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Letter coding in visual word recognition: The impact of embedded words

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ABSTRACT

Nonword classification responses are examined in this study to establish the amount of interference arising from the presence of an embedded word. In Experiment 1, greater interference is found from an initial embedding (e.g., *furb* vs *lurb*, cf. *fur*) than a final embedding (e.g., *clid* vs *clig*, cf. *lid*). In addition, an "outer" embedding (e.g., *jomb* vs *vomb*, cf. *job*) generates interference that is no greater than for an initial embedding. These results are inconsistent with the idea of left-to-right parsing, while accounts of word recognition that center on open bigrams or the spatial coding of letters require additional processes. Instead, the results are interpreted within a model of word parsing and lexical access that incorporates subsyllabic structures; an account that is supported in Experiments 2 and 3 by the critical finding that an initially embedded word interferes more when it ends in a consonant (e.g., the *fur* of *furb*, the *shadow* of *shadowl*) than with a vowel (e.g., the *tea* of *teaf*, the *coffee* of *coffeep*).

Introduction

As with most of the world's alphabetic scripts, English is read from left to right. Not only are the words in a sentence ordered in that direction, but the letters within each word correspond to each sound of the word in a left-to-right manner. This fact about the language might therefore be taken to mean that visually presented English words are recognized via a parsing mechanism that matches the individual letters to a stored lexical representation by starting from the left of the word and proceeding in a rightward direction. Such a left-to-right parsing mechanism was indeed proposed by Taft (1979) whereby a word was said to be recognized when larger and larger units were compared to representations stored in the mental lexicon until a match was made. For example, the word *climb* would be recognized after trying to access *cl*, *cli*, *clim*, and ultimately *climb* in lexical memory. A left-to-right processing model was also proposed by Kwantes and Mewhort (1999) where words are processed sequentially from their initial letter until there are no possible candidates remaining (though see Miller, Juhasz, and Rayner (2006), for evidence against this).

Support for left-to-right parsing would be seen if the correct classification of a letter-string as a nonword (i.e., a lexical decision response) were delayed by the presence of an initially embedded word, but not a finally embedded one. For example, the lexical representation for *meat* would be activated during the processing of the item *meath*,[1] but not during the processing of *smeat*, hence making it easier to decide that the latter is not actually a word. Such a result was reported by Taft (1979), along with the equivalent finding for real word items that had a competing

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[1] Underlining will be used to indicate the word embedded in a stimulus item. However, no underlining was actually present in the experiment.

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word embedded within them (e.g., a delay in recognizing *beard*, but no delay in recognizing *clove*). Interference to the lexical decision response was measured against a matched control item that had no embedding (e.g., *houth* in comparison to *meath*, or *storm* in comparison to *beard*). While the results of this study are entirely in line with a strictly left-to-right parsing mechanism, there is a potential problem with the experimental materials that were used inasmuch as the nonword control items were matched to their embedded pairings only in terms of having "similar orthographic structure" (Taft, 1979, p. 33). Such a basis for matching is so imprecise that it is quite possible that general likeness to a real word was poorly controlled. For example, the embedded and control items may not have been adequately matched on the number of words from which they differed by one-substituted letter (i.e., neighborhood size or "*N*"), which is a factor that has been shown to be important in word recognition (e.g., Andrews, 1989, 1992; Coltheart, Davelaar, Jonasson, & Besner, 1977). Similarly, the word items were only matched with their controls on word frequency, hence ignoring how confusable they were with other words.

In fact, the idea of left-to-right parsing might be seen as being incompatible with a well-established finding in another domain of visual word recognition. In particular, a word is less strongly activated when its final letters are transposed (e.g., *clibm*) than when its internal letters are transposed (e.g., *clmib*). Such a positional effect on transposed letter (TL) processing has been shown in the masked priming paradigm (e.g., Perea & Lupker, 2003a, 2003b; Schoonbaert & Grainger, 2004, at least for 5 letter words), in lexical decision responses to nonwords (e.g., Chambers, 1979), and in eye tracking research (e.g., Johnson & Eisler, 2012; White, Johnson, Liversedge, & Rayner, 2008), and might be seen as contradictory to the left-to-right parsing model. This is because information about the final letter appears to take priority in processing over letters that occur earlier in the word (apart from the initial letter, whose disruption was also shown to reduce the impact of transposed letters in the above studies). However, such a situation does not have to mean that final letters are processed earlier than medial letters. It might simply mean that the units fed into a left-to-right parsing system are imprecisely coded in relation to the medial letters such that, for example, even when *clmib* is presented, an attempt is made to access *cli*, *clim*, and *climb*. In contrast, the space after the final letter prevents lateral inhibition and therefore leads to greater precision in coding (see e.g., Johnson & Eisler, 2012; Whitney, 2001) which means that *climb* is not a candidate unit when *clibm* is presented (unlike *clb*, *clib*, *cil*, and *cilb*).

There have been several other more recent studies, however, that appear to show that a finally embedded word might have an impact on the identification of a letter-string in contradiction to the findings of Taft (1979) and, hence, to the idea of left-to-right parsing. In the first of these studies, Davis and Taft (2005) observed interference to nonword classification responses when there was a word embedded in final position. Unlike the study of Taft (1979), the nonwords that had a final embedding were carefully matched to their controls, not only on *N*, but also on other potentially important word-likeness factors such as mean bigram frequency, and the frequency of their subsyllabic "onset" and "body". The onset of a syllable comprises any consonants that precede the vowel, while the consonants that follow the vowel constitute the coda which, in combination with the vowel, forms the body of the syllable (e.g., *climb* has the onset *cl* and the body *imb*, which in turn comprises the vowel *i* and coda *mb*). Body and onset frequency were carefully controlled in the Davis and Taft (2005) study by re-combining the same onsets and bodies to create the embedded nonwords (e.g., *dwish*, *clift*) and their matched controls (*clish*, *dwift*).

An examination of the materials used in that experiment, however, reveals that a number of the finally embedded items (and none of the control items) also had what can be called, an "outer embedding". For example, the letter-string *dwish* not only includes the finally embedded word *wish*, but its outer letters also form the word *dish*. It is therefore possible that the interference effect observed by Davis and Taft (2005) with nonwords was driven to at least some extent by the existence of a word containing all but one medial letter of the nonword, rather than by the word embedded at the end. Such a possibility is reinforced by a further experiment reported by Davis and Taft (2005) which showed interference on lexical decision responses to word items not only when they had a higher frequency word embedded in initial position (e.g., *drawl*, *closet*), but also when they had an outer embedding (e.g., *rinse*, *sturdy*). Interference appeared to be weakest when the embedded word was in final position (e.g., *brisk*, *trifle*), but the interaction with position failed to reach significance on the analysis of item means.

