Position Flexibility Across Letters and Morphemes

A thesis submitted by

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In partial fulfillment of the requirements for the degree of

Master of Science

in

Psychology

Tufts University

August 2015

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Abstract

This study examines position information for letters and morphemes in visual word recognition. Experiment 1 investigates letter position at morpheme boundaries in vowel-initial and consonant-initial suffixed words using the transposed letter (TL) priming effect. Results of the masked prime lexical decision task show a TL priming advantage for vowel-initial suffixed words and consonant-initial suffixed words across the morpheme boundary. In our exploration of morpheme position, Experiments 2 and 3 evaluate three theories of suffix position coding: categorical coding (suffixes are only recognized following a root), coarse coding (suffixes are recognized equally well in a range positions) and gradient coding (suffixes are more likely to be recognized the closer they are to the end of the root). Experiment 2 compares latency to reject nonwords with real suffixes appearing as either the final, medial, or initial syllable (e.g., *forgetment*, *formentget*, *mentforget*) to those with orthographically similar control suffixes (e.g., *forgetmant*, *formantget*, *mantforget*). Experiment 3 replicates Experiment 2 but uses orthographically dissimilar control suffixes (e.g., *forgetponk*, *forponkget*, *ponkforget*). In both experiments suffixes are only recognized in word-final position, supporting the categorical theory of suffix position coding.

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Introduction

Vast amounts of research have examined whether morphologically complex words are parsed during recognition or whether they are represented as whole words. However, the question of how morphemes are recognized in written comprehension in terms of position has not been closely examined. This thesis addresses two main questions about position information in relation to morphology. First, how is letter position coded with respect to morphemes? Letter position information is necessary to distinguish between anagrams like *cat*/*act* and *houseboat*/*boathouse*, suggesting that precision in position coding is critical. There is evidence that this precision is not necessary for coding letters within monomorphemic words, but when it comes to multimorphemic words, however, the literature is mixed on whether morpheme boundaries interact with the letter position coding process. Experiment 1 addresses this issue using a more conservative set of stimuli than previous literature. Second, we investigate how morpheme position itself is coded. Specifically, we explore whether suffix recognition is flexible or position-specific in Experiments 2 and 3.

Word Recognition

Psycholinguistic theories of word recognition generally involve three major levels of processing: pre-lexical, lexical, and post-lexical. In the pre-lexical stage, basic visual features like lines and curves in different orientations are detected. This information about basic features is combined into abstract letter identities where letters that have the same identity are represented as the same, despite differing in surface features such as case, font, and size (Besner, Coltheart, & Davelaar, 1984). Some researchers have also argued for intermediate stages that include processing allographic structural representations (Schubert & McCloskey, 2013). Identification for these abstract letter identities likely occurs in parallel for letters within the same word

(Stevens & Grainger, 2003; Tydgat & Grainger, 2009). Position information for these abstract letter identities is also a critical aspect of this stage for identifying words. The letter detection system is supposed to be retinally position-specific at first, and then transformed into a relative ordering coding scheme dependent on the surrounding letters in the word (Grainger & Holcomb, 2009; Grainger & Van Heuven, 2003). From this pre-lexical orthographic level, activation spreads to corresponding phonological units according to the bi-modal interactive-activation model (BIAM; Grainger & Holcomb, 2009) as well as to the lexical level of processing where whole words become activated. Following this stage, semantic meaning is activated in post-lexical processing. Furthermore, it is well established that these stages are interactive; the levels provide cascading activation from one to the next, as well as feedback activation from later stages to earlier stages allowing for top-down information to influence lower-level processing (McClelland & Rumelhart, 1981). Regardless of the differences between different theories of word recognition, these three basic stages are consistent throughout.

Morphology.

Morphologically complex words are made up of multiple units of meaning, or morphemes. They take the form of prefixed words (e.g., *mislabel*), suffixed words (e.g., *helpful*), and compound words (e.g., *notebook*) in English. Morphology is thought to be represented at the lexical level of processing, but there is also a question of morphological representation at the orthographic stage of processing. The possible representations are either as whole words (e.g., <HELPFUL>), decomposed into separate morphemes (e.g., <HELP><FUL>), or a combination of both representations. The following section details how morphologically complex words are processed at the orthographic level of word recognition.

The four main theories of morphological processing are the obligatory decomposition account, the supralexical account, the form-then-meaning account, and the hybrid model (see Beyersmann, Coltheart, & Castles, 2012 for a review).

Obligatory decomposition suggests that everything that appears like a separate morpheme gets parsed, whether it is a true morpheme or not (e.g., decompose both the suffixed word *darkest* and the pseudosuffixed word *glossary*; Taft, 2003). In favor of obligatory decomposition, Rastle, Davis, and New (2004) showed that suffixed words prime their root (e.g., *cleaner-CLEAN*) equally as well as monomorphemic words that appear to be suffixed but are not (e.g., *corner-CORN*). However the monomorphemic orthographic controls (e.g., *brothel-BROTH*) did not prime, suggesting that the advantage for the suffixed and pseudosuffixed words is not a result of lexical priming, but orthographic decomposition. This result implies that we must have an *–er* suffix unit at the orthographic level, where groupings of '*er*' are parsed as an independent unit despite the lack of morphological meaning, as in *corner*. This, along with a number of other studies (Fruchter & Marantz, 2015; Fruchter, Stockall, & Marantz, 2013; Taft & Forster, 1975), is evidence that anything that appears multimorphemic will necessarily get decomposed.

The supralexical account suggests that the whole word is accessed and then decomposition occurs based on true morphological boundaries (e.g., decompose the suffixed word *darkest*, but not the pseudosuffixed word *glossary*; Giraudo & Grainger, 2001). Giraudo and Grainger (2001) examined masked priming of derived French suffixed words to compare whether multimorphemic words are decomposed before whole-word representations are accessed, or after. They predicted that if multimorphemic words are decomposed first, then a root should prime a suffixed target better than another derived suffixed word with the same root, because the suffixed word would require the extra step of decomposition, (e.g., *balai-*

BALAYAGE, equivalent to *clean*-*CLEANER* in English, > *balayeur*-*BALAYAGE*, equivalent to *cleanness*-*CLEANER*) where an unrelated monomorphemic prime is the baseline condition (e.g., *guitare*-*BALAYAGE*; equivalent to *wallet*-*CLEANER*). However, they found the reverse (e.g., *cleanness*-*CLEANER* > *clean*-*CLEANER*) suggesting that multimorphemic words are not decomposed first, supporting the whole-word then decomposition account. To further rule out the hypothesis of decomposition before whole-word access, the authors had to test if a root simply becomes active regardless of whether the following letters are a suffix or not. In Experiment 2, Giraudo and Grainger (2001) compared a derived suffixed word prime to a pseudoroot word prime. They found more facilitation for the suffixed word prime than the pseudoroot prime (e.g., *laitage*-*LAITIER*, equivalent to *cleanness*-*CLEANER* > *laitue*-*LAITIER*, equivalent to *surface*-*SURFER*), further supporting the theory that whole words are accessed before decomposition occurs (Lukatela, Gligorijević, Kostić, & Turvey, 1980; Manelis & Tharp, 1977).

The form-then-meaning account suggests that there is obligatory decomposition at first, and then a lemma level that further reduces inflected forms (e.g., *fell*) into their infinitive forms (e.g., *fall*; Crepaldi, Rastle, Coltheart, & Nickels, 2010). Finally, the hybrid model suggests that both the obligatory decomposition account and the supralexical account occur in parallel (Diependaele, Sandra, & Grainger, 2009).

Letter Position Coding

Theories of Letter Position Coding.

There are several different theories of letter position encoding. Slot-coding associates each letter with a single position; for example, *speak* would be S_1, P_2, E_3, A_4, K_5 which differs from *peaks* as P_1, E_2, A_3, K_4, S_5. This system was first used in the Interactive Activation Model, proposed by McClelland and Rumelhart (1981), and has been implemented in several other models since then (Dual Route Cascaded model, Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; multiple read out model, Grainger & Jacobs, 1996). The model contains a separate set of nodes of all 26 English letters for each possible letter position within the word. The identity of each letter in each position is recognized independently from each other. Similarly, the noisy slot model (Norris, Kinoshita, & van Casteren, 2010; an extension of the Bayesian Reader, Norris, 2006) and the noisy channel model (Norris & Kinoshita, 2012) adapt the concept of one letter per slot, but in a coarse way by assuming that visual perception is ambiguous and that readers are optimal Bayesian decision makers (see also the Overlap model, Gomez, Ratcliff, & Perea, 2008).

The Wickelcoding scheme of letter position coding takes surrounding context into account by incorporating neighboring letters in the form of triplets. Wickelgren (1969) originally proposed the Context-Sensitive Associative Theory for speech production in which elementary motor responses are coded in relation to the context directly before and after the phoneme in question. For example, *speak* would be coded as *_sp*, *spe*, *pea*, *eak*, *ak_*, where _ is a word boundary. Rumelhart and McClelland (1986) and Seidenberg and McClelland (1989) both adopted a version of this theory for their models of learning past tenses of English verbs and visual word recognition and naming, respectively.

Open-bigram models also take surrounding context into account. These models propose that letter position is coded with ordered letter pairs, called bigrams, that span across 0-2 letter positions (Grainger & Van Heuven, 2003; Schoonbaert & Grainger, 2004; Whitney, 2001; Whitney & Berndt, 1999). For example, *speak* would be *sp*, *se*, *sa*, *pe*, *pa*, *pk*, *ea*, *ek*, *ak*; however, *sk* would not be among the list because that pair spans 3 letters. A unique assumption about open-bigram models is that there is a distinct sublexical level of processing containing these bigram units, whereas none of the other theories of letter position coding make this assumption. One instantiation of the open-bigram model is the SERIOL model in which bigrams have continuous activations where adjacent letter bigrams have higher activations and distant letter bigrams have lower activations (Whitney, 2001; Whitney & Berndt, 1999), while other models have binary bigram activations (Grainger & Van Heuven, 2003; Schoonbaert & Grainger, 2004).

Finally, there is spatial coding, instantiated in the SOLAR model (Davis, 1999, 2010), named for the spatial patterns of activity that are produced. In this model, position for each word is coded by a distinct pattern of activation across 26 letter units, meaning that a word's orthographic representation is a vector of 26 elements with values ranging from 0 to 1. Repeated letters are handled with a latch field level of processing where each letter node has four latch nodes allowing a single letter to appear up to four times in one word. The activation pattern is proposed to decrease from left to right across a word with the highest activation on the left and lowest on the right. For example, for the word *speak*, *s* would have the highest activation, and then *p*, then *e*, and so on in decreasing levels of activation. Word recognition occurs by comparing this unique pattern to previously learned patterns stored in the lexicon. If the pattern is similar but not exact, as in the nonword *sepak*, closely matched words like *speak* and *speck* will receive partial activation.

Position Flexibility.

Position information for each letter is critical for successfully identifying a word, but it turns out we can also be quite flexible in this regard. It is now well established that a word with two transposed letters (TL; e.g., *jugde*) will prime its base word (e.g., *JUDGE*) in a masked lexical decision task better than a prime with two substituted letters (SL; e.g., *jupte*), despite both cases having an equal number of correct letters in the correct positions. Furthermore, the TL version primes the base word equally as well as an identity prime (e.g., *judge*) and the SL version primes better than an unrelated control word (e.g., *chair*; Adelman et al., 2014; Beyersmann et al., 2012; Christianson, Johnson, & Rayner, 2005; Duñabeitia, Perea, & Carreiras, 2007; Forster, Davis, Schoknecht, & Carter, 1987; Perea & Carreiras, 2006; Rueckl & Rimzhim, 2011; Sánchez-Gutiérrez & Rastle, 2013). This effect, referred to as the transposed letter prime advantage (Lupker, Perea, & Davis, 2008), is typically measured as the difference in reaction time between the SL prime and the TL prime. This means that the factors that influence either TL or SL priming will affect the advantage of TL over SL.

There are a variety of findings supporting the robustness as well as the fragility of the TL prime advantage. The TL effect has been established for a range of different languages, including English (Rueckl & Rimzhim, 2011), Spanish (Perea & Lupker, 2004; Sánchez-Gutiérrez & Rastle, 2013), Basque (Perea & Carreiras, 2006), and French (Schoonbaert & Grainger, 2004). There is evidence that the TL effect is stronger with long words (i.e., 7 letters) than short words (i.e., 5 letters; Schoonbaert & Grainger, 2004), and that it disappears for very short words (i.e., 4 letters; Humphreys, Evett, & Quinlan, 1990). Additionally, the TL effect can span across nonadjacent letters where there is one letter in between (e.g., *caniso*-*CASINO*; Perea & Lupker, 2004; see Carreiras, Vergara, & Perea, 2007 for support using ERPs).

