD = 69.52$; subtitle frequency: $M = 39.35$, $SD = 42.10$) and low-frequency words (book frequency: $M = 6.1$, $SD = 6.18$; subtitle frequency: $M = 2.43$, $SD = 1.55$). The items were matched on several important psycholinguistic variables across the phonological neighborhood and objective word frequency conditions (see Table 1).

Concreteness, imageability, and emotional valence scores were obtained from Bonin, Méot et al. (2003). Values for numbers of phonological neighbors, orthographic neighbors, letters, phonemes, and syllables as well as for objective word frequency were taken from Lexique (New, Pallier, Brysbaert, & Ferrand, 2004). Phonology-to-Orthography consistency (the ambiguity of sound-to-spelling mappings) was also controlled for (see Table 1).[2] The number of phonemes was not matched across the two phonological neighborhood conditions, with there being more phonemes in

[1] The claim that additivity necessarily implies independent processing stages has been subject to criticism, for instance in the case of the well-studied Stroop task (Stafford & Gurney, 2011) where different competing cognitive architectures have been proposed to account for Stroop effects. As far as the cognitive architecture of spelling to dictation is concerned, there is one dominant view (the dual-view) framed by cognitive neuropsychologists where the main spelling processes (e.g., orthographic output lexicon, sublexical conversion processes, peripheral orthographic processes) are staged. We would like to stress, however, that the additive factors logic (Sternberg, 1969) has been, and still is, widely used in experimental psychology to interpret RT data in factorial experiments and to study the processing stages in a variety of areas, and in particular in psycholinguistics (e.g., Zhu, Zhang, & Damian, 2016, for a recent use of this logic).

[2] In alphabetic languages such as French (or English), the relationships between sound and orthographic sublexical units are not systematic. In French, there are ambiguous phoneme-grapheme mappings (Peereman, Lété, & Sprenger-Charolles, 2007), which require access to an orthographic lexical representation in an orthographic output lexicon if the correct spelling is to be produced (Véronis, 1988).

