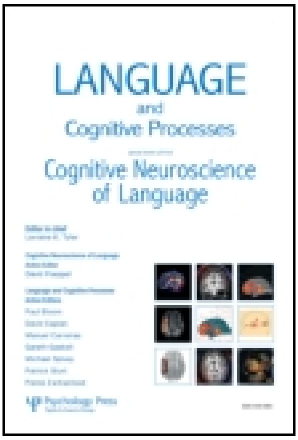

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Eric J. Stinchcombe [a], Stephen J. Lupker [a] & Colin J. Davis [b]
[a] Department of Psychology, University of Western Ontario, London, ON, Canada
[b] Department of Psychology, Royal Holloway University of London, Egham, UK
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Transposed-letter priming effects with masked subset primes: A re-examination of the "relative position priming constraint"

Eric J. Stinchcombe[1], Stephen J. Lupker[1], and Colin J. Davis[2]

[1]Department of Psychology, University of Western Ontario, London, ON, Canada
[2]Department of Psychology, Royal Holloway University of London, Egham, UK

Three experiments are reported investigating the role of letter order in orthographic subset priming (e.g., *grdn*-GARDEN) using both the conventional masked priming technique as well as the sandwich priming technique in a lexical decision task. In all three experiments, subset primes produced priming with the effect being considerably larger when sandwich priming was used. More importantly, there was very little difference in the degree of priming produced by subset primes with transposed (i.e., *gdrn*) vs. nontransposed (*grdn*) internal letters. The priming effects with transposed letter subset primes contradict Peressotti and Grainger's claim that letter order must be maintained in order to produce subset priming effects (i.e., their "relative position priming constraint").

Keywords: Transposed letters; Spatial coding; Open-bigram coding; Relative-position priming.

Correspondence should be addressed to Eric Stinchcombe, Department of Psychology, University of Western Ontario, London, ON N6A 5C2, Canada. E-mail: estinchc@uwo.ca

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One issue of relevance for theories of word recognition is the manner in which the letters within a word are assigned to specific positions. The ability to distinguish the exact positions of the letters in a word, as opposed to simply identifying which letters are present, is necessary for successful reading. That is, in order to properly recognise words, readers must be able to code letter position in a way that allows them to distinguish between the words "trial" and "trail", and also to recognise that "tairl" is not a word. Nonetheless, it has become apparent that the coding of letter position involves more than simply assigning identified letters directly to their positions in the word. An anecdotal example of the fact that the word recognition system is actually quite tolerant of incorrect letter order can be found in the well-known "Cambridge e-mail" which informs readers that "Aoccdrnig to a rscheearch at Cmabrigde Uinervtisy, it deosn't mttaer in waht oredr the ltteers in a wrod are, the olny iprmoatnt tihng is taht the frist and lsat ltteer be in the rghit pclae". In spite of the proper letter order being essentially abandoned, most readers have little trouble understanding this sentence. While there are some issues involved in interpreting the implications of this phenomenon, the fact that most people can successfully read this message in spite of the large number of letter position alterations suggests that the way in which letter position is coded cannot be absolute.

There are, of course, a number of sources of experimental evidence for the claim that letter-position coding is quite flexible. Of these, two are of particular interest for the current experiments: Transposed-letter priming and subset priming.

Transposed-letter priming

There is now a considerable body of research involving the use of transposed-letter primes, that is, primes in which the positions of a pair of letters from the target are reversed. Older "slot-based" coding schemes, such as that used in McClelland and Rumelhart's (1981) Interactive-Activation (IA) model, predict that transposing two letters within a word is equivalent to replacing the transposed letters, as the positions of all letters are presumed to be coded absolutely. Studies investigating the effect of transposed-letter primes in masked priming experiments have, however, generally demonstrated those primes to lead to larger priming effects than replacement-letter primes (e.g., Perea & Lupker, 2003) indicating that transposed-letter primes are more similar to their base words than are replacement-letter primes.

Further research by Perea and Lupker (2004) examined the effectiveness of primes using nonadjacent letter transpositions as are found in the Cambridge e-mail. To examine this issue, they used prime-target pairs in which a pair of nonadjacent consonants (*caniso*-CASINO) or nonadjacent vowels (*anamil*-ANIMAL) were transposed. Significant priming effects compared to unrelated primes as well as an advantage over primes with replacement letters were found for the transposed-consonant primes, although the latter effect was not found with the transposed-vowel primes. Again, at least as far as consonants are concerned, it appears that transposed-letter primes are indeed more similar to their base words than replacement-letter primes even if the letters in question are not adjacent.

Overall, there is a considerable amount of research supporting the claim that transposed-letter primes are more similar to their targets than equivalent replacement-letter primes (see also Forster, Davis, Schoknecht & Carter, 1987; Schoonbaert & Grainger, 2004). This fact poses a rather serious problem for any coding scheme that assumes that the positions of letters are coded absolutely. This inability of the slot-based coding schemes to account for the transposed-letter priming advantage has led to the development of a number of newer coding schemes that allow for more flexibility in letter-position coding, including the spatial coding scheme (Davis, 1999, Davis, 2010) and open-bigram coding schemes (e.g., Grainger & Van Heuven, 2003; Grainger & Whitney, 2004; Whitney, 2001).

The spatial coding scheme was introduced in Davis's (1999) Self-Organising Lexical Acquisition and Recognition (SOLAR) model, and has more recently been employed in the spatial coding model (Davis, 2010), a simplified, nonlearning version of the SOLAR model that has been shown to provide an excellent account of a large range of masked form priming data. The spatial coding scheme assumes that letter position is coded by means of noisy position codes that are dynamically assigned over position-independent letter units. The leftmost letter is assigned the lowest position code with the position codes increasing monotonically for each subsequent letter, resulting in a spatial pattern that encodes the relative positions of the letters in the stimulus. Thus, while a prime with transposed letters will not have precisely the same spatial pattern as the target, it will be coded by a relatively similar pattern that contains all of the same letter units. This model therefore predicts a level of priming from transposed-letter primes close to that observed in identity priming (i.e., when the prime and target are identical) and certainly a greater degree of priming than that produced by two-letter replacement primes.

Another recently proposed technique for coding letter position is reflected in a series of models that assume that sets of letter bigrams—ordered letter pairs—are activated when a word is read, and their activation allows accurate relative position coding of the letters in the word. For example, in the version of open-bigram coding described by Grainger and Van Heuven (2003) open-bigram units are activated for every ordered letter pair in a stimulus that is separated by two or fewer intervening letters. The activated bigram units then activate lexical units representing words. For example, the word JUDGE activates the bigrams JU, JD, JG, and so on. A transposition in letters (e.g., *jugde*) will activate all of the same bigrams as the base word would, except one (the DG bigram). Thus, *jugde* would be quite similar to JUDGE, making it an effective prime for the word JUDGE. However, the letter string *jupte*, which involves the replacement of the transposed letters, activates few of the same bigrams as the base word JUDGE. Thus, this type of coding scheme also predicts that transposed-letter primes should facilitate responding more than replacement-letter primes.