There have been mixed reports on whether the consonant-vowel status of the transposed letters plays a role. Lupker et al. (2008) compared nonadjacent transpositions of vowels (e.g., *anamil*-*ANIMAL*) and consonants (e.g., *aminal*-*ANIMAL*), to their respective substitutions. They found priming for the consonant condition, but not for the vowel condition in English words, replicating a previous study that examined the same question using Spanish words (Perea &

Lupker, 2004). However, Rueckl and Rimzhim (2011) compared CC (e.g., *teahcer-TEACHER*) and VC (e.g., *spekaer-SPEAKER*) transpositions and found no difference.

More so, there is evidence for stronger priming for word-internal transpositions over word-final and word-initial transpositions using sentence reading times (Rayner, White, Johnson, & Liversedge, 2006) and word fixation times (Johnson, Perea, & Rayner, 2007). Perea and Lupker (2003) addressed this by comparing the difference between TL and SL internal primes (e.g., TL: *uhser-USHER*; SL: *ufner-USHER*) to the difference between TL and SL final primes (e.g., TL: *ushre-USHER*; SL: *ushno-USHER*). The authors found in Experiment 1, a stronger TL prime effect word-internally (30 ms) than word finally (13 ms).

Because the TL prime advantage is most often a comparison between the reaction times to a TL prime (e.g., *jugde-JUDGE*) and an SL prime (e.g., *jupte-JUDGE*), effects of the SL prime can modulate the overall effect. In Experiments 2 and 3 of the same study described above, Perea and Lupker (2003) compared word-internal and word-final priming between TL and SL primes (e.g., TL: *uhser-USHER*; SL: *ufner-USHER*) to priming between TL and unrelated orthographic control primes (e.g., *bausn-USHER*). They found priming for both word-internal and word-final transpositions (TL primes) when the baseline was an unrelated orthographic control, but not for both conditions when the baseline was a SL prime—not because the TL condition was slow, but because the SL condition was quick. They found that the TL primes were essentially the same for word-internal (M = 562 ms) and word-final changes (M = 560 ms), but the SL conditions differed much more depending on the location of the change (word-internal: M = 584 ms, word-final: M = 571 ms). This resulted in significant priming for the word-internal comparison (22 ms difference), but not for the word-final comparison (11 ms difference) because the SL final RT was markedly faster than the SL internal condition. However there was no priming difference when using unrelated orthographic controls as the baseline measure (Internal unrelated control: *M* = 584 ms, prime 22 ms; Final unrelated control: *M* = 579 ms; prime 19 ms). The authors replicated this pattern in their third experiment using longer words as their stimuli. Perea and Lupker (2003) suggest that the SL final < SL internal result (e.g., *ushno-USHER* < *ufner-USHER*) is a product of left-to-right processing in word recognition. That is, *ushno* shares the first three letters with *USHER*, where *ufner* shares the first, fourth, and fifth letters. In left-to-right processing, the early letters benefit from longer processing times, and thus SL final primes that have more overlap in the beginning of the word have more time to activate the target word, producing greater facilitation than SL internal primes (Perea & Lupker, 2003). Duñabeitia et al. (2007) also found a similar pattern of results in Basque and Spanish for the SL across-boundary primes (e.g., *escohcro-ESCOMBRO*) in all three of the experiments they present. These findings emphasize the importance to consider TL priming in the context of the baseline measure (i.e., SL primes).

Only several of the letter position coding models described above can account for TL prime advantage (Davis & Bowers, 2006). The amount of facilitation from a prime on a target is determined by the amount of overlap between the mental representation of the prime and the mental representation of the target. In order to observe the TL advantage over SL primes, the position coding schemes must encode position in such a way that the TL prime is more similar to the target than the SL prime. Both the slot-coding scheme and Wickelcoding are unable to account for this priming effect. The slot-coding scheme is unable to accommodate these results because a TL prime and a SL prime share an equal number of identical slots, making them equally similar to the base word, and thus no different as primes. Wickelcoding is also a poor predictor of the TL prime advantage because the TL prime and the SL prime also share an equal number of triples that match the target. For example, using the TL prime *sepak* and the SL prime *sigak* for *SPEAK*, the triples are *_se*, *sep*, *epa*, *pak*, *ak_* and *_si*, *sig*, *iga*, *gak*, *ak_* respectively. But both primes only share one triplet with the target word made up of *_sp*, *spe*, *pea*, *eak*, *ak_* making them equally poor primes.

Conversely, open-bigram coding and spatial coding are both flexible enough to account for the TL prime advantage. In open-bigram models, a TL prime shares more bigrams to the target word than an SL prime because it shares more correct letter identities with the base word than the SL prime. For example, the bigrams for *sepak* and *sigak* are *se*, *sp*, *sa*, *ep*, *ea*, *ek*, *pa*, *pk*, *ak* and *si*, *sg*, *sa*, *ig*, *ia*, *ik*, *ga*, *gk*, *ak* respectively. Compared to the bigrams for *SPEAK*, *sp*, *se*, *sa*, *pe*, *pa*, *pk*, *ea*, *ek*, *ak*; the TL prime shares eight bigrams while the SL prime shares only two bigrams, making the TL version a superior prime. Spatial coding can also predict the TL priming behavioral data because the pattern of activation from the target word will always have more overlap with a TL prime than a SL prime. For example, the word *speak* would have an activation pattern where *s* has the highest activation, *p* the next highest, and so on, where all letters that are not represented in the word have an activation of 0. The TL prime *sepak* would have a very similar pattern, where only *p* and *e* differ slightly and the remaining letters are the same, whereas the SL prime *sigak* would have matching activations for *s*, *a*, and *k*, but very different activations for *p*, *e*, *i*, and *g*. Overall, only open-bigram models and spatial coding can account for the TL prime advantage.

Letter Coding and Morphology.

A TL priming effect across a morpheme boundary (e.g., *cololress-COLORLESS* < *colobmess-COLORLESS*) could have several implications. If there is a TL prime advantage across a morpheme boundary, then letter position coding does not interact with morphology, and this could happen for a few reasons. One possibility is that the mechanism that maps letter position onto orthographic representations occurs separately from morphemic decomposition and therefore is not disrupted by morpheme boundaries. Another possibility is that letter position coding is flexible enough that it occurs simultaneously with or after morphemic decomposition, but is still not disrupted across a morpheme boundary. A third possibility, posited by Beyersmann et al. (2012) is that there is no word boundary at all between morphemes to block the effect, suggesting a whole-word representation for multimorphemic words.

If the TL prime advantage does not occur across a morpheme boundary, then letter position coding does interact with morphological information. This would imply that letter position coding occurs simultaneously with or after decomposition of a multimorphemic word. Priming would be weakened in this case based on the previously described evidence that TL priming is weaker when it occurs word-finally or word-initially compared to word-internally (Perea & Lupker, 2003). In addition to seeing whether the difference between TL and SL is significant, the findings previously described by Perea and Lupker (2003) highlight the need to examine whether a lack of priming is due to a slow TL reaction time or an abnormally fast SL reaction time.

Many researchers have examined the TL prime advantage at morpheme boundaries. There has been evidence suggesting that a TL priming effect cannot span a morpheme boundary. Duñabeitia et al. (2007) found a lack of TL priming across morpheme boundaries in Basque and Spanish. Using a masked-prime lexical decision task, they compared transpositions and substitutions across morpheme boundaries (Experiment 1, Basque; Experiment 2, Spanish; e.g., TL: *mesoenro*-*MASONERO*, SL: *mesoasro*-*MESONERO*) and within morpheme boundaries (Experiment 3, Spanish; TL: *meosnero*-*MASONERO*, SL: *meurnero*-*MESONERO*) and found a

TL prime advantage only when the transposition occurred within the morpheme, but not across the boundary. As previously mentioned, however, the lack of priming for cross-boundary transpositions was due to a relatively fast SL condition, rather than a slow TL condition. Additionally, Christianson et al. (2005) used a masked-prime naming task[1] to examine transpositions across morpheme boundaries for compounds (Experiments 1 and 2) and *–er* suffixed words (Experiment 3). Experiment 2 replicated the findings from Experiment 1 but used stricter control stimuli. In Experiment 2, they compared latencies for identity primes (e.g., *airport-AIRPORT*), cross-boundary TL primes (e.g., *aiprort-AIRPORT*), and cross-boundary SL primes (e.g., *aignort-AIRPORT*) for compounds and noncompounds. Christianson et al. (2005) found that cross-boundary TL primes were significantly slower than identity primes, but significantly faster than cross-boundary SL primes (e.g., *airport-AIRPORT* < *aiprort-AIRPORT* < *aignort-AIRPORT*) for compounds, while the noncompounds showed no difference between identity primes and TL primes, though both of these were significantly faster than SL primes (e.g., *sarcasm-SARCASM* = *sacrasm-SARCASM* < *sansasm-SARCASM*). These authors interpreted this result as evidence that morpheme boundaries interact with the TL priming effect. In Experiment 3, the authors used *–er* suffixed target words and compared identity primes (e.g., *boaster-BOASTER*), cross-boundary TL primes (e.g., *boasetr-BOASTER*), and cross-boundary single substituted letter primes (e.g., *boasler-BOASTER*) and found that both the TL and SL

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[1] Christianson et al. (2005) chose to use a masked-prime naming task instead of the typical masked-prime lexical decision task because they argue that word frequency influences naming latencies less than lexical decision latencies (Balota & Chumbley, 1984).

primes had equally slow responding times, both of which were significantly slower than the identity primes. Christianson et al. (2005) describe this as evidence that the TL prime advantage interacts with morpheme boundaries. Luke and Christianson (2013) find the same pattern of results in English *–ed* inflected verbs using a self-paced reading and masked priming procedure where the target word is embedded in a sentence and latency to continue to the next word is measured. One explanation for the lack of priming across morpheme boundaries could be differences in reading speed (Duñabeitia, Perea, & Carreiras, 2014). Duñabeitia et al. (2014) that when they divided their participants in half based on overall reaction time, they found TL within-boundary priming (e.g., *vioilnista-VIOLINISTA* < *vioatnista-VIOLINISTA*) and no TL across-boundary priming (e.g., *violiinsta-VIOLINISTA* = *violiersta-VIOLINISTA*) for faster readers, but equal priming in both conditions for the slow readers (Duñabeitia et al., 2014).

Most of the research, however, has found evidence supporting a TL priming effect across morpheme boundaries, thus suggesting that TL priming does not interact with morpheme boundaries. Rueckl and Rimzhim (2011) compared identity primes (e.g., *speaker-SPEAKER*), TL within-morpheme primes (e.g., *spekaer-SPEAKER*), TL across-morpheme primes (e.g., *speaekr-SPEAKER*), and triple substituted letter primes (e.g., *speifur-SPEAKER*; Experiments 4 and 5). They found priming for the identity and both TL primes compared to the triple SL primes suggesting that morpheme boundaries do not affect the TL prime advantage. This has been replicated numerous times in English with suffixes (Beyersmann et al., 2012; Beyersmann, McCormick, & Rastle, 2013), prefixes (Masserang & Pollatsek, 2012), English-Spanish cognates with English and Spanish speakers (Sánchez-Gutiérrez & Rastle, 2013), and compounds in Basque (Perea & Carreiras, 2006).

Most of these studies examine suffix boundaries, however one major issue with these studies, particularly the ones that support that letter position coding does not interact with morpheme boundaries, has been the usage of primarily vowel-initial suffixes in their stimuli. There are 15 experiments described in eight articles that use suffixed words to investigate the TL prime advantage across morpheme boundaries. Of these 15, three did not provide the enough information to determine which affixes they used. From the remaining 12 experiments, vowel-initial suffixes were used for 100% of the stimuli in nine of the experiments, and 93%, 77%, and 67% of the stimuli in the remaining three experiments. A full list of these studies can be found in Table 1.

This lack of consonant-initial suffixes is problematic because suffixes that begin with vowels tend to appear more like monomorphemic words than consonant-initial suffixes due to their consonant-vowel structure. Consonant-initial suffixed words are more likely to have a consonant cluster at the morpheme boundary, resulting in a bigram trough (Seidenberg, 1987). This bigram trough could be an additional cue that consonant-initial suffixed words are morphologically complex, which is lacking in vowel-initial suffixed words. Because vowel-initial suffixed words do not have this cue, they may be more likely to have whole-word long-term representations, meaning that they do not have morpheme boundaries. If vowel-initial suffixed words do not have morpheme boundaries, then a TL prime effect should easily occur across the root and suffix because there is no true morpheme boundary in the lexical representation to block the effect. Another possible issue for primarily only using vowel-initial suffixed words is that vowels and consonants have been shown to interact differently with the TL priming effect. Perhaps it is the case that previous studies found priming across the morpheme boundary because transpositions with vowels are better than transpositions with consonants.