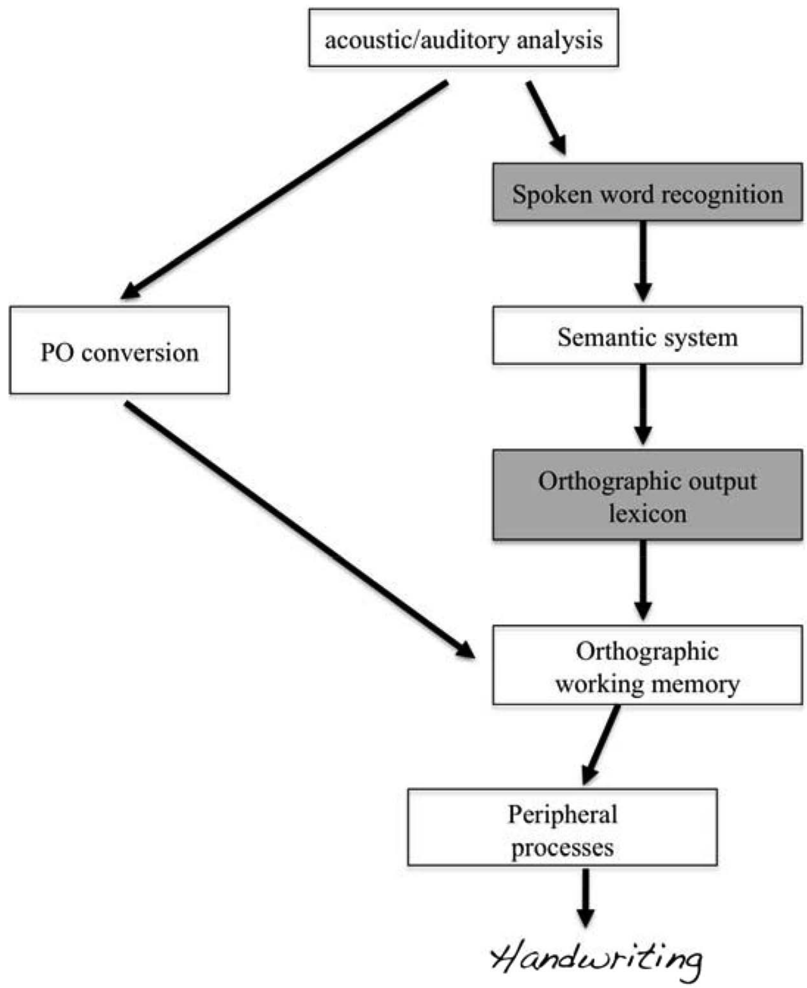

Figure 1. Cognitive architecture of spelling to dictation (potential loci of word frequency are in gray). PO = phonology to orthography.

sparse (M = 4.13, SD = 0.72) than in dense neighborhoods (M = 3.83, SD = 0.63), $t(76) = -1.98$, p = .054. This variable was therefore included as a covariate in the analyses.

Apparatus

Stimulus presentation was controlled by PsyScope X (Cohen, MacWhinney, Flatt, & Provost, 1993) running on an OSX Macintosh laptop. The participants sat in front of a digitizer (Wacom Intuos 3, sampling frequency 200 Hz, accuracy 0.02 mm) that was connected to the laptop. A sheet with 80 lines (16 lines across 5 columns) was inserted in the digitizer to record handwritten responses and a special pen (Intuos Inking Pen) was used. Headphones (Sennheiser, HD 202) were used for the spoken presentation of the stimuli.

Procedure

The participants were tested individually in a quiet room. The experimental phase was preceded by five warm-up trials. The participants were told that items would be presented orally and that they would have to write down in lowercase the word they just heard as rapidly and accurately as possible. One line was present for each written response and the participant had to position the stylus directly above the start of the line. Each trial had the following structure: A fixation point was displayed in the middle of the screen for 1,000 ms, then the spoken word was presented. A blank screen lasting 5,000 ms followed to permit participants to write down the word. All the 80 words were presented in a randomized order. The entire experiment lasted approximately 15 min.

Statistical Analyses

Reaction times (RT) were computed for each observation not aligned with the start of the item, that is, the start of the handwriting movement for the first letter of the target word, but aligned with the end of the waveform (see Perret, Schneider, Dayer, & Laganaro, 2014, for a similar procedure). The data for which the values were 2.5 standard deviations longer or shorter than the mean conditions were considered as outliers and removed from the analyses.

Table 1
Statistical Characteristics (Means, Standard Deviations) of the Control Variables

Neighborhood phonological density	Dense		Spare	
Word frequency	High frequency	Low frequency	High frequency	Low frequency
Concreteness[a]	4.54 (.36)	4.63 (.22)	4.44 (.55)	4.68 (.25)
Imageability[a]	4.22 (.40)	4.05 (.42)	4.23 (.47)	4.07 (.68)
Emotional valence[a]	2.94 (.96)	2.80 (.52)	3.13 (.82)	2.85 (.68)
Number of orthographic neighbors[b]	3.75 (2.51)	2.50 (2.33)	2.65 (2.31)	2.40 (1.46)
Bigram frequency (per million)[b]	8426.68 (5421.20)	7653.10 (3703.24)	6800.82 (4722.84)	6869.74 (3985.24)
Number of letters[b]	5.70 (.95)	5.8 (1.00)	5.50 (.92)	5.6 (.80)
Number of syllables[b]	1.60 (.49)	1.75 (.44)	1.45 (.50)	1.60 (.49)
PO Consistency[c]	72.66 (10.97)	71.98 (16.98)	75.62 (13.56)	78.42 (12.12)

Note. Standard deviations are given in parenthesis.
[a] All the scales are 5-point scales. The values were obtained from Bonin, Méot et al. (2003). [b] Values taken from Lexique (www.lexique.org; New et al., 2004). [c] Values of phonology to orthography (PO) consistency by type taken from Manulex Infra (Peereman, Lété, & Sprenger-Charolles, 2007).