One very useful feature of most of the newer coding schemes is their ability to provide a measure of orthographic similarity between any two letter strings, that is, a measure of the orthographic overlap based on the parameters of the coding scheme in question that ranges from 0 (totally unrelated strings) to 1 (identical strings). Everything else being equal, primes that are more similar to their targets should produce greater facilitation in a masked priming experiment. Hence, one can generally determine whether, and to what degree, a given model predicts priming effects in a masked priming task. It is important to note that orthographic similarity does not necessarily directly predict lexical activation and priming effects, however. As will be discussed in more detail below, other factors that are not considered in calculating similarity can also play a role.

Given the failure of the older slot-based coding schemes to account for transposed-letter priming effects, a reasonable question to ask is whether the new coding schemes actually can account for these effects. Based on the similarity scores that are produced by these models, it does seem that both spatial coding and open-bigram models do a good job of accounting for the transposed-letter priming advantage. The similarity of the prime *jugde* to the target word JUDGE is 0.92 for the spatial coding model, and 0.89 for open-bigram coding (Grainger & Van Heuven, 2003), compared to *jupte*'s scores of 0.71 according to the spatial coding model and 0.22 using open-bigram coding. The similarity of the nonadjacent letter transpositions (*caniso*-CASINO) from Perea and Lupker (2004) is 0.82 calculated with the spatial coding scheme and 0.67 with open-bigram coding, compared to *caviro*'s similarity scores of 0.75 for spatial coding and 0.33 for open-bigram coding. Thus, these models do seem to predict more priming from transposed-letter primes than from replacement-letter primes, which is what typically observed in experiments.

Subset priming

A further test of these coding schemes is provided by another masked priming phenomenon, subset priming. A subset prime is a letter string formed by deleting one or more letters of the target, e.g., *vet* is a subset of *vest*. Experiments with unprimed targets suggest that subsets automatically activate lexical, and even semantic representations of their supersets; for example, Bowers, Davis, and Hanley (2005) found that participants were slower to decide that *vet* was not an item of clothing than to decide that it was not a type of vehicle (the opposite was true for items like *pane*, which is a subset of *plane*). The first investigation of masked subset priming was reported by Humphreys, Evett, and Quinlan (1990), using a variant of the priming methodology in which the task is identification of a briefly presented, post-masked stimulus. In more recent work, using a lexical decision task, Peressotti and Grainger (1999) tested the effects of subset primes formed by removing several letters from a target word. In one condition, the absolute positions of the letters were preserved by inserting nonletter characters (dashes) in place of the deleted letters (*b-cl-n* priming BALCON) while in the other condition, the letters of the prime remained in the same relative order as in the word but the nonletter characters were removed (*blcn*-BALCON). Their results showed that both conditions produced significant priming compared to an unrelated prime, with there being no real differences between the two prime types. Thus, it would seem that subset primes do produce a significant priming effect, and it is not necessary for the letters to be in their proper absolute positions for this priming effect to occur.

What does appear to be important here, however, is that the relative positions of the letters be preserved. That is, when the relative order of the letters of subset primes was disturbed by transposing either the external (*nlcb*-BALCON) or internal (*bcln*-BALCON) letters, no significant priming was produced. Based on these data, Peressotti and Grainger (1999) claimed that it is possible to produce priming with a subset of the letters of the target word, but only if the letters remain in the proper order relative to one another. This particular phenomenon, which is central to the present research, has been referred to as the "relative position priming constraint". As Grainger and Whitney (2004) noted, this constraint appears to be at odds with the ease with which the previously mentioned Cambridge e-mail can be read.

Grainger, Ganier, Farioli, van Assche, and van Heuven (2006) examined the subset priming effect in more detail in a series of experiments, using seven and nine letter word targets. In their first experiment, Grainger et al. examined the effect of disrupting the absolute positions of letters in a prime by inserting nonletter characters in various positions within the prime. The original absolute position primes from Peressotti and Grainger (1999) had only used conditions in which the dashes were taking the place of omitted letters. In addition to using a similar condition, (1-345-7, where the numbers represent which letters of the target are included in the prime) a condition where the dashes were out of place (13-4-57) was introduced. These primes were compared to primes with no dashes (13457), as well as unrelated primes. Overall, there was no apparent effect of the placement of the dashes, or of their being removed—these conditions produced equivalent reaction times, which were significantly faster than those in the unrelated prime condition. However, as in Peressotti and Grainger (1999), the relative position priming constraint held. There was no evidence of significant priming when the order of the letters in the prime was not maintained (i.e., 1-543-7 and 7-345-1 primes).

Overall, it appears that it is possible to obtain a significant degree of priming from a subset prime. When a subset prime's letter order is altered, however, Peressotti and Grainger's (1999) results suggest that the primes lose their ability to produce priming (see also Grainger et al.'s (2006) Experiment 1B involving seven letter targets and transposed-letter subset primes). One of the clearest statements of the relative position priming constraint was made by Grainger and Whitney (2004, p. 58), who argued that this constraint was a key phenomenon:

> Priming occurs only when relative positions are respected. For example, a six-letter word such as "garden" is identified more rapidly when preceded by the masked prime "grdn" compared to the unrelated condition "pmts", and partly changing the order of letters (gdrn, nrdg) destroys the priming effect.

Grainger and Whitney (2004) further argued that the relative position priming constraint and transposed-letter priming were the "two key phenomena" that had "propelled a new approach to letter position coding" (p. 58). However, there is a tension between the relative position priming constraint (i.e., the inability of transposed-letter subset primes to produce priming) on the one hand and transposed-letter priming (in which nonsubset transposed-letter primes produce priming levels close to those observed in identity priming) on the other hand that actually appears to pose a problem for newer models of letter position coding. Certainly, if the correct relative positioning of letters is required for subset priming effects to occur, that fact will constrain (and challenge) the possible models of letter position coding. The potential importance of the failure of transposed-letter subset primes to produce priming is underlined by examining the newer models' calculations of similarity scores for the various types of primes. For the subset prime *grdn*, the similarity score with the target GARDEN is 0.68 according to the calculations of the spatial coding model, and 0.42 according to open-bigram coding (Grainger & Van Heuven, 2003). These relatively high levels of similarity for these (effective) primes and targets provide further support for these models of orthographic coding. What is problematic, however, is that both spatial coding and open-bigram coding models predict levels of similarity that are not much lower for transposed-letter subset primes and their targets, leading to the expectation that these primes should also produce priming (the prime-target pair *gdrn*-GARDEN had a similarity score of 0.57 for spatial coding, and 0.33 for open-bigram coding), in direct contrast to the lack of priming that has so far been observed.