However, this is an unlikely possibility because there is evidence that the reverse is true where consonants prime well but vowels do not (Perea & Lupker, 2004).

Experiment 1

This study addresses the gap in the literature in which nearly all of the multimorphemic stimuli used in TL prime studies use vowel-initial suffixes. By comparing consonant-initial and vowel-initial suffixed words, this study provides a more conservative test of the TL priming effect across morpheme boundaries in suffixed words. This study will allow us to determine whether 1) methodologically, consonant-initial suffixes and vowel-initial suffixes produce different results in transposed letter priming studies, and 2) provide insight into the relationship between letter position coding and morphology. The design and some stimuli are derived from Experiment 2 of Beyersmann et al. (2012) and Experiment 1b of Sánchez-Gutiérrez and Rastle (2013).

This study tests whether the process of letter position assignment does or does not interact with morphological information. If letter position assignment *does* interact with morphological information, then there will be no TL prime advantage across morpheme boundaries for at least some types of multimorphemic words (i.e., multimorphemic words that have decomposed orthographic representations—consonant-initial suffixed words). This theory suggests that letter position assignment must occur at the same time as or after a word is decomposed into separate morphemes. It would also suggest that the previous studies that have obtained the TL prime advantage across morpheme boundaries must have used stimuli that did not truly have decomposed representations, suggesting that the commonly used vowel-initial suffixed stimuli must have whole-word representations.

Conversely, if letter position assignment *does not* interact with morphemes, then we would predict that there should be a TL prime advantage for both vowel-initial and consonant-initial suffixed words. This theory would imply that letter position assignment occurs separately from decomposition. Technically, the result of finding the TL prime advantage for both vowel-initial and consonant-initial suffixed words could also be consistent with the first theory that letter position assignment does interact with morphological information, but that the stimuli used here do not block the TL prime advantage because both vowel-initial and consonant-initial suffixed words are represented as wholes. However, since it is not clear what other types of suffixed words could possibly prevent the TL prime advantage, this would be even stronger evidence that letter position assignment does not, in fact, interact with morphemes.

Methods

Participants.

One hundred twenty-five Tufts University undergraduate students participated in this study for course credit or monetary compensation. Two participants were excluded as non-native English speakers, and three were excluded because they had already participated ($N = 120$, 85 females).

Design and materials.

A list of 120 bimorphemic words was created composed of 60 consonant-initial suffixed words and 60 vowel-initial suffixed words. There were 14 consonant-initial suffixes (i.e., *-dom*, *-ful*, *-hood*, *-less*, *-let*, *-ling*, *-ly*, *-ment*, *-ness*, *-ry*, *-ship*, *-some*, *-ward*, *-wise*) and 19 vowel-initial suffixes (i.e., *-able*, *-al*, *-ate*, *-ation*, *-ee*, *-en*, *-er*, *-ess*, *-est*, *-ian*, *-ic*, *-ion*, *-ism*, *-ist*, *-ity*, *-ive*, *-ize*, *-ous*, *-y*). Thirty-five of the vowel-initial suffixed words came directly from Experiment 2 of Beyersmann et al. (2012), the remaining 25 vowel-initial suffixed words came directly from the

English suffixed stimuli in Sánchez-Gutiérrez and Rastle (2013). The consonant-initial and vowel-initial lists are matched on whole word log frequency (Consonant-initial: $M = 6.63$, $SD = 1.86$; Vowel-initial: $M = 6.97$, $SD = 1.55$), root log frequency (Consonant-initial: $M = 9.68$, $SD = 1.93$; Vowel-initial: $M = 9.19$, $SD = 1.88$), number of root letters (Consonant-initial: $M = 5.40$, $SD = 1.24$; Vowel-initial: $M = 5.20$, $SD = 1.09$), number of root phonemes (Consonant-initial: $M = 4.22$, $SD = 1.08$; Vowel-initial: $M = 4.50$, $SD = 1.13$), and number of root syllables (Consonant-initial: $M = 1.50$, $SD = 0.60$; Vowel-initial: $M = 1.67$, $SD = 0.57$; all p-values are $> .05$); there are no duplicates of any root. Importantly, the consonant-initial and vowel-initial lists did differ by average bigram sum of the two letters spanning the morpheme boundary (Consonant-initial: $M = 1899.95$, $SD = 3135.57$; Vowel-initial: $M = 3636.40$, $SD = 2778.28$; $t(118) = -3.21$, $p = .002$).

Primes were created by manipulating the type of change, either transposing two adjacent letters (TL) or substituting two adjacent letters (SL), and the location of the change, either within the root, or across root and suffix, resulting in four prime conditions for each target word (e.g., for target COLORLESS, TL across: *cololress*, SL across: *colobmess*, TL within: *cloorless*, SL within: *chuorless*). Changes within the first morpheme occurred at the 2nd and 3rd letter positions, and changes across morphemes occurred at the last letter of the root word and the first letter of the suffix. As in Sánchez-Gutiérrez and Rastle (2013), all substituted letters were matched for consonant/vowel status, ascending consonants (i.e., letters that extend above the middle line of text; e.g., *f*, *h*, *t*), and descending consonants (i.e., letters that extend below the bottom line of text; e.g., *g*, *j*, *p*). Furthermore, all SL primes matched the CV structure of their corresponding TL primes. For example, the SL prime *colobmess* matches the CV structure of the TL prime *cololress* rather than the base word *COLORLESS*. This is important because it ensures that all TL and SL primes are equally different from the base word in terms of overall shape and CV pattern. A full list of the experimental stimuli can be found in Appendix A.

An additional list of 120 nonwords was created as filler targets. These were nonword roots combined with the same suffixes as the real words; they were matched with the real roots on letter length and number of phonemes. Four prime conditions were created for these nonwords using the same method described for the words. Furthermore, a set of 24 practice stimuli was created in the same fashion.

The four prime conditions (i.e., TL across, SL across, TL within, SL within) were divided evenly to make four lists of mixed prime types. Each participant saw a variety of different prime types, and saw each of the 240 targets only once.

Procedure.

This procedure is based on Sánchez-Gutiérrez and Rastle (2013). Participants were seated at a computer and instructed to indicate whether the word on the screen is a real English word, by pressing ‘p,’ or not a real word, by pressing ‘q.’ They were encouraged to respond as quickly and accurately as possible.

For each trial, a blank screen appeared for 700 ms, a forward mask (i.e. ############) appeared for 500 ms in the center of a white screen, the prime appeared in lower case, size 36, black Geneva font for either 50 ms or 67 ms[2], immediately followed by the target word which

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[2] This variation is due to imprecision in SuperLab loading times interacting with screen refresh rates. Both 50 ms and 67 ms are well within the range of previously used prime durations (Beyersmann et al., 2012; Sánchez-Gutiérrez and Rastle, 2013).

appeared in upper case letters until a response was made or 3000 ms passed, then the next trial began. Participants completed a practice block of 24 trials, and then two experimental blocks with a one-minute break between blocks. The order of the trials was randomized. The study took approximately 10-15 minutes to complete all 264 trials.

Results

One participant was removed for not meeting the accuracy threshold of 75%; the remaining average accuracy was 94.5% (*SD* = 3.8%). Only trials with reaction times between 200 ms and 2000 ms[3] were included in the analysis, resulting in removal of 6.2% of the data. Reaction times were transformed using the inverse transformation to improve normality. Group means can be seen in Figure 1.

We computed a repeated-measures ANOVA with three factors: suffix type (consonant-initial, vowel-initial), letter change location (within morpheme, across morphemes), and letter change type (TL, SL). The analysis of reaction times (RTs) revealed no main effect of suffix type ($F_1(1, 118) = 1.33$, $p = .251$, n.s.; $F_2(1, 118) = 0.06$, $p = .809$, n.s.). There was a significant main effect of letter change location by subjects ($F_1(1, 118) = 4.47$, $p = .037$, $\eta^2 = .001$), but not by items ($F_2(1, 118) = 1.53$, $p = .219$, n.s.). Most importantly, there was a significant main effect of letter change type ($F_1(1, 99) = 37.62$, $p < .001$, $\eta^2 = .009$, $F_2(1, 118) = 14.67$, $p < .001$, $\eta^2 = .014$), in which overall TL primes (*M* = 655 ms, *SD* = 115 ms) elicited faster RTs than SL primes (*M* = 672 ms, *SD* = 108 ms). Finally, there were no significant interactions (Suffix type * Change

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[3] It is worthwhile to note that a wide variety of reaction time cutoff points have been used in the literature. Our particular cutoff points were chosen as relatively conservative boundaries.

type: $F_1(1, 118) = 1.57$, $p = .212$, n.s.; $F_2(1, 118) = 0.30$, $p = .585$, n.s.; Suffix type * Location: $F_1(1, 118) = 0.01$, $p = .918$, n.s.; $F_2(1, 118) = 0.20$, $p = .564$, n.s.; Change type * Location: $F_1(1, 118) = 0.00$, $p = 1.00$, n.s.; $F_2(1, 118) = 0.09$, $p = .760$, n.s.; Suffix type * Change type * Location: $F_1(1, 118) = 0.84$, $p = .362$, n.s.; $F_2(1, 118) = 0.44$, $p = .511$, n.s.). Accuracy ratings did not differ between consonant-initial and vowel-initial conditions ($t(118) = 0.28$, $p = .781$, n.s.).

Discussion

A difference between the TL and SL conditions suggests that there is a TL prime advantage occurring in which real words that are primed with a TL nonword are verified as words faster than if they had been primed with a SL nonword. The vowel-initial suffix conditions follow this pattern no matter whether the change in letters occurs within the stem or at the morpheme boundary, replicating previous findings by Beyersmann et al. (2012) and Sánchez-Gutiérrez and Rastle (2013). The consonant-initial suffix conditions also follow this pattern where TL primes elicit faster RTs than SL primes, both within the morpheme boundary, and across it. This overall TL prime advantage implies that letter position coding does not interact with morphological information for both vowel-initial and consonant-initial suffixed words.

This result has several possible explanations. One option is that letter position coding is not disrupted by morpheme boundaries because it occurs as a separate process. A second possibility is that letter position coding occurs at the same time as, or after morphemic decompositions, but is so flexible that this morpheme boundary does not disrupt the TL prime advantage. A final option is that both vowel-initial and consonant-initial suffixed words are represented as whole words, and thus there is no true morpheme boundary present to cause any disruption. This reasoning is in line with the conclusion made by Beyersmann et al. (2012) who argued that this supported the hybrid model of morphological processing which involves simultaneous access to whole multimorphemic words and their decomposed morphemes.

Morpheme Position Coding

We've just seen that letter position coding is incredibly flexible, but what about morpheme position coding? In reading, we come across all types of combinations of morphemes. There are stems (e.g., *help*), suffixed words (e.g., *helpful*), words with multiple suffixes (e.g., *helpfulness*), compounds (e.g., *notebook*), suffixed compounds (e.g., *notebookless*), and the list goes on. When reading these words, it is important to be able to recognize that *–ful* is the same in *helpfulness* as in *helpful* despite appearing word-medial in the former and word-final in the latter. The purpose of this study is to investigate the extent of flexibility of morpheme position coding in visual word perception.

There is already evidence suggesting that stems are very flexible in their position coding. Crepaldi, Rastle, Davis, and Lupker (2013) concluded that stems are position independent. Using rejection latencies in a lexical decision task in Experiment 1, they found that nonwords made from transposing a compound word (e.g., *applepine*) were rejected as real English words slower than control nonwords made by substituting one constituent of the compound (e.g., *baconpine*). Additionally, using a masked prime lexical decision task in Experiments 2 and 3, they showed that switched morpheme primes facilitated responding for their correctly spelled compound targets (e.g., *moonhoney-HONEYMOON*) better than switched syllable primes and their correctly spelled monomorphemic targets (e.g., *rickmave-MAVERICK*). This suggests that the real compound words (e.g., *pineapple, honeymoon*) are activated despite the reversed morphemes. The authors propose that these results indicate that the stems of a compound are not tied to a particular position; they have flexible position coding.

Suffix position coding has also been investigated using the morpheme interference effect (Taft & Forster, 1975). The morpheme interference effect suggests that nonwords with morphological structure are more difficult to reject as real words—that is, they seem more like real words—than nonwords without morphological structure. This was demonstrated by Caramazza, Laudanna, and Romani (1988) who found slower rejection latencies for nonwords composed of nonword stems and real suffixes (e.g., *biyed*) compared to nonword stems and control suffixes (e.g., *biyel*). More so, they found slower rejection latencies for real stems and suffixes (e.g., *buyed*) compared to real stems and control suffixes (e.g., *buyel*). No matter the lexical status of the stem, targets with real suffixes are rejected slower than targets without real suffixes.