The statistical analyses were performed on both latencies and error rates. ANCOVAs were run using parameters obtained with Hierarchical Linear Mixed-effect Models (Pinheiro & Bates, 2000; Snijder & Bosker, 1999) using the R-software (R version 3.1.1, R Core Team, 2014) with Participants and Items as random-effect variables. Two factors were included as fixed-effect variables in the RT and error rates. First, objective word frequency effects were tested by comparing high-frequency words with low-frequency words. Second, the two levels (spare vs. dense phonological neighborhood) made it possible to test the effects of phonological neighborhood. We added the number of phonemes as a covariate variable.

The most complex adjustment model (Bar, Levy, Scheepers, & Tily, 2013), that is, the adjustment on the by-participants and by-items intercept and by-participants slopes, was included in the model. All the mixed-effects were tested using likelihood ratio tests (Pinheiro & Bates, 2000; lmerTest packages, Kuznetsova, Brockhoff, & Christensen, 2014). Goodness-of-fit for each model (Pitt & Myung, 2002) was evaluated using the Bayesian Information Criterion (BIC, Schwarz, 1978). The model with the most complex adjustment but with the smallest BIC was retained. For all the fixed-effects tests, *p values* were obtained reporting *F* values on the Fisher distribution (Type III ANOVA) with error degree of freedom calculation based on Satterthwaite's approximation (lmerTest packages) for RT analyses. As far as error rates are concerned, we used Generalized Hierarchical Mixed-effect Models with a Poisson distribution. The fixed-effects were tested using likelihood ratio tests (Pinheiro & Bates, 2000; lmerTest packages, Kuznetsova et al., 2014) with BIC as criterion of goodness-of-fit (Pitt & Myung, 2002).

Results

We recorded 3,600 RTs. One hundred eighty-five values (5.13%) that corresponded to technical problems (e.g., no response, illegible items) were excluded. Lexical (e.g., word exchanges, 215 values, 5.97%) and sublexical errors (e.g., the French word *phoque* [seal] written *foque*, 96 values, 2.7%) were also excluded from the RTs analyses. Finally, 169 of the values were considered to be outliers (4.69%).

Error rates were significantly influenced by lexical frequency, $\chi^2(1) = 9.43$, $p = .002$, with more lexical/sublexical errors on low-frequency words than on high-frequency words (see Table 2). No other main effects or interactions reached significance, $\chi^2 < 1$.

The inclusion of participants and items as random-effect factors (intercept adjustment) significantly increased the model's fit, $\chi^2(1) = 1464$, $p < .001$, $\chi^2(1) = 696$, $p < .001$, respectively. Moreover, the inclusion of the interaction between the fixed effect of lexical frequency and the random effect of participant, that is, a mixed effect, improved the model's fit. This latter (with slopes and intercept adjustments, BIC = 37,648) exhibited a significantly better fit, $\chi^2 = 18.124$, $p < .0001$, than the model adjusted for intercepts only (BIC = 37,650).

Word frequency had a significant influence on RT, $F(1, 77.55) = 4.36$, $p = .039$. High-frequency words were initiated more rapidly than low-frequency words (see Table 2). Moreover, phonological neighborhood density had a significant inhibitory effect on RT, $F(1, 71.31) = 19.33$, $p < .001$, with shorter RT on words with a sparse phonological neighborhood than on words with a dense phonological neighborhood (see Table 2). Importantly, the interaction between word frequency and phonological neighborhood was not significant, $F < 1$. The number-of-phonemes factor just failed to reach significance, $F(1, 71.31) = 3.74$, $p = .057$.

Discussion

The locus of word frequency effects in spelling to dictation has often been ascribed to the orthographic output lexicon (Bonin, Peereman, & Fayol, 2001; Delattre et al., 2006). However, recently, Chua and Rickard Liow (2014) called into question this hypothesis and claimed to have provided empirical evidence to

Table 2
Mean RT (Standard Deviations in Parenthesis) and Error Rates (E) as a Function of Phonological Neighborhood Density and Word Frequency

	Sparse		Dense	
Frequency	RT	E	RT	E
High-frequency	362 (178.34)	3.43%	389 (195.34)	3.77%
Low-frequency	392 (205.01)	5.45%	433 (220.26)	4.89%