It is important to note that even if an embedded word were to be activated more strongly when in outer position than in final position, it would still be inconsistent with a strict left-to-right parsing mechanism. At no point in the left-to-right processing of *dwish*, for example, would the lexical representation for *dish* (or *wish*) become a candidate for recognition.

In the only other reported lexical decision experiment looking at the impact of embedded words, Davis, Perea, and Acha (2009) examined Spanish polysyllabic items and concluded, in contrast to Davis and Taft (2005), that finally embedded words had no impact on either word or nonword classification responses, unlike initial and outer embeddings. However, despite the claimed lack of interference for the finally embedded items, the interaction between interference and position of embedding failed to reach significance in the item analysis of either the speed or accuracy measure for both the word and nonword items. Moreover, the interference on error rates for nonword items was larger, if anything, when the embedded word was in final position than in the initial or outer positions. Therefore the data presented by Davis et al. (2009) are equivocal with regard to the impact of finally embedded words, despite the authors' conclusion that no impact was observed.

Another way in which embedded words have been examined is within a category judgement task. Bowers, Davis, and Hanley (2005) found that a word took longer to classify as not belonging to a semantic category when that word incorporated an embedded word belonging to the category. For example, it was harder to verify that *catch is not an animal* than to verify that *catch is not a body part* because the embedded word *cat* refers to an animal and not a body part. Importantly, the magnitude of this semantic congruency effect was the same on the RT measure regardless of the position of embedding (initial, middle, or final). However, there was a strong indication that the congruency effect was greater on the error measure for initial embedding than for the other two positions, even if the interaction with position failed to reach significance on the analysis of item means, as was also seen in the Davis and Taft (2005) and Davis et al. (2009) studies.

A semantic congruency effect was also observed on category judgement times by McCormick, Davis, and Brysbaert (2010) and, as in the Bowers et al. (2005) study, the effect was shown to be insensitive to the position of embedding. No significant effect on error rates was observed in this study, and certainly no indication of a weaker congruency effect for final than initial embedding position as suggested in the Bowers et al. (2005) study. However, Nation and Cocksey (2009) did report such an interaction between congruency and position on error rates when testing children, though without any item analysis being reported.

So, the conclusions to be drawn from category judgement studies with regard to the impact of embedding position are not entirely clear, though it is apparent that a final embedding does at least have some impact on performance in the task. It could be argued, however, that this impact emerges from top-down processes specific to the task. It is possible that a set of candidate words is activated when thinking about a category, especially when those words are expected to be short (and mostly monosyllabic) as was the case in the category judgement experiments. That is, there are only a limited number of words for animals, body parts, etc., that are short in length, and these could be primed prior to the target being presented. Therefore, if the target overlaps in some way with members of the pre-activated set, it would lead to a congruency effect. This might even arise from the target having the same body as one of the predicted words, as would be the case with a finally embedded word (e.g., *scat* sharing its body with *cat*). Such a potential strategy specific to the category judgement task throws doubt on the impact of a finally embedded word in standard lexical processing.

A more normal reading situation was examined by Weingartner, Juhasz, and Rayner (2012) where eye movement data were collected for words presented in sentences. Weingartner et al. (2012) found longer fixation times to words with an embedded word of higher frequency relative to those with an embedded word of lower frequency, but that there was some indication that this was only the case for initial embeddings, not for final ones. However, there were insufficient items for any statistical analysis of a positional effect to be meaningful.

By concluding that a word is activated when embedded in any position within a letter-string, Davis and Taft (2005) and Bowers et al. (2005) argued in favor of a spatial coding scheme for visual word identification, subsequently outlined in depth by Davis (2010). According to this model, a lexical representation is responsive to a particular spatial organization of its component letters, with small deviations from that organization still leading to its activation. The relative spatial position of the letters of an initially or finally embedded word exactly match their relative spatial position in the lexical representation of that word, which means that the impact of an embedded word should be of equal strength regardless of whether it is embedded at the beginning or end of the letter-string. The impact of an outer embedding arises from the fact that the relative pattern of activation of the letters within the embedded word overlaps quite closely with the pattern corresponding to its lexical representation, with the expected relative position of its letters being disrupted only by the extraneous medial letter. In fact, according to the spatial coding model, an outer embedding might be expected to produce even greater interference than either an initial or final embedding because of a special set of initial and final letter-banks that Davis (2010) incorporates into the model to give priority to the external letters. An outer embedding will therefore gain the benefit of both of these special letter-banks, since its external letters are in their appropriate position, whereas an initial embedding will only benefit from the initial bank and a final embedding from the final bank.

Equivalent interference from both an initial and final embedding is also compatible with another account of visual word recognition, where words are represented in terms of open bigrams (e.g., Grainger, Granier, Farioli, Van Assche, & van Heuven, 2006; Grainger, Mathôt, & Vitu, 2014; Grainger & van Heuven, 2003; Grainger & Ziegler, 2011; Schoonbaert & Grainger, 2004; Whitney, 2001, 2008; Whitney & Cornelissen, 2005, 2008). Each open bigram within a word comprises two of its letters that occur in either adjacent or non-adjacent positions in their correct order. For example, the word *meat* is recognized via activation of the bigrams *me*, *ma*, *mt*, *ea*, *et*, and *at* (as well as initial position *#m* and final position *t#*, where # indicates the edge of the word, cf. Grainger et al., 2014; Whitney & Cornelissen, 2008). The nonwords *meath* and *smeat* both include exactly the same open bigrams that are found in *meat* (apart from *t#* and *#m* respectively) and, as such, interference to the lexical decision response from activation of the lexical representation of *meat* should be the same whether the embedding is in initial or final position. Interference from an outer embedding (e.g., *meast*) will also be observed as a result of the overlap of open bigrams between the embedded word and the nonword that contains it (including both of the edge bigrams).

We see, then, that the two major accounts of letter coding in word recognition predict little or no influence of embedding position on the amount of activation an embedded word receives and, hence, no difference in the amount of interference observed in lexical decision to a nonword in which that word is embedded. In contrast, a purely left-to-right parsing account (e.g., Kwantes &

Mewhort, 1999; Taft, 1979) predicts no interference at all from a finally embedded word in contrast to an initially embedded word and it is still unclear whether this is the case. While Taft (1979) and Davis et al. (2009) claimed that there was no interference from a finally embedded word on nonword classification responses, Davis and Taft (2005) concluded that there was. However, Taft (1979) used items that may have been poorly matched, Davis et al. (2009) ignored apparent interference manifesting itself through error rates, and Davis (2005) confounded final embedding with outer embedding. The purpose of the first experiment, then, is to once again examine the impact of the presence of an embedded word, with the position of embedding being the primary focus. Lexical decision responses to nonwords will be examined in preference to lexical decision responses to words because the use of nonwords allows for greater flexibility in developing well-matched materials, especially given that word frequency and semantic factors do not need to be considered.