By exploiting the morpheme interference effect, Crepaldi, Rastle, and Davis (2010) provide evidence that suffix position coding is completely position dependent. Crepaldi et al. (2010) replicated the morpheme interference effect by showing that adding a suffix to existing stems to create nonwords (e.g., *gasful*) makes them slower to reject as words than adding a non-morphological syllable (e.g., *gasfil*). Critically, however, they demonstrate that when the suffix is word-initial (e.g., *fulgas*), it is no more word-like than the matched control (e.g., *filgas*). This finding suggests that identifying a suffix as a morphological unit requires that it appear at the end of a word, therefore, they conclude that suffix recognition is position dependent. Crepaldi, Hemsworth, Davis, and Rastle (2015) further supported this theory using a masked prime lexical decision task. These authors first established that nonword primes facilitate responding to targets with the same suffix compared to nonword primes with other suffixes or nonmorphological suffixes (e.g., *sheeter-TEACHER* < *sheetal-TEACHER* = *sheetub-TEACHER*). Based on this result, they tested the same stimuli but reversed the morphemes in the primes (e.g., *ersheet-*

TEACHER) to determine if the suffixes could be recognized word-initially. They found no facilitation for primes with word-initial suffixes, suggesting that suffixes can only be recognized to the right of the root (Crepaldi et al., 2015).

How inflexible is suffix position coding? One drawback of the studies by Crepaldi et al. (2010) and Crepaldi et al. (2015) is that the degree of position-dependence cannot be discerned from their data because they only test two positions—word-final and word-initial. Is it necessary for a suffix to appear categorically at the end of the word to be recognized as a morphologically rich unit? Or is suffix position coding more flexible?

There are several possibilities for the representations of suffix positions. It may be the case that suffixes are only recognized as suffixes if they categorically appear at the end of a word. For example, *–er* is recognized as a suffix in the word *farmer*, but not in the word *error*, because it occurs in word-initial position. If suffixes were categorically position-dependent, then there would have to be separate morpho-orthographic representations for *–ful* in *helpful* as in *helpfulness* because the morpheme *–ful* is not in word-final position in *helpfulness*. To accommodate for this, there must be a separate *–fulness* representation. This theory postulates that suffix position coding is truly inflexible and rigid.

Another theory is that suffix position is coded more flexibly. There are two possibilities within this theory: gradient coding and coarse-grained coding. Gradient coding would mean that suffixes are more easily recognized as real suffixes the closer they appear to word-final position. Therefore, in the word *helpfulness*, *–ness* would be easily recognized as a morphological unit because it is at the end of the word, followed by *–ful* because it is only one morpheme away from word-final position. Furthermore, it may not necessarily be the word-final feature that is critical, perhaps instead the location as right-of-stem is more important. Coarse-grained coding would suggest that suffixes are recognized equally well in a range of positions except for word-initial position. In *helpfulness*, *–ful* and *–ness* are equally easy to identify as individual suffixes, but the *er* in *error* is still not easily mistaken as a suffix because it appears in word-initial position. Both of these possibilities suggest that suffix position is coded flexibly.

One way this position information can be represented is at the orthographic level of processing. Assuming there are inherent morphological units at this level, each suffix would have its own unit. For the suffix units, there could be a modifier that categorically indicates that the unit needs to appear at the end of a word to be considered a morphological suffix. Alternatively, the modifier could indicate in a flexible fashion that a suffix is more easily recognized as it approaches the right edge of a word, or that it must not appear in word-initial position.

Experiment 2

This experiment addresses the rigid versus flexible question for suffix position coding using nonwords with disyllabic rather than monosyllabic roots in which the suffix appears in each syllable position (e.g., *forgetment*, *formentget*, *mentforget*) compared to control suffixes (e.g., *forgetmant*, *formantget*, *mantforget*). Following the procedure of Experiment 1 in Crepaldi et al., (2010), response time latencies and error rates in a lexical decision task will measure how word-like or not a nonword is based on how long it takes to reject the stimulus as a real English word.

If position information is categorically represented, the morpheme interference effect should be observed only when the suffix is at the end of the word (e.g., *forgetment* > *forgetmant*, but *formentget* = *formantget* and *mentforget* = *mantforget*). If suffix position is coded coarsely, morpheme interference may be observed in both word-final and word-medial positions (e.g., *forgetment* > *forgetmant*, *formentget* > *formantget*, but *mentforget* = *mantforget*). Lastly, if position is represented gradiently, the morpheme interference effect should be observed in more than one position but will decrease in magnitude with distance from the final position. We predict the pattern of error rates will follow the pattern of reaction times, regardless of the theory.

Methods

Participants.

Fifty-one Tufts University undergraduate students participated in this study for course credit or monetary compensation. Three participants were not native English-speakers and were excluded, resulting in *N* = 48 (38 females).

Design and materials.

This study employed a 2 (suffix type: suffix, control) x 3 (position: word-initial, word-medial, word-final) repeated measures design, where reaction time (RT; latency to reject the nonword) and error rate (classifying nonwords as words) were measured.

A list of 96 nonwords was compiled by combining real disyllabic monomorphemic words with suffixes. For each word, six versions were created (subscripts indicate stem syllable): $Stem_1$+$Stem_2$+Suffix, $Stem_1$+Suffix+$Stem_2$, Suffix+$Stem_1$+$Stem_2$, $Stem_1$+$Stem_2$+Control, $Stem_1$+Control+$Stem_2$, Control+$Stem_1$+$Stem_2$. Each suffix was used with six different roots, all combinations were morphotactically and phonotactically legal, and all real suffixes and control suffixes were drawn from Crepaldi et al. (2010). The control suffixes were one letter off from their matched real suffixes (e.g., *–mant* was the matched control for the real suffix *–ment*). As in Crepaldi et al. (2010), suffixes were paired with stems so that syntactic legality was maintained. The nonwords containing real suffixes had a higher mean log bigram frequency (MLBF) than the nonwords containing control suffixes (Real: *M* = 3.55, *SD* = 0.16; Control: *M* = 3.52, *SD* = 0.17;

$F(1, 570) = 4.68$, $p = .031$) due to the bigram frequencies of the real vs. control affixes. Critically, MLBF did not differ by position (Initial: $M = 3.52$, $SD = 0.17$; Medial: $M = 3.53$, $SD = 0.16$; Final: $M = 3.56$, $SD = 0.16$; $F(2, 570) = 2.81$, $p = .061$). The number of orthographic neighbors did not differ by affix type (calculated over the whole word; Real: $M = 0.01$, $SD = 0.10$; Control: $M = 0.01$, $SD = 0.10$; $F(1, 570) = 0.0$, $p = 1.0$) or position (Initial: $M = 0.01$, $SD = 0.10$; Medial: $M = 0.00$, $SD = 0.00$; Final: $M = 0.02$, $SD = 0.14$; $F(2, 570) = 2.01$, $p = .134$); and the average orthographic Levenshtein distance to the first neighbor did not differ by affix (Real: $M = 2.77$, $SD = 0.68$; Control: $M = 2.79$, $SD = 0.69$; $F(1, 570) = 0.07$, $p = .787$; Yarkoni, Balota, & Yap, 2008). A full list of experimental stimuli can be found in Appendix B.

An additional 96 real multimorphemic words, 96 real monomorphemic words, and 96 monomorphemic nonwords were added as fillers so that morphological structure would not be an obvious part of the experiment. The word fillers matched the experimental stems on letter length, syllable number, MLBF, and orthographic neighborhood size as in Crepaldi et al. (2010). A set of 12 practice stimuli was also created.

Six experimental lists were created so that each participant would see each root once, each suffix in each position once, and each matched control in each position once.

Procedure.

The study followed an unprimed lexical decision task procedure. Each trial began with a blank screen displayed for 700 ms. The target word then appeared in upper case in the center of the screen until a response was made or 3000 ms elapsed, and then the next trial began. Participants were instructed to press “p” if the word was real and “q” to indicate a nonword. The study was broken into two blocks with a one-minute break in the middle. Participants took approximately 15-20 minutes to complete 396 trials.

Results

All trials were removed with reaction times less than 200 ms or greater than 2000 ms from the data set (1.48% of the total data set). Furthermore, no participants were removed for poor accuracy (*M* = 93%, *SD* = 3%). Group means of reaction time and error rates are graphed in Figure 2. The Greenhouse-Geisser correction was used when the assumption of sphericity was violated (Greenhouse & Geisser, 1959).

Reaction times were transformed using the inverse transformation to improve normality. A repeated-measures ANOVA based on RTs revealed a main effect of suffix type that was marginally significant by subjects ($F_1(1, 47) = 3.87$, $p = .055$, $\eta^2 = .002$) and not significant by items ($F_2(1, 570) = 1.48$, $p = .225$, n.s.). There was also a significant main effect of suffix position ($F_1(2, 94) = 150.37$, $p < .001$, $\eta^2 = .125$; $F_2(2, 570) = 50.94$, $p < .001$, $\eta^2 = .150$), and an interaction of suffix type and position that was significant by subjects ($F_1(2, 94) = 10.62$, $p < .001$, $\eta^2 = .008$) and marginally significant by items ($F_2(2, 570) = 2.48$, $p = .085$, $\eta^2 = .007$). Post-hoc analyses indicated that suffixed nonwords were rejected more slowly than control nonwords in word-final position ($t(47) = -4.32$, $p < .001$), but just as quickly in word-medial position ($t(47) = 0.71$, $p = .483$, n.s.) and word-initial position ($t(47) = 0.46$, $p = .646$, n.s.). Additionally, rejection latencies increased from left to right for nonwords with real suffixes (Initial vs. Medial: $t(47) = -3.35$, $p = .002$; Medial vs. Final: $t(47) = -10.88$, $p < .001$; Initial vs. Final: $t(47) = -12.03$, $p < .001$) and nonwords with control suffixes (Initial vs. Medial: $t(47) = -3.74$, $p < .001$; Medial vs. Final: $t(47) = -7.00$, $p < .001$; Initial vs. Final: $t(47) = -10.53$, $p < .001$).

The analysis of error rates revealed the exact same pattern as the RTs. The main effects of suffix type ($F_1(1, 47) = 103.12$, $p < .001$, $\eta^2 = .083$; $F_2(1, 570) = 45.38$, $p < .001$, $\eta^2 = .050$)

and suffix position were significant ($F_1(1.15, 53.96) = 137.35$, $p < .001$, $\eta^2 = .380$; $F_2(2, 570) = 100.41$, $p < .001$, $\eta^2 = .221$), as was the interaction between suffix type and position ($F_1(1.62, 54.63) = 96.67$, $p < .001$, $\eta^2 = .169$; $F_2(2, 570) = 45.45$, $p < .001$, $\eta^2 = .100$). Post-hoc analyses revealed that suffixed nonwords were mistaken for real words more often than control nonwords in word-final position ($t(47) = -10.55$, $p < .001$), but equally as often word-medially ($t(47) = -0.12$, $p = .91$, n.s.) and word-initially ($t(47) = 0.57$, $p = .57$, n.s.). Lastly, the rate of errors increased significantly from left to right for both nonwords containing real suffixes (Initial vs. Medial: $t(47) = -3.37$, $p = .001$; Medial vs. Final: $t(47) = -12.11$, $p < .001$; Initial vs. Final: $t(47) = -13.12$, $p < .001$) and control suffixes (Initial vs. Medial: $t(47) = -2.23$, $p = .031$; Medial vs. Final: $t(47) = -4.29$, $p < .001$; Initial vs. Final: $t(47) = -4.95$, $p < .001$).

Discussion

The patterns of both RTs and error rates replicated the findings of Crepaldi et al. (2010), observing a morphological interference effect for suffixes in word-final but not word-initial position. Most importantly, we found no difference between rejection latencies or error rates between words with real and control suffixes in word-medial position, implicating that suffixes are categorically position-dependent, in line with the logic from Crepaldi et al. (2010). Furthermore, this pattern of results is inconsistent with flexible theories of suffix position coding because both coarse-coding and gradient theories would predict a morpheme interference effect at word-medial position.

One possible issue in this study is that the null result for the medial position might be caused by the specific control suffixes drawn from Crepaldi et al. (2010). The control suffixes are all orthographic neighbors of real suffixes (e.g., -*ment* and -*mant*, -*ful* and -*fil*) to ensure that as many aspects of orthographic processing are controlled across conditions as possible.