Note. RT = reaction time.

support the alternative hypothesis that word frequency effects in spelling most probably take place at the level of spoken word recognition. In the present study, we used the additive factors logic (Sternberg, 1969) which states that when two factors affect theoretically independent stages within a cognitive architecture, the mean RTs should be additive. Adults had to spell words based on their auditory presentation. Handwritten latencies and spelling errors were recorded. The words varied on objective lexical frequency in the language (high vs. low) and on phonological neighborhood (dense vs. sparse). According to the additive factors logic, if word frequency acts at a processing level in spelling to dictation, that is, orthographic output level, that is different from the level at which phonological neighborhood effects take place, that is, spoken word recognition, we should find that the two factors of word frequency and phonological neighborhood are additive. In contrast, if they affect the same processing level, namely spoken word recognition as claimed by Chua and Rickard Liow (2014), they should interact. The findings were clear-cut: There were significant main effects of both factors but no interaction. Therefore, we consider Chua and Rickard Liow's (2014) claim that they have succeeded in challenging the orthographic output hypothesis of word frequency effects in spelling to dictation to be premature.[3]

Technically, the additive relationship between word frequency and phonological neighborhood is a null finding (a nonsignificant interaction). It could be argued, in line with the conventional approach to testing null hypotheses, that we have drawn a strong inference about the locus of word frequency in spelling to dictation from a null finding (but note that Chua and Rickard Liow claimed that word frequency has a phonological input level on the basis of a null word frequency effect in a delayed production task). Given that our central finding constitutes a null result, it might be argued that our studies suffered from insufficient statistical power (Second Type Error). Fortunately, it is possible to get an estimate of the degree of confidence in a null finding using a Bayesian analysis. Following Rouder, Speckman, Sun, Morey and Iverson (2009), we computed the Bayes factor for our interaction. We compared the mixed-effect model without the critical interaction (H_0) with the model that included it (H_1). The Bayes factor was 9.09, thus suggesting that the null-hypothesis was about 9 times more probable than the alternative hypothesis. Thus, the Bayesian analysis suggests a reasonable amount of support for the null interaction, and we are therefore confident that the empirically obtained additivity in our study was genuine and not due to a lack of sufficient power to detect an interaction.

Chua and Rickard Liow (2014) examined the orthographic locus hypothesis in spelling to dictation by means of a design that combined two different tasks (imageability ratings vs. spelling to dictation). A cue provided either immediately or after a delay indicated the task that had to be performed in the individual trials. The idea was that the delayed/uncertain task captures the stages of "task cue decision," "orthographic retrieval," and "response execution," whereas the immediate/uncertain task captures the same processing stages plus the stage of "spoken word recognition." It remains questionable, however, whether their uncertainty/delayed task condition was indeed able to capture word frequency effects. However, even if we assume that Chua and Rickard Liow (2014) are correct in their interpretation that word frequency effects in spelling to dictation do not take place at the orthographic output level, it is still necessary to explain exactly how orthographic word forms are retrieved from the orthographic output lexicon. The authors have taken this caveat into account. According to them, when the stage of spoken word recognition is completed in spelling to dictation, the resting activation of orthographic word-forms in the orthographic output lexicon that correspond to the target spoken word-form reaches the same level, whatever their frequency (high or low). However, this latter interpretation does not readily account for the observation of similar word frequency effects in both spelling to dictation and immediate copying in the same participants and for the same items (Bonin et al., 2015), as we now discuss.