Experiment 1

In this experiment, lexical decision responses to nonwords were examined when there was a word embedded either at the beginning (e.g., *furb* vs *lurb*, *grince* vs *grence*), at the end (e.g., *clid* vs *clig*, *thrude* vs *thruke*), or around the outside (e.g., *jomb* vs *vomb*, *sleard* vs *skeard*). Embedded items and their controls were matched as closely as possible on measures of word-likeness other than similarity arising from the existence of the embedded word. Unlike the previous studies, the control items (e.g., *lurb*, *thruke*) were only one letter different to their paired embedded item (e.g., *furb*, *thrude*) and, therefore, were very similar in appearance. So much so that a Latin-square design was adopted, using two participant groups in such a way that no participant saw both members of an embedded/control pair (and each item was presented equally often across the two groups).

According to a pure left-to-right parsing procedure where larger and larger letter combinations are fed into the system (Taft, 1979), the only type of embedding that should be activated and hence generate interference to the nonword classification response is the initial embedding. In contrast, both the spatial coding model (e.g., Davis, 2010) and open bigram accounts (e.g., Grainger & van Heuven, 2003; Schoonbaert & Grainger, 2004; Whitney & Cornelissen, 2008) predict interference in all embedding conditions, with the initial and final embedding being of equal magnitude.

Method

Participants

Fifty undergraduate students from the University of New South Wales (UNSW Australia) participated in the experiment in exchange for course credit. All participants were English monolinguals with normal or corrected to normal vision. They were randomly assigned to one of the two subgroups of the Latin-square design.

Materials

The experimental items consisted of 30 nonwords with a real word embedded at their beginning (the "Initial" condition; e.g., *furb*), 30 nonwords with a real word embedded at their end (the "Final" condition; e.g., *clid*), and 30 nonwords with a real word forming their outer letters (the "Outer" condition; e.g., *jomb*). The three conditions were matched closely on length in letters (mean = 4.97), number of letters in addition to the embedded word (mean = 1.17), and the frequency of the embedded word (mean per million log value = 1.28, 1.30, and 1.28 for the Initial, Final, and Outer conditions respectively, according to the CELEX norms, Baayen, Piepenbrock, & van Rijn, 1993), all p's $> .9$.

A control nonword was created for each experimental item by changing one letter. This letter was in the onset for all but 5 of the Initial items (e.g., *furb* changed to *lurb*) and all but 4 of the Outer items (e.g., *jomb* changed to *vomb*), while it was in the body for all but 2 of the Final items (e.g., *clid* changed to *clig*). The number of words sharing the body was nonetheless matched between the Final items and their matched controls (with mean "body frequency" of 8.05 vs 7.57, $p > .3$). For all three experimental conditions, the frequency of the onset plus coda (i.e., "antibody frequency", see Forster & Taft, 1994) was also matched with their controls, all p's $> .1$ (with values based on the number of words listed for the antibody using the More Words website http://www.morewords.com/). In addition, both N and bigram frequency (token and type) were closely matched between each embedding condition and their control, according to the values provided through N-Watch (Davis, 2005),[2] all p's $> .8$.

The final way in which similarity to a real word was determined was orthographic Levenshtein distance or "OLD20" (Yarkoni, Balota, & Yap, 2008). This is a measure of how orthographically similar the 20 most similar words are to the letter-string, as determined by insertion, deletion, and substitution of letters. Given that an embedded word was always included amongst the most similar words when calculating OLD20, it is not surprising that the OLD20 score was smaller for the embedded conditions than their non-embedded controls (indicating greater similarity), $F(1,87) = 29.32$, $p < .001$. Importantly, however, there were no significant interactions between the size of this OLD20 difference and positional condition, all p's $> .1$.

In addition to the 90 nonword items (see Appendix), there were 70 real words included as distractors. These were all monosyllabic words that had a similar structure to the nonwords, sometimes incorporating another embedded word and sometimes not (e.g., *frog*, *pearl*, *flask*, *strict*).

Procedure

The lexical decision experiment was administered using the DMDX computer display program (Forster & Forster, 2003). All letter-strings were presented in lowercase with size 20 Arial font, and remained onscreen for 1000 ms,

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[2] When calculating N for initially embedded items reported throughout this paper, inflected forms were excluded because of the bias created by the fact that many of the embedded words could be followed by a plural or present tense *s*.

with a 1000 ms delay from the response to the presentation of the next item. The targets were presented in a different randomized order for each participant. Participants were instructed to decide whether the letter-string was a real word or not, responding as quickly but as accurately as possible. Responses were collected via keyboard, with a 'yes' key for words and a 'no' key for nonwords. A total of 12 practice trials were included, which were of a similar structure to the targets used in the experiment.

Results

The data were trimmed by removing responses that were faster than 200 ms and longer than 2000 ms. One participant was removed because they made more than 30% errors. It was also realized that, inadvertently, one of the Final item pairs was misclassified (*spize*) and three items, *gult*, *snil*, and *spem*, actually corresponded to real words with one medial letter removed (i.e., *guilt*, *snail*, and *sperm*). All of these items were, therefore, eliminated from the data-set along with their paired targets (i.e., *spife*, *dult*, *snel*, and *speg* respectively). Mean response times and error rates are presented in Table 1.

Table 1
Mean lexical decision times (RT in ms) and % error rates (ER) for the three embedding conditions of Experiment 1, based on the item means.

	Embedded	Control	Interference
		Initial	
Example	*furb*	*lurb*	
RT	825	785	+40
ER	17.9	11.7	+6.2
		Final	
Example	*clid*	*clig*	
RT	803	787	+16
ER	9.9	9.3	+0.6
		Outer	
Example	*jomb*	*vomb*	
RT	810	788	+22
ER	14.9	9.1	+5.8

The results were analyzed via linear mixed effects modeling, using the *lme4* package in R (Baayen, Davidson, & Bates, 2008). Fixed and random factors were included in the model if the chi-squared tests indicated that they improved the model's goodness of fit, which was assessed using a step-wise model selection procedure. The fixed factors of interest were whether or not an embedded word was present in the target (i.e., embedded vs control), and the location of the embedded word in the letter-string (i.e., Initial, Final, or Outer condition). The covariates that were considered in the model were response time on the previous trial, OLD20 scores, neighborhood size, body frequency, antibody frequency, token bigram frequency, and type bigram frequency. These variables were centered according to their respective means. The model selection procedure revealed that response times on the previous trial, OLD20 scores, body frequency, and token bigram frequency improved the model's goodness of fit and, hence, were retained in the final model.