Sandwich priming

As noted previously, however, there is not a direct connection between similarity scores and predictions of priming. To understand why that is, consider a study by Guerrera and Forster (2008) in which they examined the priming produced by a large number of more extreme transpositions. The condition of interest for the current discussion was what was referred to as the "T-All" condition. The primes in this condition were constructed by transposing every pair of adjacent letters in a word (*avacitno*-VACATION). While the newer position coding schemes show a significant degree of orthographic similarity between these primes and their targets, when these T-All primes were used in a masked priming lexical decision task, no significant priming effect was found.

As with the null effect produced by transposed-letter subset primes, this finding appears to pose something of a problem for the newer coding schemes. However, as Lupker and Davis (2009) discuss (see also Davis, 2003; and Perry, Lupker & Davis, 2008), the orthographic similarity of primes and targets is not the only factor that determines the effectiveness of a prime. According to most models of lexical processing, priming is a phenomenon that occurs due to activation of a target's representation in the lexicon, and there is not a perfect relationship between orthographic similarity and lexical activation. A specific assumption common to lexical processing models is that the activation of any lexical unit inhibits the activation of any other lexical unit. Thus, whenever a prime activates the lexical units for words other than that of the target, these other units will then inhibit the activation of the target's unit. This can result in the activation of the target's unit being essentially nullified or even driven to a lower level at prime offset than if an unrelated prime had been presented. If this was the case with Guerrera and Forster's (2008) T-All primes, the absence of facilitation from such primes would follow even though the orthographic similarity scores for these primes and targets was relatively large.

Lupker and Davis (2009) examined the question of the impact of lateral inhibition with Guerrera and Forster's (2008) T-All primes by running simulations using the spatial coding model. What they found was that for many prime-target pairs (e.g., *avacitno*-VACATION) the prime activates many words in the lexicon, including some (in this case, AVIATION) that are actually more similar to the prime than the target is. As a result of a number of strong competitors to the target being activated, the process of activating the target was slowed. In fact, for this set of primes and targets, the inhibition from activated competitor words essentially eliminated any facilitation produced as a result of the prime pre-activating the target. Thus, the spatial coding model actually predicts the null priming effect observed in Guerrera and Forster's experiment using T-All primes. More importantly, these simulations demonstrate why orthographic similarity does not necessarily directly predict the level of priming to be expected—the inhibitory processes in the lexicon also need to be accounted for.

In order to substantiate their analysis of the situation with T-All primes, Lupker and Davis (2009) developed an experimental technique intended to reduce or eliminate the inhibition produced by activated competitor words, thus allowing the activation of the target produced by an orthographically similar prime to be observed. The technique devised by Lupker and Davis is known as the "sandwich priming" technique. In a sandwich priming experiment, a forward mask is presented as is normally done in masked priming experiments, followed by a brief (typically 33 ms) exposure of the target item itself in lowercase. The initial target item is followed by the prime of interest, and finally the target is presented in uppercase until a response is made. The initial presentation of the target is presumed to provide an early boost to the target's level of activation. As a result, the target word is already activated to a significant degree when the prime of interest (the second prime) is presented. Thus, any other words that the prime of interest might normally activate when it is presented will quickly be suppressed by the more-active target word, allowing researchers to observe the direct impact of the prime of interest (due to orthographic similarity) on the target. Because the target has the same degree of pre-activation from the brief presentation of itself on every trial, it can be assumed that any systematic differences between conditions are due to differences in the second prime's effects.

Using this technique, Lupker and Davis (2009) demonstrated that Guerrera and Forster's (2008) T-All primes do actually produce priming at a level that could be predicted based on their orthographic similarity scores. These results suggest that this technique may well be useful for eliminating inhibitory effects from activated competitors, allowing for an examination of the predicted priming effects based on orthographic similarity. If so, this technique would be of clear value for investigating the predictions of the various coding schemes. That is, a method that allows for comparisons based primarily on the calculated similarities of the prime and target will make direct comparisons of different models' predictions much simpler.

The relative position priming constraint reconsidered

The purpose of the present experiments was to re-examine Peressotti and Grainger's (1999) relative position priming constraint, specifically, the idea that transposed-letter subset primes do not have the potential to activate their base word's lexical representations, producing priming effects. As has been noted, despite the lack of facilitation observed from the transposed-letter subset primes, their orthographic similarity scores are quite high, although not as high as for the nontransposed-letter subset primes. So, the first question is how much priming should one expect from these two prime types?

For the present experiments, a set of 96 six-letter English words were selected, and priming simulations were run using Davis's (2010) spatial coding model (see Tables 1 and 2). Parameter settings were identical to those used in Davis (2010), with one exception: the α_{WL} parameter, which controls the strength of top-down feedback from words to letters, was set to zero. This parameter setting is one that we have used in previous simulations (e.g., Lupker & Davis, 2009); we delay further discussion of the specific motivation for this setting in the present simulations until the General Discussion. In the simulations, time steps are purposely set up so that one cycle of processing within the model corresponds approximately to one millisecond. In line with Peressotti and Grainger's (1999) results, the nontransposed-letter subset primes (i.e., the 1346 condition) produced a reasonable priming effect (i.e., fewer cycles to threshold than when the prime was unrelated—see Table 1). Also, in general correspondence with Peressotti and Grainger's nonsignificant priming effect with the 1436 primes, the simulation produced only a small effect for these primes, in spite of their reasonably high orthographic similarity scores. The implication is that the lack of a significant priming effect from the transposed-letter subset primes may not be at all surprising. The priming effect with 1346 primes is not expected to be large and the priming effect with 1436 primes is expected to be about half of that size.

Table 2 presents the predictions for these same two types of primes when a sandwich priming technique is used (an additional prime condition, 1dd6, was also included in the simulation; this condition was examined in

TABLE 1
Results from simulations using the spatial coding model with standard priming

Prime type	*Related Mean cycles*	*Unrelated Mean cycles*	*Priming effect*
1346	83.6	99.4	15.8
1436	91.4	99.4	7.9

Experiment 3 and is discussed below). In this simulation, both types of primes produced noticeable priming effects. In essence then, according to the model, the implication is that the relative position priming constraint is not a constraint in the sense that priming can only be had if the relative position of the letters is maintained. Rather, to the extent that there is a relative position priming constraint, it merely reflects the fact that transposed-letter subset primes are less similar to their targets than nontransposed-letter subset primes which are, themselves not overly potent primes. Thus, unless the impact of lexical competition is diminished, it will inevitably be hard to observe the impact of transposed-letter subset primes.

In order to examine these predictions, these 96 target words were used in both conventional and sandwich priming experiments. The expectation, based on both empirical work (i.e., Peressotti & Grainger, 1999) and the just reported simulations is that, in a conventional priming task, we should observe some priming for the 1346 primes and only a very small (and, likely nonsignificant) priming effect for the 1436 primes. In, contrast, both types of primes should produce priming using the sandwich priming technique.