In a recent study, Bonin et al. (2015) compared the determinants of handwritten latencies in written object naming, spelling to dictation, and immediate copying using the same items and the same participants. They found that word frequency made a reliable contribution in all spelling tasks but, interestingly, they found a stronger contribution of word frequency when the participants had to produce the spellings of words in written naming than in either the spelling or copying tasks. To account for the differential influence of word frequency in written naming and in the other two spelling tasks, Bonin et al. (2015) put forward the hypothesis that frequency effects cannot be ascribed to a single processing level shared across tasks, namely, the lexical orthographic output level. We acknowledge therefore that it is difficult to assume that there is one single locus for word frequency effects in spelling to dictation, because words presented orally have to be recognized in order to be spelled. Insofar as word recognition stage is involved in spelling to dictation, word frequency effects can logically also take place at this level. Moreover, word frequency effects have been reported in the literature on spoken word recognition (Connine et al., 1990; Dahan et al., 2001; Luce & Pisoni, 1998). However, we believe that our findings strongly suggest that it would not be reasonable to reject the hypothesis that word frequency effects in spelling to dictation may occur at an output level. This claim gains further support from the finding reported by Bonin et al. (2015) that word frequency effects on latencies were nearly the same in spelling to dictation and in immediate copying, because the two spelling tasks very likely share a common level at which frequency effects occur, namely the orthographic output level (Indeed it is more parsimonious to infer one locus rather than two different loci, i.e., an orthographic input locus for copying and a phonological input locus for spelling to dictation, in order to account for similar frequency effects.) Another interesting possibility that might make it possible to pinpoint more precisely the locus of word frequency in spelling to dictation in future studies would be to use Event-Related Potentials and spatiotemporal segmentation analysis, because EEG recordings permit the continuous tracking of the periods of stable electrophysiological activity influenced by a given variable of interest. Recently, this approach has been successfully used to address the issue of the shared and

[3] Could the use of typing in Chua & Rickard Liow's study compared with handwriting in the present one have made a difference? As claimed by Rapp, Purcell, Hillis, Capasso, and Miceli (2016), all the formats used to elicit the spelling of words (e.g., handwriting, typing) involve motor processes shared by other tasks that use the same muscles. Of importance to us here is the fact that peripheral processes have been ruled out as the locus of word frequency effects in both handwriting (Bonin, Peereman, & Fayol, 2001) and typing (Chua & Rickard Liow, 2014).

separate processing stages in the spoken and written production of isolated words (Perret & Laganaro, 2012) and to determine the locus of age-of-acquisition effects in object naming (Perret, Bonin, & Laganaro, 2014).

One interesting aspect of our data that we have not discussed so far is the observation of an interaction between the fixed effect of objective word frequency and the random effect of participants, that is, a mixed effect. This effect suggests that for certain participants, objective word frequency norms may somewhat imperfectly reflect the frequency of encounter of certain words (Perret & Kandel, 2014). It would be interesting in future studies to identify certain characteristics of the participants who exhibit smaller word frequency effects in the spelling performance compared with those who exhibit larger effects. Perhaps the degree to which participants are confronted with different types of media (e.g., the time spent on the Internet, on texting; the number of books read per year etc.) accounts for the mixed effect observed here.

To conclude, our study makes a valuable contribution by strongly suggesting that word frequency effects in spelling to dictation are located at the level of the orthographic output lexicon as has often been claimed in the past (e.g., Delattre et al., 2006). This stands in sharp contrast to Chua and Rickard Liow's (2014) claim that this level is not affected by objective word frequency in spelling to dictation and that word frequency effects are located solely at the level of auditory word recognition. It is interesting to note that Chua and Rickard Liow (2014) wrote:

> "According to Sternberg's (1969, 2001) logic, if word frequency interacts with a factor that is well established to be affecting spoken word recognition only, such as phonological neighborhood density, then the word frequency effects should be located at the spoken word recognition."

The present paper has reported the findings of such a study and our findings are clear-cut: Phonological neighborhood density and objective word frequency do not interact, but have independent influences on spelling performance. Thus, it is still reasonable to assume that the locus of word frequency effects in spelling to dictation is mostly at the orthographic level!

References

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language, 68,* 255–278. http://dx.doi.org/10.1016/j.jml.2012.11.001

Bonin, P., & Méot, A. (2002). Writing to dictation in real time in adults: What are the determinants of written latencies? In S. P. Shohov (Ed.), *Advances in psychology research* (Vol. 16, pp. 139–165). New York, NY: Nova Science Publishers.