However, the orthographic similarity may have inadvertently led real suffixes to become partially activated when control suffixes were viewed. This activation would lead to inhibited rejection latencies, and potentially mask a morpheme interference effect in word medial position. This concern was addressed in Experiment 3.

Experiment 3

This study provides a replication for Experiment 2 but under more strict circumstances by utilizing orthographically dissimilar control suffixes (e.g., *forgetponk*, *forponkget*, *ponkforget*).

Methods

Participants.

Forty-nine native English-speaking Tufts University undergraduate students participated in this study for course credit (29 females).

Design and materials.

The design and materials were identical to Experiment 1 except for the control suffixes. New control suffixes were created that were pronounceable nonsense letter strings, matching the real suffixes on letter length, syllables, consonant/vowel structure, mean bigram frequency, and orthographic neighborhood. Crucially, they were orthographically dissimilar to the real suffixes; 11/16 control suffixes shared no letters with their corresponding suffix while the remaining five shared one letter in the same position (e.g., the control for *–ment* was *–ponk*). As in Experiment 2, the nonwords containing real suffixes had a higher MLBF than the nonwords with control suffixes (Real: $M = 3.55$, $SD = 0.16$; Control: $M = 3.52$, $SD = 0.16$; $F(1, 570) = 5.50$, $p = .019$), but this did not differ by position (Initial: $M = 3.52$, $SD = 0.16$; Medial: $M = 3.53$, $SD = 0.15$; Final: $M = 3.55$, $SD = 0.16$; $F(2, 570) = 1.98$, $p = .139$, n.s.). Additionally, these nonwords did not differ across affix in the number of orthographic neighbors (calculated over the whole word;

Real: *M* = 0.01, *SD* = 0.10; Control: *M* = 0.01, *SD* = 0.10; *F*(1, 570) = 0.0, *p* = 1.00, n.s.) or orthographic Levenshtein distance to the first neighbor (Real: *M* = 2.77, *SD* = 0.68; Control: *M* = 2.87, *SD* = 0.69; *F*(1, 570) = 3.41, *p* = .065, n.s.). A full list of experimental stimuli can be found in Appendix C.

Procedure.

The procedure was the same as Experiment 2.

Results

We removed all trials with reaction times less than 200 ms or greater than 2000 ms from the data set (2.45% of the total data set). Furthermore, one participant did not meet the 75% accuracy threshold and was thus removed, resulting in *N* = 48. The remaining participants had an average accuracy rate of 93% (*SD* = 3%). Group means of reaction time and error rates are graphed in Figure 3. As before, inverse transformed RTs were analyzed and the Greenhouse-Geisser correction was used when the assumption of sphericity was violated.

The results were very similar to Experiment 2. For RTs, significant main effects of suffix type ($F_1(1, 47) = 24.32$, $p < .001$, $\eta^2 = .016$; $F_2(1, 569) = 13.09$, $p < .001$, $\eta^2 = .018$) and position were found ($F_1(2, 94) = 84.62$, $p < .001$, $\eta^2 = .129$; $F_2(2, 569) = 47.65$, $p < .001$, $\eta^2 = .134$) as well as a significant interaction between suffix type and position ($F_1(2, 94) = 31.52$, $p < .001$, $\eta^2 = .037$; $F_2(2, 569) = 17.33$, $p < .001$, $\eta^2 = .049$). Post-hoc analyses showed that suffixed nonwords were rejected more slowly than control nonwords in word-final position ($t(47) = -7.88$, $p < .001$), but just as quickly in word-medial position ($t(47) = 1.04$, $p = .306$, n.s.) and word-initial position ($t(47) = -0.55$, $p = .586$, n.s.), replicating Experiment 2. Also as before, rejection latencies significantly increased across each position for nonwords with real suffixes (Initial vs. Medial: $t(47) = -3.92$, $p < .001$; Medial vs. Final: $t(47) = -8.64$, $p < .001$; Initial vs. Final: $t(47) =$

-12.81, $p < .001$). For nonwords with control suffixes, word-initial rejection latencies were significantly faster than word-medial ($t(47) = -5.48$, $p < .001$) and word-final position ($t(47) = -6.64$, $p < .001$), but RTs for word-medial and word-final position did not differ significantly ($t(47) = -0.36$, $p = .77$, n.s.).

In the error rate analysis, significant main effects of suffix type ($F_1(1, 47) = 86.17$, $p < .001$, $\eta^2 = .108$; $F_2(1, 570) = 79.39$, $p < .001$, $\eta^2 = .079$) and position were observed ($F_1(1.21, 56.84) = 89.98$, $p < .001$, $\eta^2 = .285$; $F_2(2, 570) = 104.89$, $p < .001$, $\eta^2 = .209$), as well as a significant interaction between suffix type and position ($F_1(1.44, 67.73) = 125.77$, $p < .001$, $\eta^2 = .197$; $F_2(2, 570) = 72.46$, $p < .001$, $\eta^2 = .144$). Suffixed nonwords were incorrectly judged as real words more often than control nonwords in word-final position ($t(47) = -11.74$, $p < .001$), but not in word-medial ($t(47) = -1.76$, $p = .085$, n.s.) or word-initial position ($t(47) = 1.35$, $p = .184$, n.s.), replicating Experiment 2. As before, error rates for nonwords with real suffixes increased across positions (Initial vs. Medial: $t(47) = -2.60$, $p = .012$; Medial vs. Final: $t(47) = -11.45$, $p < .001$; Initial vs. Final: $t(47) = -11.35$, $p < .001$). Error rates for nonwords with control suffixes did not differ between word-initial and word-medial position ($t(47) = 0.09$, $p = .929$, n.s.) but word-final error rates were significantly higher than word-medial ($t(47) = -2.45$, $p = .018$) and word-initial position ($t(47) = -2.66$, $p = .011$).

To determine if there was a difference between the orthographically similar control suffixes from Experiment 2 and the dissimilar control suffixes in Experiment 3, we also ran a three-way ANOVA with experiment as a between-subjects factor and position and suffix type as within-subjects factors for error rate and RT. For the error rate analysis, there was only a significant main effect of suffix ($F(1, 94) = 185.23$, $p < .001$, $\eta^2 = .095$), main effect of position ($F(1.18, 111.07) = 223.44$, $p < .001$, $\eta^2 = .332$), and an interaction between suffix and position

($F(1.33, 169.33) = 219.89$, $p < .001$, $\eta^2 = .182$). For the RT analysis, we found a main effect of suffix ($F(1, 94) = 23.41$, $p < .001$, $\eta^2 = .006$), a main effect of position ($F(2, 188) = 222.90$, $p < .001$, $\eta^2 = .123$), and no main effect of experiment ($F(1, 94) = 0.92$, $p = .341$, n.s.). In terms of interactions, there was a two-way interaction between suffix and experiment ($F(1, 94) = 4.02$, $p = .048$, $\eta^2 = .001$), a two-way interaction between position and experiment ($F(2, 188) = 4.85$, $p = .009$, $\eta^2 = .003$), a two-way interaction between suffix and position ($F(2, 188) = 39.81$, $p < .001$, $\eta^2 = .018$), and a three way interaction between suffix, position, and experiment ($F(2, 188) = 3.43$, $p = .034$, $\eta^2 = .002$). This three-way interaction shows that the difference in word-final position is greater in Experiment 3 using dissimilar controls than in Experiment 2 using similar controls.

Discussion

We find support for truly rigid position coding of suffixes. As in Experiment 2, we find that suffixed nonwords differ in RT and error rate compared to control nonwords only in word-final position, and not in word-medial or word-initial positions. This suggests that suffixes must be at the end of a word in order for them to be recognized as a true morphological unit. If the suffix appears in any other position, responding does not differ from control nonwords suggesting that they are not recognized any differently from the nonsense syllables that were used as controls.

We find further evidence for inflexible coding of suffix position from the difference in word final position for control suffixes between Experiments 2 and 3. We hypothesized that real suffixes may have been partially activated by the orthographically similar control trials in Experiment 2, slowing rejection latencies. If this were the case and if suffix recognition is truly bound to word-final position, then rejection latencies for orthographically similar control trials in

Experiment 2 should be slower than orthographically dissimilar control trials in Experiment 3, but only in word-final position because the similar control suffixes partially activated real suffixes. This prediction is supported by the significant three-way interaction where experiment is a between-subjects factor. These results suggest that the RT difference between stimuli with real suffixes and dissimilar control suffixes is greater than the difference between stimuli with real suffixes and similar control suffixes.

General Discussion

These experiments explore the extent of position flexibility, or lack thereof, for letters and morphemes. With regard to letter position, Experiment 1 demonstrates great flexibility for letter position coding. TL primes facilitate lexical decision to the target word more than SL primes. We find this difference for multimorphemic words that have vowel-initial suffixes. This suggests that letter position coding is flexible across multimorphemic words that are not easily parsable due to a lack of a bigram trough at the morpheme boundary or are more likely to have whole-word representations in long-term memory. This finding replicates the previous literature that finds the TL prime advantage for suffixed words using primarily vowel-initial suffixes (Beyersmann et al., 2012; Sánchez-Gutiérrez & Rastle, 2013). More importantly, however, we also find the same result for the stricter stimuli set of consonant-initial suffixed words. Again we find that letter position coding is flexible across multimorphemic words that are easily parsable due to a bigram trough at the morpheme boundary or are less likely to have whole-word representations in long-term memory. This experiment provides stricter support that letter position coding does not interact with morpheme boundaries.

Future work on letter position coding is necessary to determine the full extent of position flexibility. This work would involve replications using different letters as substitutions to ensure that this result is not an anomaly of the specific letters chosen as substitutes.

In terms of morpheme position flexibility, Experiments 2 and 3 demonstrate support for the categorical theory of suffix position coding in which a suffix is only recognized word-finally. In Experiment 2, we find the morpheme interference effect for reaction times and error rates only when suffixes appear in word-final (post-root) position, but not word-initially or word-medially, ruling out the flexible theories of suffix position coding. Due to the orthographic similarity between real suffixes and the control suffixes, we suspected the control-suffixed nonwords were partially activating real suffixes. This is problematic because it could induce a weak morpheme interference effect, thereby increasing RTs and masking a difference between the conditions. Experiment 3 resolved this problem by using orthographically dissimilar control suffixes instead of the previously used orthographically similar suffixes in Experiment 2 and in Crepaldi et al. (2010). Results of Experiment 3 replicated the findings from Experiment 2 providing strong evidence that suffix position is represented categorically in English, in line with previous work by Crepaldi et al. (2010), and contrasting with the flexibility in the way that letters and roots are encoded.

Interestingly, there was a clear linear pattern where overall rejection latencies and error rates increased as the suffix neared the right edge of the word, which is in line with the gradient theory of suffix position coding. However, this linear increase was also present in the control suffix conditions, indicating that the effect is not morphological in nature. This pattern may reflect general orthographic (e.g., Davis, 1999; Rastle & Coltheart, 2006; Whitney, 2001) or task-specific left-to-right processing instead.

Future directions involve comparing whether certain suffixes are more position independent than others. There are some suffixes that must appear at the end of words (e.g., *-s*) and there are other suffixes that may themselves be suffixed (e.g., *-ful* as in *forgetfulness*). We would hypothesize that suffixes that can be suffixed should be more flexible than ones that must appear at the end of a word. One way this could be examined is by using other languages that are more morphologically productive, like Turkish, where many suffixes can attach to a single stem at once.

Along similar lines, one may investigate whether stems in English vary in position independence. As previously described, Crepaldi et al. (2013) find evidence that stems are position independent. However, they do not address that some stems might be less position independent than others based on how frequently they occur as the first or last constituent of a compound. In the case of compounds, the two morpheme constituents can either occur equally as often in the first and last position or one morpheme can occur more frequently in one of the two positions (e.g., *sea* appears more frequently as the left constituent of a compound than the right constituent: *undersea* versus *seawater*, *seagull, seashore, seafood, seahorse*, etc.). Furthermore, Libben (2014) argues that compound constituents take on their own positional bound representations (e.g., *-berry* in *blueberry*, *strawberry*, *boysenberry*), separate from the standalone word (e.g., *berry*). Depending on this distribution of position, a stem may be more or less position-independent. The recognition of stems likely depends on its frequency of occurring in a particular position.