There are a couple of other aspects of Peressotti and Grainger's (1999) experiment that deserve comment. In that experiment, the baseline used to determine the size of the priming effect was a single, unrelated string of letters (see also Grainger et al., 2006). Essentially, what those authors were assuming is that any set of completely unrelated primes would lead to the same target latencies. Although this is a common assumption in the literature, there is evidence that it isn't always correct (e.g., see Perea & Lupker, 2003). That is, although the reason that different sets of unrelated primes produce different mean latencies is not clearly understood (e.g., it could be due to different unrelated primes having different perceptual characteristics), such events do occur, as shown in Perea and Lupker's experiments. As a result, the observed priming effect can vary as a function of the nature of the unrelated primes used. The only real way of ensuring that there is an appropriate unrelated prime condition for each related condition is to use exactly the same primes in the two conditions. In order to accomplish this, the creation of the unrelated condition would need to involve re-pairing the primes and targets from the

TABLE 2
Results from simulations using the spatial coding model with sandwich priming

Prime type	*Related Mean cycles*	*Unrelated Mean cycles*	*Priming effect*
1346	53.2	96.6	43.4
1436	62.4	96.5	34.2
1dd6	94.5	96.3	1.9

relevant related condition in such a way that no prime shares letters with its unrelated target. Doing so ensures that any overall latency differences created by the primes (for whatever reason) are equivalent in the related and unrelated conditions and, hence, any priming effects that are observed are actually due to the primes' relationship with the targets rather than being due to any characteristic of the primes themselves. Taking such precautions would seem to be especially crucial in situations like in the present experiment where the sizes of these effects are small in the first place.

The re-pairing procedure is the procedure used here. That is, in order to control for any possible impact of differing unrelated conditions on the observed priming effects, the present experiments used re-paired related primes and targets in the unrelated prime conditions. The use of these two unrelated conditions also allows for a more direct comparison between the sizes of the priming effects. That is, to convincingly argue, as Peressotti and Grainger (1999) have, that 1346 primes are effective primes while 1436 primes are not, one should be able to show an interaction between prime type and relatedness. Because Peressotti and Grainger used only a single unrelated prime condition, there was no chance to provide such a demonstration. (The only direct contrast Peressotti and Grainger could make, between their related conditions (i.e., 1346 and 1436), showed a marginally significant difference between those conditions, at least in their subject analysis.) The inclusion of separate unrelated conditions for each of the related conditions in the present experiments allows for a test of the relevant interaction.

In addition, there are a number of other characteristics of Peressotti and Grainger's (1999) experiments showing the relative position priming constraint that are slightly different from those in more conventional masked priming experiments. The one most likely to be relevant is that Peressotti and Grainger used a prime duration of 33 ms, which is a bit shorter than the more standard 40–60 ms prime duration used in most masked priming experiments. To determine whether this the prime duration may be important for observing a relative position priming constraint, both a more standard 55 ms prime duration (Experiment 1a) and a 33 ms prime duration (Experiment 1b) were used here.[1]

It is also potentially worth noting that Peressotti and Grainger's (1999) primes were not forward masked, as is also standard in most masked priming experiments, and that the primes and targets were both presented in lowercase letters. Generally, primes are displayed in lowercase and targets

[1] A shorter prime duration can be simulated with the model by activating the prime's letter units for fewer cycles. When the number of cycles of letter activation by the prime was scaled back to reflect the difference between a 55 ms prime exposure and a 33 ms prime exposure, the predictions were for a 12 cycle priming effect for 1346 primes and a 7 cycle priming effect for 1436 primes.

in uppercase as a means of limiting the visual overlap of the prime and target. Thus, the possibility of visual overlap as well as the absence of a mask may, in theory, have impacted the observed pattern of results. As the expected result of both of these manipulations would be to increase priming rather than to produce a condition (i.e., the 1436 condition) in which there was a null effect, neither factor was investigated here. In the present experiments the more standard technique of using a forward mask and presenting the prime and target in different cases was used.

EXPERIMENT 1

Method

Participants. Thirty-six undergraduate students from the University of Western Ontario participated in Experiment 1a and twenty-four participated in Experiment 1b. All spoke English fluently and had normal or corrected to normal vision. Participants were compensated monetarily or with course credit for their time.

Stimuli and design. The target stimuli consisted of 96 six-letter English words (with no repeated letters) and 96 orthographically legal, pronounceable nonwords. The primes were four-letter strings that were subsets of the targets. There were four primes used for each target (both word and nonword targets). In the first priming condition (1346) the prime consisted of the first, third, fourth, and sixth letters from the target. In the second condition (1436), primes were formed by a transposition of the internal letters of the 1346 prime, resulting in a 1436 sequence. Two unrelated prime conditions were also used. These primes consisted of the related (1346 and 1436) primes of a different target, which shared no letters with the target they were paired with. Four lists of 192 items were constructed. Each list contained all of the word and nonword targets, with a different prime for each target on the different lists. Thus, no target or prime was presented more than once to any one participant, but each target was primed equally often by all four prime types across the full set of participants. Thus, both prime relatedness (related or unrelated) and prime type (transposition or no transposition) factors were within-subject and within-item factors.

Equipment. Stimuli were presented on a standard PC monitor, running Forster and Forster's (2003) DMDX software. Responses were made on a standard PC keyboard.

Procedure. Each trial involved the presentation of three stimuli. First, a series of six hash marks was presented for 500 ms, followed immediately by the prime for 55 ms (Experiment 1a) or 33 ms (Experiment 1b), followed by the target for 3 seconds or until a response was made. Primes were displayed in lowercase and targets in uppercase to minimise visual overlap between the primes and targets.

Participants were assigned to one of the four stimulus lists based on the order of their arrival. Participants were seated approximately 18 inches in front of the monitor used to display the stimuli. Participants were instructed to determine as quickly and accurately as possible whether a given target was an English word or not. Responses were made by pressing one of the Shift keys on a standard keyboard, the right key for a word target and the left key for a nonword target. The stimuli were presented in a different random order for each subject.

RESULTS (EXPERIMENT 1a)

Incorrect responses (6.6% of the word data and 5.5% of the nonword data), as well as response time less than 150 ms or greater than 2,000 ms (0.1% of the word data, and 0.1% of the nonword data) were excluded from the analyses. Two (prime relatedness) by two (prime type) ANOVAs by subjects (F_1) and items (F_2) were performed on the mean correct latencies and error rates to word targets. The results from the subject analysis are reported in Table 3. There was a main effect of prime relatedness, $F_1(1, 35) = 9.45$, $MSE = 772.4$, $p < .005$; $F_2(1, 96) = 3.38$, $MSE = 2{,}372.3$, $p < .07$, although it was only marginal in the item analysis. Latencies were shorter following related primes. The effect of prime type was significant in the subject analysis, $F_1(1, 36) = 8.58$, $MSE = 642.2$, $p < .01$; $F_2(1, 96) = 1.72$, $MSE = 3{,}610.0$, $p > .15$. Latencies were shorter following nontransposed-letter primes. The interaction of prime relatedness and prime type was not significant although it was marginal in the item analysis, $F_1(1, 35) = 1.41$, $MSE = 1{,}049.2$, $p > .20$; $F_2(1, 96) = 3.52$, $MSE = 2{,}100.5$, $p < .07$.