The random effects included the random intercepts for subjects and items. The effects of subject-related variance on the fixed factors of interest were assessed via by-subject random slopes, but these were omitted from the final model as they did not improve the model's fit. For the response time measure, inverse RTs were used as the DV (i.e., $-1000/\mathrm{RT}$) to minimize the impact of positive skew in the RT distribution. Values for p were obtained by using the R package *lmerTest* (Kuznetsova, Brockhoff, & Christensen, 2014). The analyses of error rates (ER) followed the same logic, but with ERs being entered as a binary variable using the *glmer* function in the *lme4* package, and p values being generated using the Wald z statistic for the fixed factors.

The RT analyses revealed that significant interference effects (i.e., embedded nonwords taking longer than their controls) emerged for all three conditions: $t = 5.46$, $p < .001$, for the Initial condition; $t = 1.97$, $p < .05$ for the Final condition; and $t = 2.40$, $p < .01$, for the Outer condition. Further interaction analyses, however, showed that the size of the interference effect for the Initial condition was greater than that for the Final condition, $t = 2.34$, $p < .05$, and the Outer condition, $t = 2.15$, $p < .05$. The difference between the interference effect in the Final and Outer conditions was not statistically discernable, $t = 0.21$, $p > .1$.

For the ER analysis, there were significant interference effects found for the Initial condition, $z = 2.42$, $p < .05$, and Outer condition, $z = 3.37$, $p < .05$, but not for the Final condition, $z = 0.31$, $p > .1$. The interaction analyses revealed that the interference effect from the Outer condition was greater than the null effect from the Final condition, $z = 2.05$, $p < .05$, while the equivalent interaction between the Initial and Final conditions was a strong trend, $z = 1.77$, $p = .08$.

Discussion

The results of this experiment can be summed up as follows. Interference is stronger for initial embedding (e.g., *meath*) than final embedding (e.g., *smeat*), though the latter still shows some evidence for activation of the embedded word. Outer embedding also generates interference which is just as strong as initial embedding on the accuracy measure, though weaker on the response time measure.

Such an outcome clearly invalidates a strictly left-to-right parsing mechanism (Kwantes & Mewhort, 1999; Taft, 1979) because that account fails to explain how there could be interference from either a final or outer embedding, no matter how weak the interference is relative to an initial embedding. Words embedded in a non-initial position within a letter-string will never be candidate units for access according to the left-to-right parsing account, so could never interfere with the classification of that letters-string as a nonword.

Having said that, however, the alternative letter-coding schemes that have been prominent in the literature are also found wanting. According to the spatial coding model (e.g., Davis, 2010), the magnitude of interference should be the same for initial and final embedding. The pattern of relative letter activation that overlaps between the letter-string and a lexical representation will be the same regardless of the position of that overlap. Moreover, given the special bank of letter units for both initial and final letters, it makes no difference which of the external letters is intact in the letter-string (e.g., the *f* of *furb* or the *d* of *clid*). So, the weaker interference effect for the Final than Initial items observed in the current experiment runs counter to the expectations of the spatial coding model as originally outlined.

The open bigram coding scheme appears to fare no better than spatial coding. The overlap between the open bigrams of the letter-string and the lexical representation of the embedded word is identical for initial and final embedding, and this is true regardless of whether the open bigrams are set up in a serial fashion with differential weighting as a function of the number of intervening letters (e.g., Whitney, 2008; Whitney & Cornelissen, 2005, 2008) or activated in parallel with all bigrams being given the same weight (e.g., Grainger & van Heuven, 2003; Grainger et al., 2006; Grainger et al., 2014; Schoonbaert & Grainger, 2004).

The results for the Outer condition also appear problematic for both the spatial coding account (as acknowledged by Davis et al., 2009) and the open bigram account. With the special status afforded to the initial and final letters in both models, the Outer condition might have been expected to have generated stronger interference than the Initial condition. It is actually hard to interpret the results for the Outer condition given that the amount of interference relative to the Initial condition depended on the DV. Perhaps the majority of errors in the Outer condition happened to be made by the slower participants, hence reducing the mean RT. Nevertheless, it is apparent that the impact of an outer embedding was by no means greater than that of an initial embedding.

How, then, might the spatial coding and open bigram models be modified to handle the results of Experiment 1? That is, how might they be modified to reduce the impact of a final embedding relative to an initial embedding and avoid having the strongest interference arise from an outer embedding? One possibility would be to reduce the impact of the final letter relative to the initial letter, which would accord with recent results showing that letter visibility is greater in initial than final position (e.g., Marzouki & Grainger, 2014; Scaltritti & Balota, 2013). Within the spatial coding model (Davis, 2010) this could be incorporated by reducing the contribution of the letter-bank for final letters relative to the letter-bank for initial letters. Indeed, Davis et al. (2009) suggest this possibility when attempting to handle the apparent lack of interference from a finally embedded word. It remains to be seen, however, what the impact of such a modification would have on the capacity of the model to simulate other data. In terms of the open bigram account proposed by Grainger and colleagues where letters are processed in parallel, a greater weighting might be given to bigrams that include the initial letter of the stimulus compared to those that include the final letter, and perhaps the same could hold for the initial and final edge bigrams of the model proposed by Whitney and colleagues.

Another possibility is to suggest that phonology has an impact on the amount of interference observed. For example, Grainger and Ziegler (2011) propose that open bigrams are a component of only one pathway to word identification; one involving "coarse-grained" processing that allows rapid, but not necessarily precise, access to the lexical representations. A second "fine-grained" pathway is also available for precise letter coding where letters are chunked into graphemes (e.g., TH or EA) as well as into morphemes (e.g., UN or ING). Graphemes are important in this pathway because they are the orthographic units that correspond to phonemes, and it is via this pathway that the phonology of the letter-string is activated in order to participate in the reading process. A dual-pathway account such as this provides a potential alternative locus for the effects of embedding. In particular, if phonology is activated during lexical decision, especially in the case of nonwords (cf. Frost, 1998), the conversion of graphemes into phonemes comes into play and this is typically seen as a serial process (e.g., Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Perry, Ziegler, & Zorzi, 2007, 2010, 2013). As such, an initially embedded word will be activated during the generation of phonology, which would lead to interference if that phonological representation were to participate in the word recognition process.