References

Adelman, J. S., Johnson, R. L., McCormick, S. F., McKague, M., Kinoshita, S., Bowers, J. S., … Davis, C. J. (2014). A behavioral database for masked form priming. *Behavior Research Methods*, *46*(4), 1052–1067. doi:10.3758/s13428-013-0442-y

Balota, D. A., & Chumbley, J. I. (1984). Are lexical decisions a good measure of lexical access? The role of word frequency in the neglected decision stage. *Journal of Experimental Psychology: Human Perception and Performance*, *10*(3), 340–357. doi:10.1037/0096-1523.10.3.340

Besner, D., Coltheart, M., & Davelaar, E. (1984). Basic processes in reading: Computation of abstract letter identities. *Canadian Journal of Psychology*, *38*(1), 126–134. doi:10.1037/h0080785

Beyersmann, E., Coltheart, M., & Castles, A. (2012). Parallel processing of whole words and morphemes in visual word recognition. *The Quarterly Journal of Experimental Psychology*, *65*(9), 1798–819. doi:10.1080/17470218.2012.672437

Beyersmann, E., McCormick, S. F., & Rastle, K. (2013). Letter transpositions within morphemes and across morpheme boundaries. *The Quarterly Journal of Experimental Psychology*, *66*(12), 2389–2410. doi:10.1080/17470218.2013.782326

Caramazza, A., Laudanna, A., & Romani, C. (1988). Lexical access and inflectional morphology. *Cognition*, *28*(3), 297–332. Retrieved from http://dx.doi.org/10.1016/0010-0277(88)90017-0

Carreiras, M., Vergara, M., & Perea, M. (2007). ERP correlates of transposed-letter similarity effects: Are consonants processed differently from vowels? *Neuroscience Letters*, *419*(3), 219–24. doi:10.1016/j.neulet.2007.04.053

Christianson, K., Johnson, R. L., & Rayner, K. (2005). Letter transpositions within and across morphemes. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *31*(6), 1327–39. doi:10.1037/0278-7393.31.6.1327

Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. *Psychological Review*, *108*(1), 204–256. doi:10.1037/0033-295X.108.1.204

Crepaldi, D., Hemsworth, L., Davis, C. J., & Rastle, K. (2015). Masked suffix priming and morpheme positional constraints. *The Quarterly Journal of Experimental Psychology*, (June), 1–41. doi:10.1080/17470218.2015.1027713

Crepaldi, D., Rastle, K., Coltheart, M., & Nickels, L. (2010). “Fell” primes “fall”, but does “bell” prime “ball”? Masked priming with irregularly-inflected primes. *Journal of Memory and Language*, *63*(1), 83–99. doi:10.1016/j.jml.2010.03.002

Crepaldi, D., Rastle, K., & Davis, C. J. (2010). Morphemes in their place: Evidence for position-specific identification of suffixes. *Memory & Cognition*, *38*(3), 312–21. doi:10.3758/MC.38.3.312

Crepaldi, D., Rastle, K., Davis, C. J., & Lupker, S. J. (2013). Seeing stems everywhere: Position-independent identification of stem morphemes. *Journal of Experimental Psychology: Human Perception and Performance*, *39*(2), 510–525. doi:10.1037/a0029713

Davis, C. J. (1999). *The self-organising lexical acquisition and recognition (SOLAR) model of visual word recognition.* (Unpublished doctoral dissertation.) University of New South Wales.

Davis, C. J. (2010). SOLAR versus SERIOL revisited. *European Journal of Cognitive Psychology*, *22*(5), 695–724. doi:10.1080/09541440903155682

Davis, C. J., & Bowers, J. S. (2006). Contrasting five different theories of letter position coding: Evidence from orthographic similarity effects. *Journal of Experimental Psychology: Human Perception and Performance*, *32*(3), 535–57. doi:10.1037/0096-1523.32.3.535

Diependaele, K., Sandra, D., & Grainger, J. (2009). Semantic transparency and masked morphological priming: the case of prefixed words. *Memory & Cognition*, *37*(6), 895–908. doi:10.3758/MC.37.6.895

Duñabeitia, J. A., Perea, M., & Carreiras, M. (2007). Do transposed-letter similarity effects occur at a morpheme level? Evidence for morpho-orthographic decomposition. *Cognition*, *105*(3), 691–703. doi:10.1016/j.cognition.2006.12.001

Duñabeitia, J. A., Perea, M., & Carreiras, M. (2014). Revisiting letter transpositions within and across morphemic boundaries. *Psychonomic Bulletin & Review*, *21*(6), 1557–1575. doi:10.3758/s13423-014-0609-2

Forster, K. I., Davis, C., Schoknecht, C., & Carter, R. (1987). Masked priming with graphemically related forms: Repetition or partial activation? *The Quarterly Journal of Experimental Psychology*, *39*(2), 211–251. doi:10.1080/14640748708401785

Fruchter, J., & Marantz, A. (2015). Decomposition, lookup, and recombination: MEG evidence for the Full Decomposition model of complex visual word recognition. *Brain and Language*, *143*, 81–96. doi:10.1016/j.bandl.2015.03.001

Fruchter, J., Stockall, L., & Marantz, A. (2013). MEG masked priming evidence for form-based decomposition of irregular verbs. *Frontiers in Human Neuroscience*, *7*(November), 798. doi:10.3389/fnhum.2013.00798

Giraudo, H., & Grainger, J. (2001). Priming complex words: Evidence for supralexical representation of morphology. *Psychonomic Bulletin & Review*, *8*(1), 127–31. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11340857

Gomez, P., Ratcliff, R., & Perea, M. (2008). The overlap model: A model of letter position coding. *Psychological Review*, *115*(3), 577–600. doi:10.1037/a0012667

Grainger, J., & Holcomb, P. J. (2009). Watching the word go by: On the time-course of component processes in visual word recognition. *Language and Linguistics Compass*, *3*(1), 128–156. doi:10.1111/j.1749-818X.2008.00121.x

Grainger, J., & Jacobs, A. M. (1996). Orthographic processing in visual word recognition: A multiple read-out model. *Psychological Review*, *103*(3), 518–565.

Grainger, J., & Van Heuven, W. J. B. (2003). Modeling letter position coding in printed word perception. In P. Bonin (Ed.), *Mental lexicon: "Some words to talk about words"* (pp. 1–23). New York: Nova Science.

Greenhouse, S. W., & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrika*, *24*(2), 95–112.

Humphreys, G. W., Evett, L. J., & Quinlan, P. T. (1990). Orthographic processing in visual word identification. *Cognitive Psychology*, *22*(4), 517–560. doi:10.1016/0010-0285(90)90012-S

Johnson, R. L., Perea, M., & Rayner, K. (2007). Transposed-letter effects in reading: Evidence from eye movements and parafoveal preview. *Journal of Experimental Psychology: Human Perception and Performance*, *33*(1), 209–229. doi:10.1037/0096-1523.33.1.209

Libben, G. (2014). The nature of compounds: A psychocentric perspective. *Cognitive Neuropsychology*, *31*(1-2), 8–25. doi:10.1080/02643294.2013.874994

Lukatela, G., Gligorijević, B., Kostić, A., & Turvey, M. T. (1980). Representation of inflected nouns in the internal lexicon. *Memory & Cognition*. *8*(5), 415-423. doi:10.3758/BF03211138

Luke, S. G., & Christianson, K. (2013). The influence of frequency across the time course of morphological processing: Evidence from the transposed-letter effect. *Journal of Cognitive Psychology*, *25*(7), 781–799. doi:10.1080/20445911.2013.832682

Lupker, S. J., Perea, M., & Davis, C. J. (2008). Transposed-letter effects: Consonants, vowels and letter frequency. *Language and Cognitive Processes*, *23*(1), 93–116.

Manelis, L., & Tharp, D. A. (1977). The processing of affixed words. *Memory & Cognition*, *5*(6), 690–695. doi:10.3758/BF03197417

Masserang, K. M., & Pollatsek, A. (2012). Transposed letter effects in prefixed words: Implications for morphological decomposition. *Journal of Cognitive Psychology*, *24*(4), 476–495. doi:10.1080/20445911.2012.658037.

McClelland, J. L., & Rumelhart, D. E. (1981). An Interactive Activation Model of Context Effects in Letter Perception: Part 1. An Account of Basic Findings. *Psychological Review*, *88*(5), 375–407. doi:10.1037/h0021465

Norris, D. (2006). The Bayesian Reader: Explaining word recognition as an optimal Bayesian decision process. *Psychological Review*, *113*(2), 327–357. doi:10.1037/0033-295X.113.2.327

Norris, D., & Kinoshita, S. (2012). Reading through a noisy channel: Why there’s nothing special about the perception of orthography. *Psychological Review*, *119*(3), 517–545. doi:10.1037/a0028450

Norris, D., Kinoshita, S., & van Casteren, M. (2010). A stimulus sampling theory of letter identity and order. *Journal of Memory and Language*, *62*(3), 254–271. doi:10.1016/j.jml.2009.11.002

Perea, M., & Carreiras, M. (2006). Do transposed-letter effects occur across lexeme boundaries? *Psychonomic Bulletin & Review*, *13*(3), 418–22. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/17048724

Perea, M., & Lupker, S. J. (2003). Transposed-Letter Confusability Effects in Masked Form Priming. In *Masked Priming: The State of the Art* (pp. 97–120).

Perea, M., & Lupker, S. J. (2004). Can CANISO activate CASINO? Transposed-letter similarity effects with nonadjacent letter positions. *Journal of Memory and Language*, *51*(2), 231–246. doi:10.1016/j.jml.2004.05.005

Rastle, K., & Coltheart, M. (2006). Is there serial processing in the reading system; and are there local representations? In S. Andrews (Ed.), *From inkmarks to ideas: Current issues in lexical processing* (pp. 3–24). Hove, UK: Psychology Press.

Rastle, K., Davis, M. H., & New, B. (2004). The broth in my brother's brothel: Morpho-orthographic segmentation in visual word recognition. *Psychonomic Bulletin & Review*, *11*(6), 1090–1098. doi:10.3758/BF03196742

Rayner, K., White, S. J., Johnson, R. L., & Liversedge, S. P. (2006). Raeding wrods with jubmled lettres: There is a cost. *Psychological Science*, *17*(3), 192–193. doi:10.1111/j.1467-9280.2006.01684.x

Rueckl, J. G., & Rimzhim, A. (2011). On the interaction of letter transpositions and morphemic boundaries. *Language and Cognitive Processes*, *26*(4-6), 482–508. doi:10.1080/01690965.2010.500020.On

Rumelhart, D. E., & McClelland, J. (1986). On learning the past tenses of English verbs. In J. L. McClelland & D. E. Rumelhart (Eds.), *Parallel Distributed Processing, Vol. 2*. Cambridge, MA: MIT Press.

Sánchez-Gutiérrez, C., & Rastle, K. (2013). Letter transpositions within and across morphemic boundaries: Is there a cross-language difference? *Psychonomic Bulletin & Review*, *20*(5), 988–96. doi:10.3758/s13423-013-0425-0

Schoonbaert, S., & Grainger, J. (2004). Letter position coding in printed word perception: Effects of repeated and transposed letters. *Language and Cognitive Processes*, *19*(3), 333–367. doi:10.1080/01690960344000198

Schubert, T., & McCloskey, M. (2013). Prelexical representations and processes in reading: Evidence from acquired dyslexia. *Cognitive Neuropsychology*, *30*(6), 360–95. doi:10.1080/02643294.2014.880677

Seidenberg, M. S. (1987). Sublexical structures in visual word recognition: Access units or orthographic redundancy? In M. Coltheart (Ed.), *Attention and performance 12: The psychology of reading* (pp. 245–263). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review*, *96*(4), 523–568. doi:10.1037/0033-295X.96.4.523

Stevens, M., & Grainger, J. (2003). Letter visibility and the viewing position effect in visual word recognition. *Perception & Psychophysics*, *65*(1), 133–151. doi:10.3758/BF03194790

Taft, M., & Forster, K. I. (1975). Lexical storage and retrieval of prefixed words. *Journal of Verbal Learning and Verbal Behavior*, *14*(6), 638–647. Retrieved from http://dx.doi.org/10.1016/S0022-5371(75)80051-X

Tydgat, I., & Grainger, J. (2009). Serial position effects in the identification of letters, digits, and symbols. *Journal of Experimental Psychology: Human Perception and Performance*, *35*(2), 480–498. doi:10.1037/a0013027

Whitney, C. (2001). How the brain encodes the order of letters in a printed word: The SERIOL model and selective literature review. *Psychonomic Bulletin & Review*, *8*(2), 221–243. doi:10.3758/BF03196158

Whitney, C., & Berndt, R. S. (1999). A new model of letter string encoding: Simulating right neglect dyslexia. *Progress in Brain Research*, *121*, 143–163.

Wickelgren, W. A. (1969). Context-sensitive coding, associative memory, and serial order in (speech) behavior. *Psychological Inquiry*, *76*(1), 1–15.