An analysis of error rates showed a significant effect of prime relatedness, $F_1(1, 35) = 6.45$, $MSE = 0.002$, $p < .05$; $F_2(1, 95) = 4.08$, $MSE = 0.007$, $p < .05$. Error rates were lower following related primes. There was no effect from prime type, ($F_1(1, 35) = 2.08$, $MSE = 0.003$, $p > .15$; $F_2(1, 95) = 2.86$, $MSE = 0.005$, $p < .10$. Likewise, the interaction of prime relatedness and prime type was not significant, $F_1(1, 35) = 0.27$, $MSE = 0.002$, *ns*; $F_2(1, 95) = 0.26$, $MSE = 0.006$, *ns*.

ANOVAs by both subjects and items were performed on the mean correct latencies and error rates to nonword targets. No significant effects were found (all ps $> .12$).

TABLE 3
Results from Experiment 1a-55 ms prime exposure (reaction times in milliseconds, error rate in percent)

	Related		*Unrelated*		
Prime type	*Reaction time*	*Error rate*	*Reaction time*	*Error rate*	*Priming effect*
Word data					
1346	549	4.9	569	7.0	20 (2.1)
1436	567	6.5	575	7.8	8 (1.3)
Nonword data					
1346	626	4.4	621	5.7	–5 (1.3)
1436	621	5.9	618	6.0	–3 (0.1)

RESULTS (EXPERIMENT 1b)

Incorrect responses (3.9% of the word data and 4.5% of the nonword data), as well as response times less than 150 ms or greater than 2,000 ms (0.1% of the word data and 0.7% of the nonword data) were excluded from the analyses. The results from the subject analysis are reported in Table 4. The effect of prime relatedness was significant in the subject analysis ($F_1(1, 23) = 4.67$, MSE = 612.82, $p < .05$; $F_2(1, 95) = .13$, MSE = 8,901.75, *ns*) with shorter latencies following related primes. The effect of prime type was not significant ($F_1(1, 23) = .32$, MSE = 787.95, *ns*; $F_2(1, 95) = 2.17$, MSE = 4,754.21, $p > .10$). Most importantly, there was no significant interaction of prime relatedness and prime type ($F_1(1, 23) = .02$, MSE = 775.92, *ns*; $F_2(1, 95) = .02$, MSE = 8,340.89, *ns*).

The analysis of error rates showed no significant effect of prime relatedness ($F_1(1, 23) = 2.47$, MSE = 0.002, $p < .13$; $F_2(1, 95) = 2.58$, MSE = 0.006, $p < .12$). There was also no effect of prime type ($F_1(1, 23) = .45$, MSE = 0.002, *ns*; $F_2(1, 95) = .62$, MSE = 0.006, *ns*). Likewise, the interaction of prime relatedness and prime type was not significant ($F_1(1, 23) = .32$, MSE = 0.001, *ns*; $F_2(1, 95) = .36$, MSE = 0.006, *ns*).

Similar ANOVAs were performed on the mean correct response times and error rates to nonword targets. None of the main effects or interactions were significant (all *F*s < 3.0), either in the subject or item analysis.

DISCUSSION

The results of Experiment 1a (a 20 ms priming effect for 1346 primes and an 8 ms priming effect for 1436 primes) were not appreciably different from those reported by Peressotti and Grainger (1999) using subset primes (in one

TABLE 4
Results from Experiment 1b-33 ms prime exposure (reaction times in milliseconds, error rate in percent)

	Related		*Unrelated*		
Prime type	*Reaction time*	*Error rate*	*Reaction time*	*Error rate*	*Priming effect*
Word data					
1346	600	3.2	611	5.0	11 (1.8)
1436	604	3.0	614	4.0	10 (1.0)
Nonword data					
1346	729	6.0	707	5.8	–22 (–0.2)
1436	715	5.3	712	3.8	–3 (1–.5)

experiment they reported a 20 ms priming effect for 1346 primes and a 5 ms priming effect for 1436 primes, while in a separate experiment they reported a 27 ms priming effect for 1346 primes and a 12 ms priming effect for 1436 primes). Further, those effects were comparable to those predicted in the simulation using the spatial coding model (16 cycles of priming for 1346 primes and 8 cycles for 1436 primes). The results of Experiment 1b (an 11 ms priming effect for 1346 primes and a 10 ms effect for 1436 primes) were perhaps slightly different than those of Peressotti and Grainger. However, the main point to note here is that, even though the prime exposure was reduced to 33 ms, there was still significant subset priming.

More centrally, however, what also should be noted is there was no evidence of a significant interaction between prime type and prime relatedness in either experiment. Thus, at this point, there is still no strong statistical evidence that there is a significant difference in the sizes of the priming effects in these two conditions, specifically, there is no strong statistical evidence for the relative position priming constraint, that is, that 1346 primes produce priming whereas 1436 primes do not.

An additional point to note is that there was a small difference in the latencies in the two unrelated conditions. If we had used a single unrelated condition, as Peressotti and Grainger (1999) did, the pattern of results could have looked slightly different. That is, if the only unrelated condition used had been the unrelated condition for the 1346 primes, there would still have been a priming effect for those primes. However, the priming effect for the 1436 primes would have only been 2 ms which would have been quite consistent with a qualitative version of the relative position priming constraint (i.e., priming effects do not exist for 1436 primes) as well as being somewhat less consistent with the predictions derived from the spatial coding model. Thus, the present results (see also Perea & Lupker, 2003) point to the value of using an unrelated condition that matches the related conditions as closely as possible, especially when the effect sizes are expected to be small to begin with.

EXPERIMENT 2

The results of the first experiment are consistent with the idea that the only real difference between transposed- and nontransposed-letter subset primes is that the latter are quantitatively better primes than the former. In a conventional masked priming experiment, a difference of this sort can produce a situation in which one prime type produces a small but significant priming effect whereas the other produces a smaller and nonsignificant priming effect, which is essentially the pattern Peressotti and Grainger (1999) observed. If so, the expectation is that a sandwich priming paradigm, a paradigm in which the impact of competitors is diminished, should allow both of these prime types to produce substantially larger priming effects, as predicted in the simulations reported earlier. In contrast, if 1436 primes actually are ineffective primes (i.e., if there really is a relative position priming constraint based on a qualitative difference between 1346 and 1436 primes), the prediction is that 1436 primes should produce no priming even when using a sandwich priming technique. Experiment 2, using the same display parameters as Experiment 1a together with the sandwich priming technique, was an attempt to evaluate these predictions.

Method

Participants. Twenty-four undergraduate students from the University of Western Ontario participated in this experiment. All spoke English fluently and had normal or corrected to normal vision. Participants were compensated with course credit for their time.