Davis et al. (2009) also consider the serial nature of phonological activation in explaining their putative lack of interference from a finally embedded word. However, the present research suggests that a finally embedded word does generate some interference and it is hard to see how this, along with interference from an outer embedding, can be explained in terms of serially generated phonology, following a similar argument to the original left-to-right parsing account (Taft, 1979). Thus, while phonological activation cannot fully explain the results of Experiment 1, its involvement in the task combined with the impact of spatial coding or open bigram coding could potentially account for the greater interference from an initial embedding than a final one. It might also explain why interference from an initial embedding is just as strong, if not stronger, than an outer embedding because the outer embedded word will not be fully activated through serial phonological processing.

There is, however, another proposed model of letter coding that provides quite a different way of handling the results of Experiment 1. This will be referred to here as the Subsyllabic Processing account (SSP). Lee and Taft (2009) and Taft and Krebs-Lazendic (2013) propose an interactive-activation framework where lexical representations are accessed via an orthographic system that incorporates onset and body units, with the latter being activated through vowel and coda units. When a letter-string is presented, vowels are immediately differentiated from consonants (see e.g., Chetail & Content, 2012; Perea & Lupker, 2004) and assigned to a vowel letter-bank that has up to three slots (since this is the longest sequence of vowels existing within an English syllable, cf. *beauty*). Meanwhile, each consonant must be assigned to an onset or coda slot (with the onset letter-bank having at least three slots, cf. *strap*, and the coda letter-bank having at least four consonants, cf. *length*). The corresponding unit within the orthographic access system will become activated on the basis of the assignment of the letters to the letter-banks. A schematic version of the model is depicted in Fig. 1.

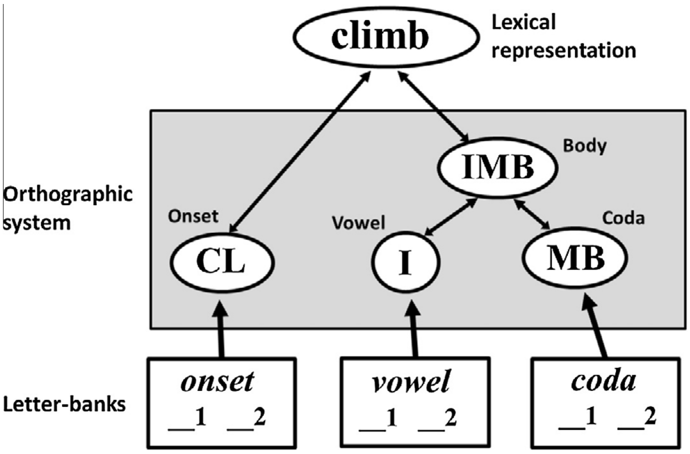

Fig. 1. Schematic diagram of the SSP model where the orthographic system comprises a hierarchical set of units representing onsets, vowels, and codas, with the latter two combining to activate body units. When a letter-string is presented, its vowels are assigned to slots within a vowel letter-bank, and consonants are assigned to slots in onset and coda letter-banks. For the sake of simplicity, only two slots are depicted within each bank.

Assignment to the appropriate subsyllabic slot is readily achieved for external consonants because the adjacent space makes them physically salient: An initial consonant will always fill the first onset slot, while a final consonant will always fill the final coda slot. In contrast, the assignment of an internal consonant to its slot is ambiguous and, as such, all possibilities are entertained. That is, the *l* of *climb* will be tried out in both onset and coda slots, but only the former will lead to the successful activation of a stored onset unit in the orthographic system and, ultimately, a whole-word representation. Conversely, the same procedure used for the *m* of *climb* will only be successful when it is tried out in a coda slot. When the *m* of the TL nonword *clmib* is tried out in a coda slot, it will also lead to activation of the real word *climb*, hence explaining the TL effect (while *clibm* is less likely to activate *climb* because the *m* will be more precisely assigned to the final coda slot).

Support for the SSP model comes from the finding that, in contrast to English, there is no TL effect in Korean when medial consonants are transposed (Lee & Taft, 2009). In the Korean alphabetic script, onset and coda positions are physically demarcated, so there is no ambiguity in terms of assignment of a consonant to its appropriate slot. The model is also consistent with the findings of Taft and Krebs-Lazendic (2013) where the magnitude of the TL effect for medial consonants was shown to be modulated by the subsyllabic status of those consonants.

So, how might this SSP account handle the results of Experiment 1? One possibility lies in the fact that the subsyllabic units within the orthographic access system are hierarchically structured. The coda *rb* will be activated when *furb* or *lurb* is presented, but so will the codas *r* and *b* to some extent. In turn, the body *urb* will be activated, but so too will the bodies *ur* and *ub*. Thus, there will be competition at both the coda and body levels. Importantly, the competition will be greater in the case of *furb* than *lurb*, because a lexical representation will be activated through the units *r* and *ur* when combined with the onset *f*, and this will feed back to support those units in their competition with *rb* and *urb*. In this way, strong interference from an initial embedding is explained. When it comes to a final embedding, there will also be competition between units. For example, the *cl* of *clid* and *clig* will experience competition from both *c* and *l* as onsets, and the latter will lead to the activation of a lexical representation in the case of *clid*, but not *clig*. However, the competition in this case only occurs at a single level (i.e., amongst onsets) which means that the interference will be weaker than when there is competition at two levels (i.e., amongst codas and bodies), as in the case of an initial embedding.

Outer embedding will lead to interference via the same competition mechanism, except that the effect might be expected to be even stronger. On the grounds that assignment of the initial onset and final coda to their respective slots is unambiguous, it is possible that the activation arising from a more precisely placed onset or coda will provide the strongest competition. For example, the *b* of *jomb* will be readily assigned to the final coda slot which corresponds to its position in the competing word *job*, whereas the *r* of *furb* will be assigned to a coda slot, rather than the more exact final coda slot in which it appears in *fur*. The fact that the outer embedding effect was weaker than the initial embedding effect on the RT measure (and no stronger on the ER measure) might therefore be considered a problem for the SSP model. However, since this was a problem for the spatial coding and open bigram accounts as well, a similar explanation might be given here. That is, either there is an additional involvement of phonology, or an initial letter is more easily perceived than a final letter. The latter would hold if it is assumed that assignment of a final consonant to the final coda slot is not as precise as its putatively salient position might suggest, unlike the assignment of an initial consonant to the first onset slot. Such a mechanism might more accurately reflect the results obtained in the Outer condition because the potential advantage in assigning the *b* of *jomb* to a coda slot relative to the *r* of *furb* would be less pronounced.