Yarkoni, T., Balota, D., & Yap, M. (2008). Moving beyond Coltheart's N: A new measure of orthographic similarity. *Psychonomic Bulletin & Review*, *15*(5), 971–9. doi:10.3758/PBR.15.5.971

Article		Proportion of Vowel-Initial Suffixes
Beyersmann, Coltheart, & Castles (2012)		
	Exp 2	93%
Beyersmann, McCormick, & Rastle (2013)		
	Exp 1	100%
	Exp 2	100%
	Exp 3	77%
Christianson, Johnson, & Rayner (2005)		
	Exp 3	100%
Duñabeitia, Perea, & Carreiras (2007)		
	Exp 1	Not enough information
	Exp 2	Not enough information
	Exp 3	Not enough information
Duñabeitia, Perea, & Carreiras (2014)		
	Exp 1	67%
Luke & Christianson (2013)		
	Exp 1a	100%
	Exp 1b	100%
Rueckl & Rimzhim (2011)		
	Exp 4	100%
	Exp 5	100%
Sánchez-Gutiérrez, & Rastle (2013)		
	Exp 1a	100%
	Exp 1b	100%

Table 1: Summary of literature investigating TL prime advantage across morpheme boundary of suffixed words.

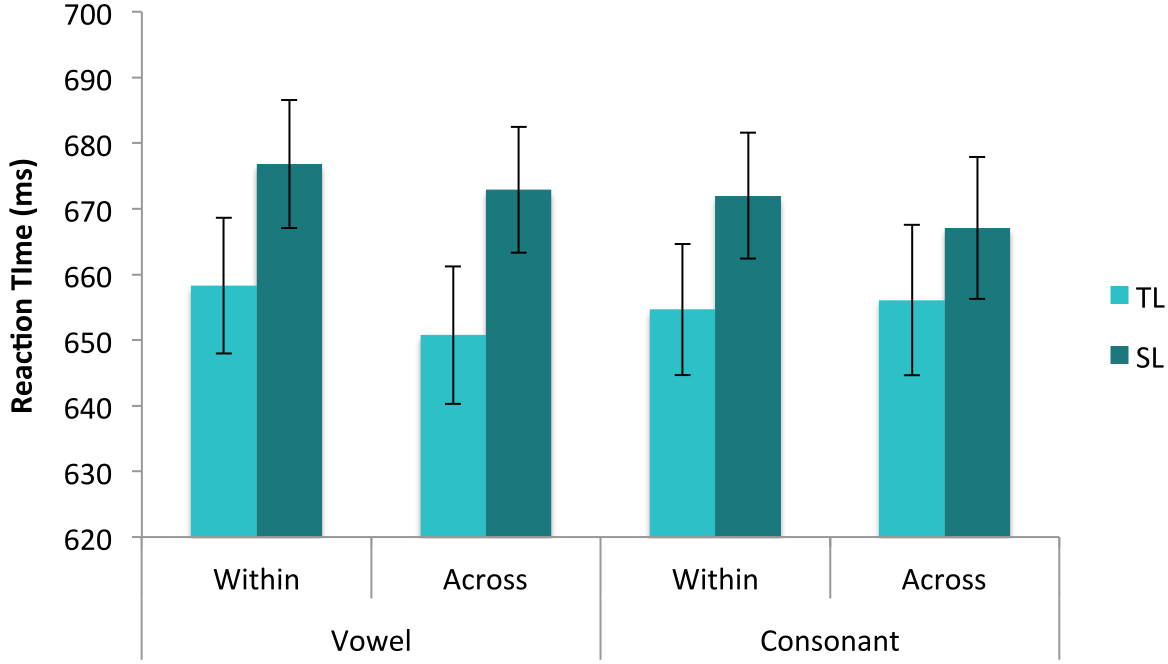

Figure 1: Group means and standard error bars for Experiment 1.

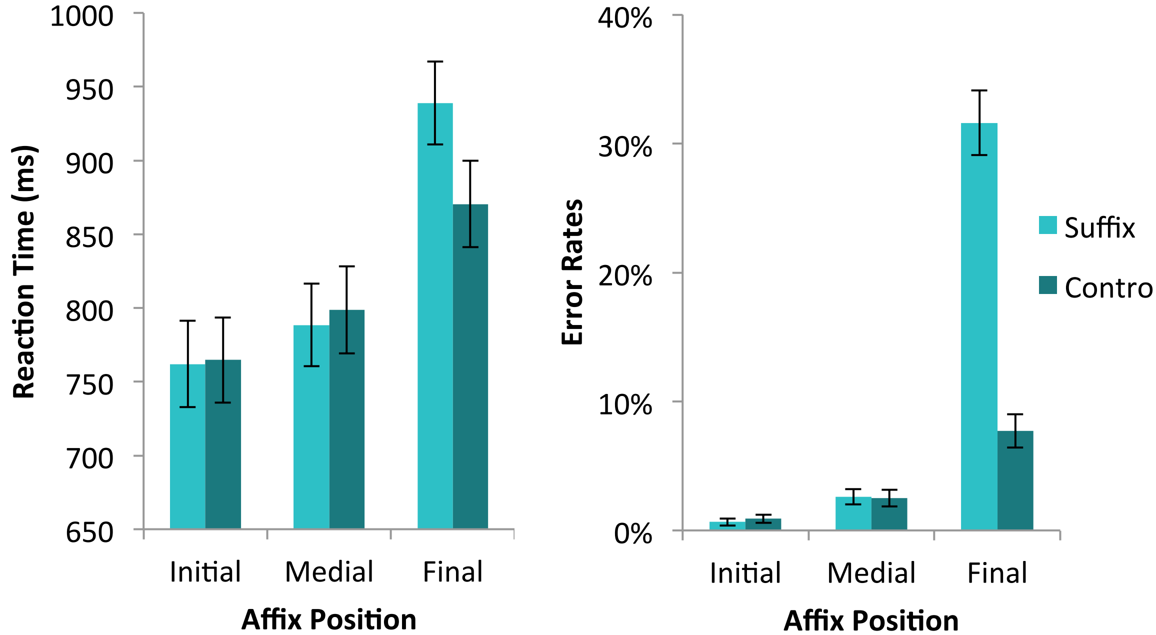

Figure 2: Group means and standard error bars for Experiment 2. Reaction time data is shown on the left, error rate data is shown on the right.

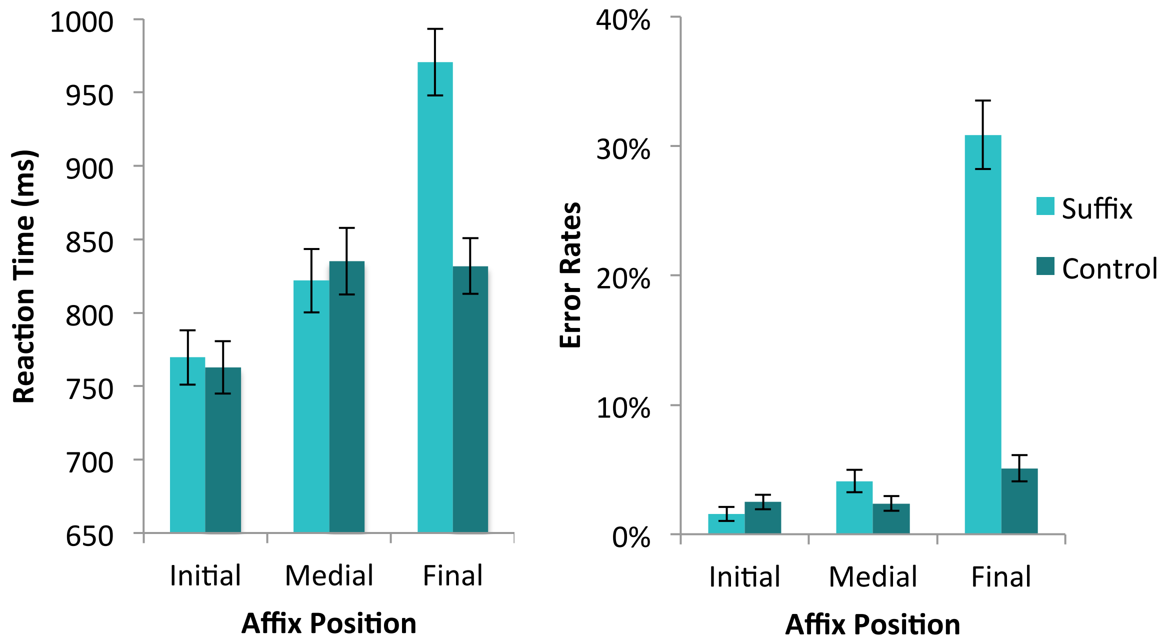

Figure 3: Group means and standard error bars for Experiment 3. Reaction time data is shown on the left, error rate data is shown on the right.

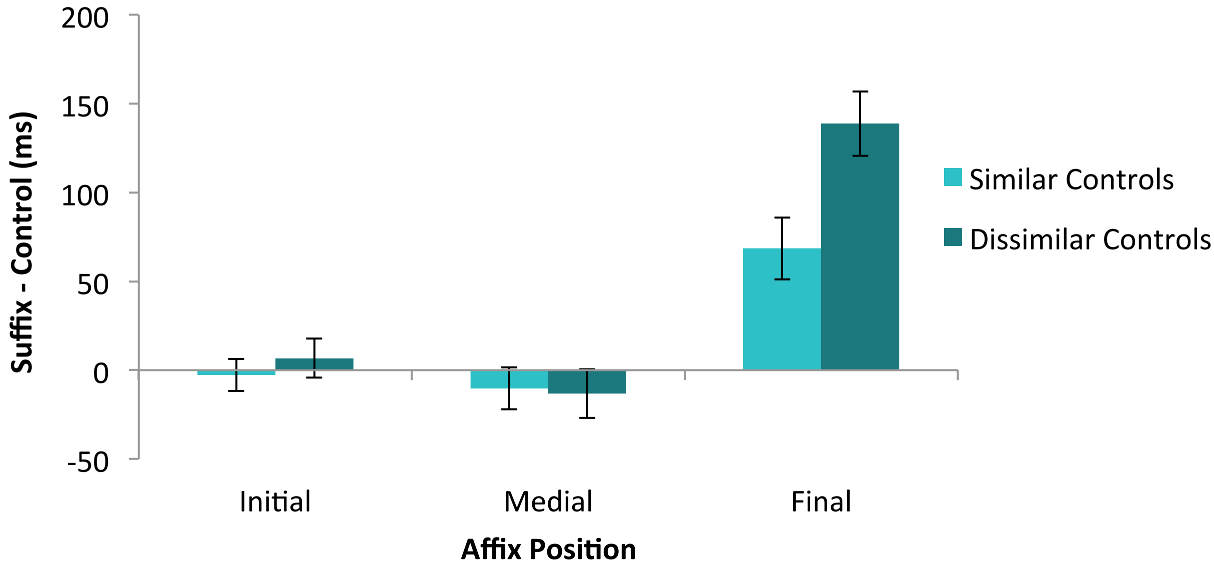

Figure 4: Differences (i.e., real suffix minus control suffix) in reaction time latencies between orthographically similar controls (Experiment 2) and dissimilar controls (Experiment 3).

Appendix A

Critical stimuli for Experiment 1.