Stimuli and design. The stimuli and design used were the same as in Experiment 1.

Equipment. The equipment used for this experiment was the same as in Experiment 1.

Procedure. Each trial consisted of four stimuli. First, a series of six hash marks was presented for 550 ms, followed immediately by the target for 33 ms, followed by the prime for 55 ms, and finally the target for 3 seconds or until a response was made. The first display of the target and the prime were in lowercase, while the display of the target was in uppercase to minimise visual similarity between the target and the preceding stimuli.

The setup of the apparatus and instructions given to participants was the same as that in Experiment 1.

RESULTS

Incorrect responses (5.2% of the word data and 10.3% of the nonword data), as well as response times less than 150 ms or greater than 2,000 ms (2.7% of the word data and 0.6% of the nonword data) were excluded from the analyses.[2] As in the previous experiment, two (prime relatedness) by two (prime type) ANOVAs by subjects and items were performed on the mean correct latencies and error rates to word and nonword targets. The results from the subject analyses are reported in Table 5. In the word data, there was a significant effect of prime relatedness, $F_1(1, 23) = 51.90$, $MSE = 1{,}393.5$, $p < .001$; $F_2(1, 95) = 118.99$, $MSE = 2{,}709.6$, $p < .001$, as latencies were shorter following related primes. The effect of prime type was not significant, $F_1(1, 23) = 0.74$, $MSE = 736.2$, *ns*; $F_2(1, 95) = 0.20$, $MSE = 5{,}046.2$, *ns*. Once again, there was no significant interaction of prime relatedness and prime type, $F_1(1, 23) = 0.50$, $MSE = 566.0$, *ns*; $F_2(1, 95) = 1.06$, $MSE = 3{,}155.2$, $p > .30$.

In the analysis of error rates there was a significant effect of prime relatedness, $F_1(1, 23) = 8.66$, $MSE = 0.006$, $p < .01$; $F_2(1, 95) = 34.24$, $MSE = 0.006$, $p < .001$, as error rates were lower following related primes. There was no effect of prime type, $F_1(1, 23) = 0.12$, $MSE = 0.002$, *ns*; $F_2(1, 95) = 0.26$, $MSE = 0.007$, *ns*, nor was there a significant interaction, $F_1(1, 23) = 1.06$, $MSE = 0.002$, $p > .30$; $F_2(1, 95) = 0.93$, $MSE = 0.006$, *ns*.

In the nonword data, due to the fact that there was a 21 ms advantage for related 1346 primes over the unrelated 1346 primes, there was a nearly significant prime relatedness effect, $F_1(1,23) = 2.73$, $MSE = 960.1$, $p < .15$; $F_2(1,95) = 1.44$, $MSE = 6{,}582.5$, $p > .20$, and a marginally significant prime relatedness by prime type interaction, $F_1(1,23) = 4.00$, $MSE = 749.0$, $p < .06$; $F_2(1,95) = 3.74$, $MSE = 5{,}928.0$, $p < .06$. The prime type effect was not significant, $F_1(1,23) = 0.40$, $MSE = 1{,}567.4$, *ns*; $F_2(1,95) = 0.04$, $MSE = 7{,}281.3$, *ns*. Neither of the main effects nor the interaction approached significance in the error analysis (all Fs < 0.85).

[2] In Experiment 2, all six participants who received the word fiscal in the unrelated transposed-letter prime condition made an error on that word. Thus, this word was removed from the items analyses in all conditions.

TABLE 5
Results from Experiment 2-sandwich primes (reaction times in milliseconds, error rate in percent)

	Related		Unrelated		
Prime type	*Reaction time*	*Error rate*	*Reaction time*	*Error rate*	*Priming effect*
Word data					
1346	547	2.2	602	7.5	55 (5.3)
1436	555	3.6	601	7.3	46 (3.7)
Nonword data					
1346	670	11.1	691	9.6	21 (–1.5)
1436	685	10.3	683	10.3	–2 (0.0)

DISCUSSION

As expected, the sandwich priming technique produced much larger priming effects for the 1346 primes. More importantly, there was now a large priming effect for the 1436 primes. Clearly, these primes can be effective primes. Therefore, their inability to produce significant priming elsewhere does not appear to reflect an inability to activate the lexical representation of their base word.

One point to note is that although there was a difference in the size of the priming effects in the 1346 and 1436 conditions that difference was not large enough to produce a significant interaction. Experiment 3 was designed to provide another empirical examination of the question of whether 1346 primes are more effective than 1436 primes when using a sandwich priming procedure and to test an alternative explanation of the sandwich priming effects for the 1436 primes.

EXPERIMENT 3

Before concluding that 1436 primes truly are effective primes due to the existence of the transposed-letter pair in the middle of the prime, the following alternative explanation needs to be investigated. Given that there was no difference between the effects for 1346 and 1436 primes even when using sandwich priming, one could propose that both of these effects are being driven by the existence of correct end letters in the prime. A simple way to examine this possibility is to determine what degree of priming is produced when the internal letters are not simply transposed, but are instead replaced with a pair of letters not in the target (a 1dd6 condition). If the internal letters are unimportant (regardless of whether they are in the correct order or not), then a 1dd6 prime should produce a level of priming equivalent to that of 1346 and 1436 primes in a sandwich priming experiment, in spite of the 1dd6 primes being a poorer match for the target word according to any current model of letter position coding. Thus, such a condition serves as an effective test of whether the priming observed in the 1436 condition in Experiment 2 was at all related to the fact that the middle letters of the target were in the prime, even though they were not in their appropriate relative positions, or whether the priming effect was due simply to the 1436 primes sharing end letters with their targets.

Method

Participants. Fifty-four undergraduate students from the University of Western Ontario participated in this study. All spoke English fluently and had normal or corrected to normal vision. Participants were compensated with course credit for their time.

Stimuli and design. The stimuli and design used were the same as in Experiments 1 and 2, with the addition of an extra related and corresponding unrelated condition. The extra related condition (1dd6) involved primes having the same initial and final letters as the target word, separated by two letters not in the target (e.g., *cfsn*-COLUMN), while the extra unrelated condition involved a re-pairing of primes and target from the related condition with the restriction that those primes contained four letters that were not in the target (e.g., *vfsr*-COLUMN). (The prediction for the priming effect in the 1dd6 condition according to the simulation is contained in Table 2.) Each target was now primed by 6 different primes and, as a result, there were now 6 stimulus lists and, therefore, 6 groups of participants.

Equipment. The equipment used for this experiment was the same as in Experiments 1 and 2.

Procedure. The procedure, setup of the apparatus and instructions given to participants was the same as that in Experiment 2.