Regardless of what further assumptions might be required in order to explain the results of Experiment 1, the spatial coding and open bigram models can be potentially differentiated from the SSP model on the basis of a further experimental manipulation. According to the SSP account, the interference arising from an initial embedding is primarily the result of competition that occurs between the codas of the embedded word and the letter-string, as well as between their bodies. What happens, then, if the embedded word has no coda? This is the situation that is found when the embedded word ends in a vowel, such as *tea* embedded in *teaf*. Not only will there be no competition between coda units in this case, but competition between body units will be minimal as well. This is because the body unit for the embedded word (i.e., *ea*) corresponds to the vowel that sends activation to the body unit for the stimulus item (i.e., *eaf*), hence being more supportive than it is competitive. Such a situation is very different to what happens when the embedded word ends in a consonant, such as the *fur* of *furb*. Here, there is competition between the coda units for the embedded word and the stimulus item (*r* and *rb*), as well as between their body units (*ur* and *urb*). So, the SSP model makes the prediction that interference from an initial embedding will be significantly greater when the embedded word ends in a consonant than when it does not.

Neither of the other models of letter coding take the consonant/vowel status of the letters into account, nor do they incorporate codas and bodies. The similarity between two letter-strings is determined solely on the basis of the position of their overlapping letters. As such, there is no reason at all for these models to expect any impact of the existence of a coda in the embedded word. Experiment 2 tests whether this is the case or not.

Experiment 2

Only initial embedding is examined in the second experiment, with the contrast being made between embedded words that have a coda (e.g., *furb*, *dealm*, *tinch*) and those that end in a vowel (e.g., *teaf*, *truel*, *diece*). According to the SSP account, interference arising from the former should be greater than that arising from the latter because of the qualitative difference in the competition between subsyllabic units. Only when the embedded word has a coda will there be conflict with the coda and the body of the carrier letter-string. In contrast, neither the spatial coding nor open bigram models expect any reduction in the amount of interference from an initial embedding when it ends in a vowel.

Method

Participants

A new group of 34 participants were selected in the same way as in Experiment 1.

Materials

The experimental items were 48 nonwords that began with a real word. For half of these, the embedded word ended in a coda (e.g., the *fur* of *furb*: the "Coda" condition), while for the other half, the embedded word ended in a vowel (e.g., the *tea* of *teaf*: the "Vowel" condition). All but 6 of the Coda items were drawn from the Initial condition of Experiment 1. The Coda and Vowel conditions were closely matched on length in letters (mean = 4.63), number of letters in addition to the embedded word (mean = 1.17), and the frequency of the embedded word (mean per million log = 1.09 and 1.07 for the Coda and Vowel conditions respectively, according to the CELEX norms, Baayen et al., 1993), all *p*'s > .9.

A control nonword was created for each experimental item by changing a single letter, which was always a consonant in the onset (e.g., *lurb* as the control for *furb*, *neaf* as the control for *teaf*). A Latin-square design was again adopted so that no participant responded to both an embedded item and its control. Mean *N* and bigram frequency (token and type) were closely matched between each of the two embedding conditions and their control, according to the values provided through *N*-Watch (Davis, 2005), all *p*'s > .6. As in Experiment 1, the OLD20 scores were significantly smaller for the embedded conditions than their controls, $F(1,46) = 31.64$, $p < .001$, and there was no sign of an interaction between OLD20 score and condition, $p > .7$. Antibody frequency was not considered in this experiment because of the inherent difference between the two conditions in the nature of their antibodies. That is, the antibody (i.e., the onset plus vowel combination) coincided with the embedded word in the Vowel condition, but only with part of the embedded word in the Coda condition. All items are presented in Appendix A.

The distractor items in this experiment consisted of 48 monosyllabic words that had similar structure to the nonword items, sometimes with an initially embedded word and sometimes not (e.g., *punt*, *crawl*, *tier*, *break*).

Procedure

The procedure was exactly the same as in Experiment 1.

Results

The data was trimmed using the same process as in Experiment 1. Three participants were eliminated from the analyses because they made errors on more than 30% of the trials. Mean response times and error rates are presented in Table 2.

Linear mixed effects models were again used to analyze the RT and ER data. The fixed effects and DVs were processed in the same way as in Experiment 1. The same fixed effects and random effects were entered into the model and then assessed for whether they improved the model's goodness of fit. For Experiment 2, the covariates that were included in the final model were the OLD20 scores and type bigram frequency. As in Experiment 1, by-subject random slopes were not included in the final model.

The RT analyses showed a significant interaction between the size of the interference effect and the condition, $t = 2.29$, $p < .05$. Specifically, the interference effect from the Coda condition, $t = 4.19$, $p < .001$, was statistically discriminable from the null effect from the Vowel

Table 2
Mean lexical decision times (RT in ms) and % error rates (ER) for the two initial embedding conditions of Experiment 2, based on the item means.

	Embedded	Control	Interference
		Coda	
Example	*furb*	*lurb*	
RT	729	697	+32
ER	11.2	9.1	+2.1
		Vowel	
Example	*teaf*	*neaf*	
RT	710	708	+2
ER	7.3	8.2	−0.9

condition, $t = .95$, $p > .05$. No significant effects emerged from the error rates analyses, p's > .1.

Discussion

It is apparent from the results of Experiment 2 that the consonant/vowel structure of a word that appears at the beginning of a nonword has an impact on whether that word is sufficiently activated to interfere with the nonword classification. Interference is only observed when the embedded word ends in a coda. Such a situation is consistent with the SSP model inasmuch as interference arises from competing codas and bodies. In contrast, the results are inconsistent with an account of letter coding within which the interference to nonword classifications from the presence of an embedded word is influenced only by the number and position of the overlapping letters. This is the case with both the spatial coding model (e.g., Davis (2010) and open bigram account (e.g., Grainger & van Heuven, 2003; Grainger & Ziegler, 2011; Schoonbaert & Grainger, 2004; Whitney, 2001, 2008; Whitney & Cornelissen, 2005, 2008).

At the very least, such models need to incorporate a distinction between vowels and consonants which they currently do not do. In fact, a distinction between vowels and consonants in letter assignment has previously been shown using the TL paradigm. That is, the impact of transposing two vowels is weaker than the impact of transposing two consonants (e.g., Lupker, Perea, & Davis, 2008; Perea & Lupker, 2004). However, Lupker et al. (2008) argue that this effect can be largely ascribed to the difference in the frequency of vowels and consonants in the language rather than their functional status per se. While that may be so, an explanation in terms of letter frequency would be hard to sustain for the results of the present experiment because vowels are not being directly compared to consonants.