Bonin, P., Méot, A., Aubert, L., Malardier, N., Niedenthal, P., & Capelle-Toczek, M.-C. (2003). Normes de concrétude, de valeur d'imagerie, de fréquence subjective et de valence émotionnelle pour 866 mots [Concreteness, imageability, subjective frequency and emotional valence norms for 866 words]. *L'Année Psychologique, 103,* 655–694. http://dx.doi.org/10.3406/psy.2003.29658

Bonin, P., Méot, A., Lagarrigue, A., & Roux, S. (2015). Written object naming, spelling to dictation, and immediate copying: Different tasks, different pathways? *The Quarterly Journal of Experimental Psychology, 68,* 1268–1294. http://dx.doi.org/10.1080/17470218.2014.978877

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. http://dx.doi.org/10.1006/jmla.2000.2786

Brysbaert, M., Buchmeier, M., Conrad, M., Jacobs, A. M., Bölte, J., & Böhl, A. (2011). The word frequency effect: A review of recent developments and implications for the choice of frequency estimates in German. *Experimental Psychology, 58,* 412–424. http://dx.doi.org/10.1027/1618-3169/a000123

Chua, S. M., & Rickard Liow, S. J. (2014). The locus of word frequency effects in skilled spelling-to-dictation. *The Quarterly Journal of Experimental Psychology, 67,* 1720–1741. http://dx.doi.org/10.1080/17470218.2013.868915

Cohen, J., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavior Research Methods, Instruments, & Computers, 25,* 257–271. http://dx.doi.org/10.3758/BF03204507

Connine, C. M., Mullennix, J., Shernoff, E., & Yelen, J. (1990). Word familiarity and frequency in visual and auditory word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 1084–1096. http://dx.doi.org/10.1037/0278-7393.16.6.1084

Dahan, D., Magnuson, J. S., & Tanenhaus, M. K. (2001). Time course of frequency effects in spoken-word recognition: Evidence from eye movements. *Cognitive Psychology, 42,* 317–367. http://dx.doi.org/10.1006/cogp.2001.0750

Delattre, M., Bonin, P., & Barry, C. (2006). Written spelling to dictation: Sound-to-spelling regularity affects both writing latencies and durations. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32,* 1330–1340. http://dx.doi.org/10.1037/0278-7393.32.6.1330

Dufour, S., Brunellière, A., & Frauenfelder, U. H. (2013). Tracking the time course of word-frequency effects in auditory word recognition with event-related potentials. *Cognitive Science, 37,* 489–507. http://dx.doi.org/10.1111/cogs.12015

Dufour, S., & Peereman, R. (2003). Inhibitory priming effects in auditory word recognition: When the target's competitors conflict with the prime word. *Cognition, 88,* B33–B44. http://dx.doi.org/10.1016/S0010-0277(03)00046-5

Goh, W. D., Suárez, L., Yap, M. J., & Tan, S. H. (2009). Distributional analyses in auditory lexical decision: Neighborhood density and word-frequency effects. *Psychonomic Bulletin & Review, 16,* 882–887. http://dx.doi.org/10.3758/PBR.16.5.882

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2014). *LmerTest: Tests for random and fixed effects for linear mixed effect models (lmer objects of lme4 packages).* http://CRAN.R-project.org/package=lmerTest/

Luce, P. A., & Pisoni, D. B. (1998). Recognizing spoken words: The neighborhood activation model. *Ear and Hearing, 19,* 1–36. http://dx.doi.org/10.1097/00003446-199802000-00001

New, B., Pallier, C., Brysbaert, M., & Ferrand, L. (2004). Lexique 2: A new French lexical database. *Behavior Research Methods, Instruments, & Computers, 36,* 516–524. http://dx.doi.org/10.3758/BF03195598

Peereman, R., Lété, B., & Sprenger-Charolles, L. (2007). Manulex-infra: Distributional characteristics of grapheme-phoneme mappings, and infralexical and lexical units in child-directed written material. *Behavior Research Methods, 39,* 579–589. http://dx.doi.org/10.3758/BF03193029