RESULTS

Incorrect responses (4.7% of the word data and 6.8% of the nonword data), as well as response times less than 150 ms or greater than 2,000 ms (0.5% of the word data and 1.1% of the nonword data) were excluded from the analyses. Two (prime relatedness) by three (prime type) ANOVAs by subjects and items were performed on the mean correct latencies and error rates to word and nonword targets. The results from the subject analyses are reported in Table 6. In the word data, there was a significant effect of prime relatedness, ($F_1(1, 53) = 50.61$, MSE = 2,025.8, $p < .001$; $F_2(1, 95) = 56.06$, MSE = 3,283.5, $p < .001$) as latencies were shorter following related primes. The effect of prime type was also significant ($F_1(2, 106) = 7.51$, MSE = 2,192.9, $p < .001$; $F_2(2, 190) = 10.14$, MSE = 4,628.0, $p < .001$). In addition, there was a significant interaction of prime relatedness and prime type ($F_1(2, 106) = 15.57$, MSE = 1,437.3, $p < .001$; $F_2(2, 190) = 13.34$, MSE = 3,259.5, $p < .001$).

In order to examine the interaction, *t*-tests were performed to compare the related and unrelated conditions for each prime type. In the 1346 condition, there was a significant advantage for related primes over unrelated primes, $t(53) = 7.78$, $p < .001$. Likewise, in the 1436 condition, there was a significant advantage for related primes over unrelated primes, $t(53) = 5.00$, $p < .001$. However, in the 1dd6 condition, there was no advantage of the related primes over unrelated primes, $t(53) = 0.65$, *ns.*

In the analysis of error rates, there were significant effects of prime relatedness ($F_1(1, 53) = 6.94$, MSE = 0.003, $p < .025$; $F_2(1, 95) = 9.61$, MSE = 0.005, $p < .01$), and of prime type ($F_1(2, 106) = 2.85$, MSE = 0.004, $p < 0.07$; $F_2(2, 190) = 6.08$, MSE = 0.004, $p < .01$). There was also a marginally significant interaction between prime type and prime relatedness ($F_1(2, 106) = 2.82$, MSE = 0.005, p < .07; $F_2(2, 190) = 2.99$, MSE = 0.005, $p < .06$).

In the nonword data, there were no significant effects of either prime relatedness, $F_1(1, 53) = 1.44$, MSE = 2,867.6, $p > .20$; $F_2(1, 95) = 2.18$, MSE = 6,360.8, $p > .10$, or prime type, $F_1(2, 106) = 2.04$, MSE = 3,546.3, $p > .10$; $F_2(2, 190) = 0.71$, MSE = 14,032.4, *ns.* The interaction was also not significant, $F_1(2, 106) = 1.38$, MSE = 2,467.5, $p > .25$; $F_2(2, 190) = 1.55$,

TABLE 6
Results from Experiment 3-sandwich primes (reaction times in milliseconds, error rate in percent)

	Related		*Unrelated*		
Prime type	*Reaction time*	*Error rate*	*Reaction time*	*Error rate*	*Priming effect*
Word data					
1346	566	6.6	628	6.1	62 (–0.5)
1436	587	2.7	627	6.0	40 (3.3)
1dd6	619	3.8	624	5.8	5 (2.0)
Nonword data					
1346	724	8.9	714	7.2	–10 (–1.7)
1436	741	7.6	725	8.7	–16 (1.1)
1dd6	716	8.4	721	6.5	5 (–1.9)

MSE = 6,289.5, $p > .20$. Neither of the main effects nor the interaction approached significance in the error analysis (all Fs < 0.15).

DISCUSSION

The question addressed in Experiment 3 was whether the end letters in the 1346 and 1436 primes were responsible for the large and equivalent priming effects observed in Experiment 2. To do so, a prime condition was added in which only the end letters were preserved (i.e., 1dd6). The results of Experiment 3 are very clear with respect to this question. When the sandwich priming technique is used, there is little evidence of priming with 1dd6 primes. In contrast, both the 1346 and 1436 conditions continue to produce substantial priming effects. Thus, it seems reasonable to conclude that the similar effects of the 1346 and 1436 primes in Experiment 2 were not simply due to the impact of just the end letters.[3]

As noted earlier, the parameter settings in the simulations reported here were identical to those used in Davis (2010), with the exception of the α_{WL} parameter, which was set to zero. This parameter choice implies that there is no top-down feedback from words to letters (i.e., the model is noninteractive). Previous work by Grainger and Jacobs (1994, 1996) has demonstrated that noninteractive and interactive versions of the interactive activation model can provide equally good accounts of critical data from lexical decision, perceptual identification, and Reicher-Wheeler tasks, and we have used a noninteractive version of the spatial coding model in previous simulations of masked priming (Lupker & Davis, 2009). Davis (2010) compared noninteractive and interactive versions of the model with respect to their ability to explain a broad set of masked priming results, and found that the performance of the model without top-down feedback was virtually identical to performance of the model with top-down feedback. The only noteworthy difference was the tendency of the noninteractive model to underestimate subset priming effects, relative to the interactive model. However, as Davis (2010) noted, although top-down feedback can fit some of the subset priming data better, it achieves this by overwriting activities at the letter level, which may not necessarily be desirable. Davis (2010, p. 751) concluded that "the study of subset priming may be fertile territory for the continuing debate between interactive and noninteractive models of perception".

[3] Unlike in Experiment 2, the difference in the sizes of the priming effects in the 1346 (62 ms) and 1436 (40 ms) conditions in Experiment 3 was large enough to produce a significant interaction when the data were analysed with 1dd6 condition removed, at least in the subject analysis, $F_1(1, 53) = 4.56$, MSe = 1409.7, $p < .05$; $F_2(1, 95) = 3.23$, MSe = 2884.7, $p < .08$.

The present data illustrate these issues nicely. A model with top-down feedback would predict slightly greater priming effects for the 1346 and 1436 primes, which would result in a slightly better fit to the empirical data than that achieved by a model without top-down feedback (contrast the predictions in Table 2 with the results in Tables 5 and 6). However, such a model would also predict a reasonably large sandwich priming effect (of 38 cycles) for 1dd6 primes, a prediction that is substantially at odds with the nonsignificant 5 ms priming effect obtained in Experiment 3. The reason for this prediction is that the combination of sandwich priming with top-down feedback produces a situation where subset primes (even those which share only two letters with the target) trigger a feedback loop. That is, the pre-activation of the target by the sandwich prime leads to top-down feedback signals to the letter nodes, so that the 1dd6 prime is effectively transformed to a 1dd656 prime, which can then further reinforce the activity of the target word node. This mismatch between the prediction of the model for 1dd6 primes and the empirical results provides evidence against the specific form of top-down feedback incorporated in the IA and spatial coding models. The development of a more appropriate implementation of top-down feedback might lead to the creation of a model that neither produces the slight underestimation of subset priming effects observed in the present simulations nor produces the feedback loop problem for 1dd6 primes. Doing so will be a goal of future modelling work.