Because of the theoretical importance of establishing whether the subsyllabic structure of an embedded word modulates the amount of interference observed, the manipulation of coda versus vowel ending was examined in a further experiment.

Experiment 3

Owing to the relative scarcity of monosyllabic words in English that end in a vowel, it was not possible to repeat Experiment 2 with a different set of materials. What was possible, however, was to extend the manipulation of whether or not the initially embedded word ended in a coda to polysyllabic cases, such as *shadow* in *shadowl* versus *coffee* in *coffeep*. According to the SSP model, the onset/vowel/coda structure is relevant to all the syllables of a word (see Taft & Krebs-Lazendic, 2013), which means that even second syllables have bodies (e.g., *ow* in *shadow* and *ee* in *coffee*). For this reason, the greater interference observed in Experiment 2 for embedded words ending in a coda than for those ending in a vowel should logically extend to polysyllabic cases. The only difference might be that the intact first syllable of the polysyllabic word provides sufficient information for the Vowel condition to generate some interference, even if weaker than for the Coda condition. For example, the *coff* of *coffeep* will contribute considerable activation to the lexical representation of *coffee*, in contrast to the minimal contribution of the onset *t* in *teaf* to the activation of *tea*.

Method

Participants

There were 44 new participants selected in the same way as in Experiments 1 and 2.

Materials

The experimental items were again 48 nonwords, this time beginning with a polysyllabic word. Half of these embedded words ended in a coda (e.g., the *shadow* of *shadowl*), while the other half ended in a vowel (e.g., the *coffee* of *coffeep*). As in Experiment 2, the Coda and Vowel conditions were exactly matched on length in letters (mean = 6.67) and the number of letters in addition to the embedded word (mean = 1.08), while the frequency of the embedded word did not differ between conditions (mean per million log = 0.63 and 0.56 for the Coda and Vowel conditions respectively, according to the CELEX norms, Baayen et al., 1993), $p > .8$.

The control nonwords for each experimental item were created by changing a single letter in any position of the embedded word (e.g., *shapowl* as the control for *shadowl*, *caffeep* as the control for *coffeep*), again requiring a Latin-square design. Each embedding condition and its control were closely matched on mean N and bigram frequency (token and type), according to the values provided through N-Watch (Davis, 2005), all p's > .3. As in the other experiments, the OLD20 scores were significantly smaller for the embedded conditions than their controls, $F(1,46) = 30.84$, $p < .001$, and critically, there was no sign of an interaction between OLD20 score and condition, $p > .9$. All items are presented in Appendix A.

A set of 44 polysyllabic words served as distractor items, having similar structure to the nonword items, sometimes with an initially embedded word, but mostly not (e.g., *herald*, *pioneer*, *ration*, *pattern*).

Procedure

The procedure was exactly the same as in Experiments 1 and 2.

Table 3
Mean lexical decision times (RT in ms) and % error rates (ER) for the two initial embedding conditions of Experiment 3, based on the item means.

	Embedded	Control	Interference
		Coda	
Example	*shadowl*	*shapowl*	
RT	840	761	+79
ER	12.4	3.1	+9.3
		Vowel	
Example	*coffeep*	*caffeep*	
RT	824	801	+23
ER	10.2	4.8	+5.4

Results

The data were trimmed using the same procedure as in Experiments 1 and 2. One participant was eliminated from the analysis because of an error rate of over 30%. Mean response times and error rates are presented in Table 3.

Linear mixed effects models were again used to analyze RT and ER data. The same fixed and random effects tested in the previous experiments were entered into the model and then assessed for whether they improved the model's goodness of fit. Arising from this, the only covariate that was included in the final model for Experiment 3 was the response time on the previous trial. Unlike Experiments 1 and 2, by-subject random slopes were included in the final model because they did improve the model's fit.

The RT analyses showed a significant interaction between the size of the interference effect and condition, $t = 2.3$, $p < .05$. That is, the interference from the Coda condition, $t = 6.34$, $p < .001$, was statistically discriminable from the strong trend observed in the Vowel condition, $t = 1.81$, $p = .07$. In the ER analysis, significant interference effects were found for both the Vowel condition, $z = 1.99$, $p < .05$, and the Coda condition, $z = 3.26$, $p < .01$. However, despite the latter showing a numerically greater effect, the interaction between interference and condition was not significant, $z = 0.77$, $p > .1$.

Discussion

The results of Experiment 3 replicate with polysyllabic nonwords the central finding observed with the monosyllabic nonwords of Experiment 2. In particular, interference arising from the presence of a word embedded at the beginning of the nonword is greater when that word ends in a coda than when it ends in a vowel. Thus, any model of letter coding must account for more than mere letter position by incorporating vowel/consonant status in such a way that a vowel is treated differently when followed by a coda than when it is not. By emphasizing the representation of subsyllabic structure, the SSP model has the potential to do this.

Although replicating the critical interaction observed in Experiment 2, the results of Experiment 3 do differ with regard to the existence of an interference effect for embedded words ending in a vowel. In particular, unlike the results for the monosyllabic items of Experiment 2, the interference effect was significant on error rates and there was also a strong indication of an effect on the RT measure. Such an outcome is not surprising though. When the nonword items are polysyllabic, the first syllable coincides with the first syllable of the embedded word, and this provides greater activation of the lexical representation of the interfering word than is the case for monosyllabic items. Such a conclusion does not detract from the fact that the interference was weaker when the final syllable of the embedded word ended in a vowel than when it ended in a consonant.

General discussion

By establishing the impact on nonword classifications of the existence of an embedded word, the three experiments reported in this paper examine the way in which letters are encoded during visual word recognition. In Experiment 1, it is clearly shown that an embedding at the beginning of a nonword generates greater interference than an embedding at the end. Such a result is inconsistent with the spatial coding model proposed by Davis (2010) and with many versions of the open bigram account of letter coding (e.g., Grainger & van Heuven, 2003; Schoonbaert & Grainger, 2004; Whitney, 2008). For those models to handle the impact of embedding position, it is suggested that they may have to incorporate an additional phonological component or place more weight on initial than final letters in their instantiation. However, the effect that this has on the ability of those models to explain other phenomena would then need to be established. Moreover, an explanation would still be needed for the finding in Experiments 2 and 3 that a word that ends in a coda is more strongly activated when embedded at the beginning of a nonword than a word that does not end in a coda. That is, the similarity between two letter-strings needs to take into account their consonant/vowel structure and not just the number and position of their overlapping letters.