Perret, C., Bonin, P., & Laganaro, M. (2014). Exploring the multiple-level hypothesis of AoA effects in spoken and written object naming using a topographic ERP analysis. *Brain and Language, 135,* 20–31. http://dx.doi.org/10.1016/j.bandl.2014.04.006

Perret, C., & Kandel, S. (2014). Taking advantage of between- and within-participant variability? *Frontiers in Psychology, 5,* 1235. http://dx.doi.org/10.3389/fpsyg.2014.01235

Perret, C., & Laganaro, M. (2012). Comparison of electrophysiological correlates of writing and speaking: A topographic ERP analysis. *Brain Topography, 25,* 64–72. http://dx.doi.org/10.1007/s10548-011-0200-3

Perret, C., Schneider, L., Dayer, G., & Laganaro, M. (2014). Convergences and divergences between neurolinguistic and psycholinguistic data in the study of phonological and phonetic encoding; a parallel investigation of syllable frequency effects in brain damaged and healthy speakers. *Language, Cognition, and Neuroscience, 29,* 714–727. http://dx.doi.org/10.1080/01690965.2012.678368

Pinheiro, J. C., & Bates, D. M. (2000). *Mixed-effects models in S and S-PLUS*. New York, NY: Springer. http://dx.doi.org/10.1007/978-1-4419-0318-1

Pitt, M. A., & Myung, I. J. (2002). When a good fit can be bad. *Trends in Cognitive Sciences, 6,* 421–425. http://dx.doi.org/10.1016/S1364-6613(02)01964-2

Rapp, B., Purcell, J., Hillis, A. E., Capasso, R., & Miceli, G. (2016). Neural bases of orthographic long-term memory and working memory in dysgraphia. *Brain: A Journal of Neurology, 139,* 588–604. http://dx.doi.org/10.1093/brain/awv348

R Core Team. (2014). *R: A language and environment for statistical computing. R Foundation for Statistical Computing*. Vienna, Austria: Author. http://www.R-project.org/

Rouder, J. N., Speckman, P. L., Sun, D., Morey, R. D., & Iverson, G. (2009). Bayesian t tests for accepting and rejecting the null hypothesis. *Psychonomic Bulletin & Review, 16,* 225–237. http://dx.doi.org/10.3758/PBR.16.2.225

Schwarz, G. (1978). Estimating the dimension of a model. *Annals of Statistics, 6,* 461–464. http://dx.doi.org/10.1214/aos/1176344136

Snijder, T. A. B., & Bosker, R. J. (1999). *Multilevel analysis: An introduction to basic and advanced multilevel modeling*. London, UK: Sage Publishers.

Stafford, T., & Gurney, K. N. (2011). Additive factors do not imply discrete processing stages: A worked example using models of the Stroop task. *Frontiers in Psychology, 2,* 287. http://dx.doi.org/10.3389/fpsyg.2011.00287

Sternberg, S. (1969). The discovery of processing stages: Extensions of Donders' method. In W. G. Koster (Ed.), Attention and performance II: Proceedings from a symposium on attention and performance. *Acta Psychologica, 30,* 276–315.

Sternberg, S. (2001). Separate modifiability, mental modules, and the use of pure and composite measures to reveal them. *Acta Psychologica, 106,* 147–246. http://dx.doi.org/10.1016/S0001-6918(00)00045-7

Tainturier, M. J., & Rapp, B. (2001). The spelling process. In B. Rapp (Ed.), *The handbook of cognitive neuropsychology: What deficits reveal about the human mind* (pp. 263–289). Philadelphia, PA: Psychology Press.

Véronis, J. (1988). From sound to spelling in French: Simulation on a computer. *Cahiers de Psychologie Cognitive/Current Psychology of Cognition, 8,* 315–335.

Zhu, X., Zhang, Q., & Damian, M. F. (2016). Additivity of semantic and phonological effects: Evidence from speech production in Mandarin. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology,* 1–20.

Ziegler, J. C., Muneaux, M., & Grainger, J. (2003). Neighborhood effects in auditory word recognition: Phonological competition and orthographic facilitation. *Journal of Memory and Language, 48,* 779–793. http://dx.doi.org/10.1016/S0749-596X(03)00006-8

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