GENERAL DISCUSSION

The overall purpose of this research was to re-examine the relative position priming constraint reported by Peressotti and Grainger (1999) (see also Grainger et al., 2006). The term "relative position priming constraint" refers to the idea that subset primes produce priming but only if the relative positions of the letters shared by the prime and target are preserved. Experiment 1 essentially replicated the pattern of results Peressotti and Grainger reported, that is, a small but significant priming effect for 1346 primes and a smaller priming effect for 1436 primes. In neither case, however, was there evidence of a significant interaction between prime type and relatedness, consistent with the idea that any difference between the two prime types is quantitative rather than qualitative.

The conclusion that the difference between prime types is quantitative rather than qualitative is further supported by the results of Experiments 2 and 3 as well as the simulations. That is, as shown in these experiments, 1436 primes do produce large priming effects when the sandwich priming procedure is used, indicating that they do activate the lexical representation of their base word. Further, the simulations show that: (1) in a conventional masked priming paradigm, little priming is actually expected from 1436 primes (with slightly more being expected from 1346 primes) due to the impact of lexical competition and (2) large priming effects are expected from both prime types in the sandwich priming paradigm, results completely consistent with the observed data. The more general conclusion, therefore, is that Peressotti and Grainger's (1999) "relative position priming constraint" is not a strict constraint in the sense that transposed-letter subset primes do not prime. It is merely a reflection of the fact that these types of primes are somewhat less effective primes than nontransposed-letter subset primes.

In terms of the newer models of letter position coding, therefore, the results of the present experiments must be regarded as being reasonably supportive of those models, although they do not provide any strong reason to prefer one specific letter position coding scheme over another. Both spatial coding (as employed in the SOLAR model) and open-bigram coding schemes of letter position suggest that there is a relatively high degree of orthographic similarity between both the nontransposed-letter subset primes and the transposed-letter subset primes used in the present experiments and their base words. This fact is consistent with the results showing significant priming effects from both the 1346 and 1436 primes, particularly when sandwich priming is used. If there were a relative position priming constraint of the kind suggested by Peressotti and Grainger (1999), this constraint could potentially cause serious problems for these newer models of letter position coding. The fact that there does not appear to be such a relative position priming constraint indicates that the results from transposed-letter subset priming are not problematic for current models of letter position coding.

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APPENDIX A: WORD AND NONWORD TARGETS

Word targets (Target, 1346 prime, 1436 prime)

ABSENT, aset, aest, ANYHOW, ayhw, ahyw, AUTHOR, athr, ahtr, BEHALF, bhaf, bahf, BEYOND, byod, boyd, BOTHER, bthr, bhtr, BRANCH, banh, bnah, BREATH, beah, baeh, BRIGHT, bigt, bgit, BUNDLE, bnde, bdne, CAMPUS, cmps, cpms, CARBON, crbn, cbrn, CAUGHT, cugt, cgut, CHAPEL, capl, cpal, COLUMN, clun, culn, COMBAT, cmbt, cbmt, COMEDY, cmey, cemy, COUNTY, cuny, cnuy, CREDIT, cedt, cdet, DOUBLE, dubl, dbul, FACTOR, fctr, ftcr, FAMILY, fmiy, fimy, FAMOUS, fmos, foms, FINGER, fngr, fgnr, FISCAL, fscl, fcsl, FLOWER, fowr, fwor, FORMAL, frml, fmrl, FROZEN, fozn, fzon, GARDEN, grdn, gdrn, GATHER, gthr, ghtr, GLANCE, gane, gnae, GROUND, goud, guod, GUILTY, gily, gliy, HATRED, htrd, hrtd, HEIGHT, higt, hgit, HEROIC, hroc, horc, HONEST, hnet, hent, HUNGRY, hngy, hgny, IMPACT, ipat, iapt, INJURY, ijuy, iujy, JACKET, jckt, jkct, JUNGLE, jnge, jgne, LAWYER, lwyr, lywr, LINEAR, lner, lenr, LUMBER, lmbr, lbmr, MANTLE, mnte, mtne, MARBLE, mrbe, mbre, MELODY, mloy, moly, MIGHTY, mghy, mhgy, MINUTE, mnue, mune, MODEST, mdet, medt, MUSCLE, msce, mcse, NORMAL, nrml, nmrl, NUMBER, nmbr, nbmr, OBJECT, ojet, oejt, OBTAIN, otan, oatn, PATROL, ptrl, prtl, PENCIL, pncl, pcnl, PERMIT, prmt, pmrt, PISTOL, pstl, ptsl, POCKET, pckt, pkct, POLICY, pliy, pily, POWDER, pwdr, pdwr, PRISON, pisn, psin, PROFIT, poft, pfot, PUBLIC, pblc, plbc, RANDOM, rndm, rdnm, REFUND, rfud, rufd, RITUAL, rtul, rutl, SAFETY, sfey, sefy, SEARCH, sarh, srah, SECOND, scod, socd, SELDOM, sldm, sdlm, SENIOR, snir, sinr, SHADOW, sadw, sdaw, SILENT, slet, selt, SILVER, slvr, svlr, STREAM, srem, serm, STRONG, srog, sorg, STUDIO, sudo, sduo, STUPID, supd, spud, SUBTLE, sbte, stbe, SWITCH, sith, stih, TONGUE, tnge, tgne, UPWARD, uwad, uawd, VISUAL, vsul, vusl, VOLUME, vlue, vule, WARMTH, wrmh, wmrh, WEALTH, walh, wlah, WEAPON, wapn, wpan, WHISKY, wisy, wsiy, WISDOM, wsdm, wdsm, WITHIN, wthn, whtn, WONDER, wndr, wdnr, WORTHY, wrty, wtry

Nonword targets

APURDI, ARNUSD, ASIPED, AVERNO, BAFMOD, BISTOR, BOFNIT, BRASTI, BUDITA, BURKIN, BALURD, CALURD, CIBROT, CILTAR, CIPNUR, COLPAR, CRIDAR, CUDRIP, CURNEY, CUWALP, DIBLOP, FALPOD, FANTID, FILDAR, FINORK, FLUGAM, FRASIP, FULGOR, FUDSIM, GAVIST, GINWEB, GLESPA, GURDIT, GUSTUP, HINROV, HIPARD, HOBNIT, HORDAN, HUDOIN, ILTANS, IVRAST, JIBART, JULTOD, LIESAN, LINTAD, LOSIND, MALDIN, MENART, MEOR-AD, MESNIT, MINPOD, MISARD, MURANT, NILAST, NURGLE, OMAREP, OMRAND, PALNOR, PALROD, PERKIL, PERNIK, PUSARD, PIDNAK, POSLIN, PRANDK, PREDUN, PRENSK, RIBANT, RIDLEY, RUSANT, SILRED, SAMTID, SENRUL, SHINTA, SIFANT, SIFTEV, SLUDAF, SLURTA, SREDIN, SRENAP, STILVA, SULCEN, SURVIN, SUVANT, TRANSU, ULSANT, VENKOR, VUGARD, WANIST, WEDRAL, WILTOD, WINUSP, WINSED, WALNTI, WUGNAT, WURLID