The SSP account is one such model that incorporates sensitivity to consonant/vowel structure when parsing a word for recognition, with consonants being further analyzed into onsets and codas. It is suggested that the greater interference from an initial than a final embedding might arise from the fact that the former generates competition between two levels of representation (i.e., codas and bodies), while the latter only generates competition at a single level (i.e., onsets). If it is further assumed that the position of an initial letter is coded more precisely than that of a final letter, this would also contribute to greater interference for initial than final embedding. Such an additional assumption might also help explain why a nonword with an outer embedding takes no longer to classify than a nonword with an initial embedding, as revealed in Experiment 1, even though the former maintains both the initial and final letters of the embedded word.

Given the possibility that phonology also has some impact on the task, it needs to be considered whether phonological factors can account for the critical difference observed in Experiments 2 and 3 between embedded words ending in a coda and those ending in a vowel. In fact, if vowels are analyzed separately from codas when translating graphemes into phonemes, the opposite of what was found might have been expected. That is, the Vowel items (e.g., *teaf*), would show the greater interference because their analysis entirely coincides with two of the subsyllabic structures found in the embedded word (i.e., the *t* and the *ea*), whereas the overlap for the Coda items (e.g., *furb*) is only partial (i.e., the *r* of *rb*). It might be argued, though, that more words that end in a vowel change their pronunciation when embedded in a nonword (e.g., the *die* of *diece*, the *ski* of *skib*, the *canoe* of *canoem*) than words that end in a coda, and that such a lack of phonemic overlap leads to a reduction in interference. However, only 9 of the 24 Vowel items in Experiment 1 might be considered to have changed the pronunciation of their embedded word, and when these are removed from the Vowel condition, there is still no sign of an interference effect (a 4 ms RT difference between the embedded and control conditions, and a −0.33% difference on error rates). Moreover, there are actually more items in the Coda condition of Experiment 3 that change the pronunciation of the embedded word than there are in the Vowel condition (e.g., *vitamin* in *vitamink*, *motor* in *motork*, *migrant* in *migranth*). Therefore, an explanation for the results of Experiments 2 and 3 in terms of an additional phonological pathway seems unlikely.

Conclusion

It is apparent that information extracted from a word embedded in a letter-string is more accessible when in initial than final position, hence generating greater interference in the lexical decision task. Furthermore, the interference from an initially embedded word is greater when it ends in a coda than when it ends in a vowel. Such a pattern of results is incompatible with a strictly left-to-right parsing of letter-strings during word recognition (Taft, 1979), but also with accounts of letter coding that do not incorporate internal consonant–vowel structure (e.g., Davis, 2010; Grainger & van Heuven, 2003; Whitney, 2008). A model in which words are represented in terms of their onset-body structure, such as the Subsyllabic Processing account of Lee and Taft (2009) and Taft and Krebs-Lazendic (2013), is largely compatible with the data, though it remains to be seen whether a computational implementation of that model is able to stand up to the scrutiny to which the spatial coding, SERIOL, and other open bigram models have been subjected as a result of their computational instantiation.

Acknowledgments

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Appendix A

The following are the embedded and control item pairs used in the two experiments.

Experiment 1

Initial: furb, lurb; squatch, squitch; thince, trince; plusk, clusk; zinch, jinch; nound, dound; gumb, fumb; gapt, dapt; knowd, knawd; gymph, dymph; glend, clend; starl, sharl; thight, shight; faird, taird, crowl, drowl; grince, grence; gask, gark; trimb, drimb; cleart, gleart; hourd, bourd; tinch, vinch; jamp, zamp; dript, fript; flext, clext; vaint, jaint; cheft, choft; pigh, vigh; newl, tewl; clawn, blawn; dealm, fealm.

Final: clid, clig; splunch, sprunch; thrude, thruke; knext, kneft; shalf, shalk; broam, broal; twad, twam; snil, snel; dwalk, dwilk, splog, splig; tweep, tweer; psalt, psald; spoint, spoist; closs, closh; fripe, frike; shrein, shreil; smud, smur; spize, spife; claugh, craugh; glake, gloke; thrag, thrab; speg, spem; crich, crith; smend, sment; glost, glont; plame, plade; trow, trew; frap, frab; snewt; snewd; wherb, wherm.

Outer: jomb, vomb; shrauce, thrauce; sleard, skeard; choal, thoal; florm, blorm; dresk, bresk; dalm, talm; nimp, fimp; trile, drile; sprelf, sprelk; slarp, glarp; bract, blact; sprend, scrend; thraw, shraw; frolk, fralk; quirst, guirst; brud, grud; truge, cruge; ghoust, gloust; linse, hinse; cound, tound; gult, dult; rinch, minch; fruss, druss; reast, deast; grumb, trumb; bair, dair; lind, vind; trown, trawn; sneep, sneet.

Experiment 2

Coda: furb, lurb; thince, trince; zinch, jinch; dewl, tewl; nound, dound; gumb, lumb; gapt, dapt; gymph, dymph; jawk, vawk; glend, clend; starl, sharl; mowt, fowt; laxt, gaxt; faird, taird, grince, grence; gask, gark; trimb, drimb; cleart, gleart; tinch, vinch; jamp, zamp; pigh, vigh; dealm, fealm; guth, suth; tarf, darf.

Vowel: teaf, neaf, diece, riece; truel, pruel; skib, slib; kneef, sneef; piel, fiel; zoop, noop; liert, siert; boal, roal; pleag, cleag; freen, dreen; viar, giar; foem, loem; trion, crion; spalf, swalf; flum, clum; cluet, pluet; spreet, spleet; beeve, meeve; shoet, choet; huem, tuem; treep, greep; fleal, gleal; mool, hool.

Experiment 3

Coda: shadowl, shapowl; napkint, napgint; radarce, nadarce; mayord, mayerd; zodiach, zotiach; limitch, linitch; bonust, bonost; modemp, modimp; cigard, cimard; hyphent, hychent; motork, mitork; basisk, rasisk; migranth, migrasth; toxict, toxect; hermitz, hernitz; tulipt, tunipt; opalt, odalt; vitamink, vidamink; blossomp, brossomp; cashewn, bashewn; spidern, spodern; oniond, oniand; robusth, robunth; vapourt, vabourt.

Vowel: coffeep, caffeep; iglood, igrood; moviece, loviece; magpiel, magbiel; plateaul, slateaul; cocoad, cacoad; photor, photer; mangob, mangub; zombien, zompien; studiog, stubiog; nausear, hausear; pianom, piasom; degreel, depreel; cameod, sameod; venuel, venoel; tissuet, tassuet; phobian, phodian; plazar, plazor; canoem, capoem; oboet, odoet; bambood, bampood; jubileen, jubireen; cochleat, cochreat; zebrant, zeprant.

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