Consonant-Initial Suffixed Words

Targets	TL across	TL within	SL across	SL within
ABRUPTLY	abruplty	arbuptly	abrupkby	askuptly
AUTHORSHIP	authosrhip	atuhorship	authocnhip	alehorship
AWKWARDNESS	awkwarndess	akwwardness	awkwarvkess	alvwardness
BLISSFUL	blisfsul	bilssful	blislnul	bohssful
BOREDOM	bordeom	broedom	borkoom	bvaedom
BOTHERSOME	bothesrome	btohersome	bothenwome	bhuhersome
BRIEFLY	brielfy	birefly	briehky	buvefly
BROADLY	broaldy	boradly	broabty	bewadly
BROTHERHOOD	brothehrood	bortherhood	brothekwood	bistherhood
CALLOUSLY	calloulsy	claloulsy	calloubny	ckolously
CHANGELING	changleing	cahngeling	changfoing	colngeling
CHILDHOOD	chilhdood	cihldhood	chiltfood	colldhood
CITIZENSHIP	citizesnhip	ctiizenship	citizerwhip	ckeizenship
CLOCKWISE	clocwkise	colckwise	clocshise	cedckwise
COLORLESS	cololress	cloorless	colobmess	chuorless
COVERLET	covelret	cvoerlet	covetcet	cwuerlet
CUTENESS	cutneess	ctueness	cutxuess	cfieness
DERANGEMENT	derangmeent	dreangement	derangnoent	dsuangement
DEVELOPMENT	develompent	dveelopment	develorgent	dsaelopment
DISCIPLESHIP	disciplsehip	dsicipleship	disciplrahip	drocipleship
DOWNWARD	dowwnard	dwonward	dowmrard	dmunward
DROPLET	drolpet	dorplet	drodget	dewplet
DUCKLING	duclking	dcukling	ducfting	dnekling
EVENTFUL	evenftul	eevntful	evenklul	eurntful
FELLOWSHIP	felloswhip	flelowship	fellomvhip	ffolowship
FREEDOM	fredeom	feredom	frebaom	fanedom
FULLNESS	fulnless	flulness	fulwfess	fhelness
HUSBANDRY	husbanrdy	hsubandry	husbansfy	hvabandry
JEWELRY	jewerly	jweelry	jewenhy	jnuelry
KINGDOM	kindgom	knigdom	kinfyom	kmagdom
LEAFLET	lealfet	laeflet	leabhet	luiflet
LENGTHWISE	lengtwhise	lnegthwise	lengtvtise	lmagthwise
LOATHSOME	loatshome	laothsome	loatvtome	liethsome
MARTYRDOM	martydrom	mratyrdom	martyhsom	mcetyrdom
MEASUREMENT	measurmeent	maesurement	measursient	moisurement
MILDLY	milldy	mlidly	mildby	mtedly
MOTHERHOOD	mothehrood	mtoherhood	mothefzood	mbiherhood
MOTIONLESS	motiolness	mtoionless	motiodwess	mfaionless
NORTHWARD	nortwhard	nrothward	nortclard	nrithward
OTHERWISE	othewrise	ohterwise	othemvise	odferwise
PARENTHOOD	parenhtood	praenthood	parenldood	pmeenthood
PAVEMENT	pavmeent	pvaement	pavcaent	pciement
PEASANTRY	peasanrty	paesantry	peasanmly	poisantry

Targets	**TL across**	**TL within**	**SL across**	**SL within**
POETRY	poerty	peotry	poenby	pautry
QUIETNESS	quientess	qiuetness	quiesless	qaoetness
REGARDLESS	regarldess	rgeardless	regarfkess	rpaardless
RESOURCEFUL	resourcfeul	rseourceful	resourcbaul	rnuourceful
SCORNFUL	scorfnul	socrnful	scordmul	semrnful
SELFLESS	sellfess	slefless	selhbess	shofless
SOUTHWARD	soutwhard	suothward	soutrkard	saethward
STARLET	stalret	satrlet	stafmet	sobrlet
STEPWISE	stewpise	setpwise	stenyise	sakpwise
THOROUGHNESS	thorougnhess	tohroughness	thorougstess	telroughness
THOUGHTFUL	thoughftul	tohughtful	thoughklul	talughtful
TROUBLESOME	troublseome	torublesome	troublciome	tesublesome
UNDERLING	undelring	udnerling	undehming	ufserling
WEAKLING	wealking	waekling	weatfing	wiokling
WHOLESOME	wholseome	wohlesome	wholxoome	weflesome
WINDWARD	winwdard	wnidward	winnfard	wsodward
WIRELESS	wirleess	wrieless	wirkiess	wcaeless

Vowel-Initial Suffixed Words

Targets	**TL across**	**TL within**	**SL across**	**SL within**
ABORTIVE	aboritve	aobrtive	aborofve	aikrtive
ACCUSATION	accuastion	acucsation	accuemtion	acersation
ACIDIC	aciidc	aicdic	aciukc	aurdic
ACROBATIC	acrobaitc	arcobatic	acrobaobc	asnobatic
ADAPTABLE	adapatble	aadptable	adapelble	aebptable
ADMIRABLE	admiarble	amdirable	admiuvble	awlirable
ADOPTIVE	adopitve	aodptive	adopalve	aalptive
ALCOHOLIC	alcohoilc	acloholic	alcohoohc	arhoholic
ANGELIC	angeilc	agnelic	angeetc	apmelic
ARMORY	armoyr	amrory	armopv	azcory
ATHLETIC	athleitc	ahtletic	athleafc	akfletic
BANKER	banekr	bnaker	banilr	bmeker
BULBOUS	bulobus	blubous	bulehus	bkibous
BURGLARY	burglayr	bruglary	burglajs	bcoglary
BUSHY	busyh	bsuhy	busgk	brahy
CHEAPEN	cheaepn	cehapen	cheaogn	culapen
COMPARABLE	compaarble	cmoparable	compaocble	criparable
CONFESSION	confesison	cnofession	confesunon	cvufession
COUNTABLE	counatble	cuontable	counedble	ceantable
DARKEST	darekst	drakest	darufst	dsekest
DEMONIC	demoinc	dmeonic	demoarc	dvuonic
DULLEST	dulelst	dlulest	dulahst	dhalest
EARTHY	eartyh	erathy	eartpt	emethy
EDITION	ediiton	eidtion	ediedon	eabtion
FAULTY	faulyt	fualty	faulpb	foilty
FIRMEST	firemst	frimest	firicst	fnomest
GAWKY	gawyk	gwaky	gawgh	gmuky
HEROISM	heriosm	hreoism	heruasm	hxuoism

Targets	**TL across**	**TL within**	**SL across**	**SL within**
HOSTESS	hosetss	hsotess	hosalss	hratess
HUMANITY	humainty	hmuanity	humaesty	hveanity
IDEALIST	ideailst	iedalist	ideaobst	iahalist
IDYLLIC	idylilc	iydllic	idylodc	igtllic
INVITATION	inviattion	ivnitation	inviudtion	irsitation
ITEMIZE	iteimze	ietmize	iteuvze	ialmize
LONGEST	lonegst	lnogest	lonapst	lrigest
MAGICIAN	magiican	mgaician	magienan	mpoician
MARGINAL	margianl	mraginal	margiesl	mmeginal
MISERABLE	misearble	msierable	miseinble	mvoerable
MUSICIAN	musiican	msuician	musioman	mmaician
OPTICIAN	optiican	otpician	optiunan	ofyician
ORIENTAL	orienatl	oirental	orienohl	oenental
PAINTER	painetr	pianter	painafr	pounter
PERILOUS	periolus	preilous	periahus	pcuilous
PERVERSION	perverison	preversion	perveranon	psiversion
PRICEY	pricye	pircey	pricqa	pewcey
RACIST	raicst	rcaist	raevst	rnoist
REALISM	reailsm	raelism	reaohsm	roilism
REASONABLE	reasoanble	raesonable	reasouwble	ruosonable
SCRATCHY	scratcyh	srcatchy	scratcpl	smnatchy
SHARPEN	sharepn	sahrpen	sharayn	sefrpen
SYMBOLIC	symboilc	smybolic	symboefc	svpbolic
SYNTACTIC	syntaixc	snytactic	syntauzc	svgtactic
SYRUPY	syruyp	sryupy	syrugj	sngupy
TIGHTEN	tighetn	tgihten	tighibn	tyahten
TRAINEE	traiene	tarinee	traioxe	tuninee
URGENCY	urgenyc	ugrency	urgengr	uycency
VALIDATE	valiadte	vlaidate	valiutte	vteidate
VERBAL	verabl	vrebal	veretl	vcabal
VOCATIONAL	vocatioanl	vcoational	vocatioiml	vreational
WORKABLE	worakble	wrokable	worelble	wsukable

Appendix B

Critical stimuli for Experiment 2.

$Stem_1$+$Stem_2$ +Suffix	$Stem_1$+Suffix +$Stem_2$	Suffix+$Stem_1$ +$Stem_2$	$Stem_1$+$Stem_2$ +Control	$Stem_1$+Control +$Stem_2$	Control+$Stem_1$ +$Stem_2$
explainance	exanceplain	anceexplain	explainange	exangeplain	angeexplain
furnishance	furancenish	ancefurnish	furnishange	furangenish	angefurnish
listenance	lisanceten	ancelisten	listenange	lisangeten	angelisten
offendance	ofancefend	anceoffend	offendange	ofangefend	angeoffend
remainance	reancemain	anceremain	remainange	reangemain	angeremain
suggestance	sugancegest	ancesuggest	suggestange	sugangegest	angesuggest
gingerary	ginaryger	aryginger	gingerady	ginadyger	adyginger
onionary	onaryion	aryonion	onionady	onadyion	adyonion
picnicary	picarynic	arypicnic	picnicady	picadynic	adypicnic
tattooary	tatarytoo	arytattoo	tattooady	tatadytoo	adytattoo
walrusary	walaryrus	arywalrus	walrusady	waladyrus	adywalrus
yogurtary	yoarygurt	aryyogurt	yogurtady	yoadygurt	adyyogurt
adjustence	adencejust	enceadjust	adjustenge	adengejust	engeadjust
aggressence	agencegress	enceaggress	aggressenge	agengegress	engeaggress
cancelence	canencecel	encecancel	cancelenge	canengecel	engecancel
finishence	finenceish	encefinish	finishenge	finengeish	engefinish
happenence	hapencepen	encehappen	happenenge	hapengepen	engehappen
obsessence	obencesess	enceobsess	obsessenge	obengesess	engeobsess
abhorer	aberhor	erabhor	abhorel	abelhor	elabhor
acquainter	acerquaint	eracquaint	acquaintel	acelquaint	elacquaint
astounder	asertound	erastound	astoundel	aseltound	elastound
deterer	deerter	erdeter	deterel	deelter	eldeter
exerter	exerert	erexert	exertel	exelert	elexert
tamperer	tamerper	ertamper	tamperel	tamelper	eltamper
answerful	anfulswer	fulanswer	answerfil	anfilswer	filanswer
compassful	comfulpass	fulcompass	compassfil	comfilpass	filcompass
degreeful	defulgree	fuldegree	degreefil	defilgree	fildegree
grizzleful	grizfulzle	fulgrizzle	grizzlefil	grizfilzle	filgrizzle
lessonful	lesfulson	fullesson	lessonfil	lesfilson	fillesson
supremeful	sufulpreme	fulsupreme	supremefil	sufilpreme	filsupreme
contentic	conictent	iccontent	contentig	conigtent	igcontent
daughteric	daughicter	icdaughter	daughterig	daughigter	igdaughter
doctoric	docictor	icdoctor	doctorig	docigtor	igdoctor
expertic	exicpert	icexpert	expertig	exigpert	igexpert
ketchupic	ketchicup	icketchup	ketchupig	ketchigup	igketchup
orchardic	oricchard	icorchard	orchardig	origchard	igorchard
behalfish	beishhalf	ishbehalf	behalfith	beithhalf	ithbehalf
conceitish	conishceit	ishconceit	conceitith	conithceit	ithconceit
desertish	deishsert	ishdesert	desertith	deithsert	ithdesert
jacketish	jackishet	ishjacket	jacketith	jackithet	ithjacket
portalish	porishtal	ishportal	portalith	porithtal	ithportal
tennisish	tenishnis	ishtennis	tennisith	tenithnis	ithtennis
butterism	butismter	ismbutter	butterilm	butilmter	ilmbutter
digitism	digismit	ismdigit	digitilm	digilmit	ilmdigit
iglooism	igismloo	ismigloo	iglooilm	igilmloo	ilmigloo
kidneyism	kidismney	ismkidney	kidneyilm	kidilmney	ilmkidney

Stem$_1$+Stem$_2$ +Suffix	**Stem$_1$+Suffix +Stem$_2$**	**Suffix+Stem$_1$ +Stem$_2$**	**Stem$_1$+Stem$_2$ +Control**	**Stem$_1$+Control +Stem$_2$**	**Control+Stem$_1$ +Stem$_2$**
meterism	meismter	ismmeter	meterilm	meilmter	ilmmeter
silverism	silismver	ismsilver	silverilm	sililmver	ilmsilver
chimneyist	chimistney	istchimney	chimneyilt	chimiltney	iltchimney
harvestist	haristvest	istharvest	harvestilt	hariltvest	iltharvest
monsterist	monistster	istmonster	monsterilt	moniltster	iltmonster
mountainist	mounisttain	istmountain	mountainilt	mounilttain	iltmountain
paperist	paistper	istpaper	paperilt	pailtper	iltpaper
pumpkinist	pumpistkin	istpumpkin	pumpkinilt	pumpiltkin	iltpumpkin
abruptity	abityrupt	ityabrupt	abruptidy	abidyrupt	idyabrupt
certainity	ceritytain	itycertain	certainidy	ceridytain	idycertain
correctity	corityrect	itycorrect	correctidy	coridyrect	idycorrect
openity	oitypen	ityopen	openidy	oidypen	idyopen
robustity	roitybust	ityrobust	robustidy	roidybust	idyrobust
suddenity	sudityden	itysudden	suddenidy	sudidyden	idysudden
basketize	basizeket	izebasket	basketime	basimeket	imebasket
curfewize	curizefew	izecurfew	curfewime	curimefew	imecurfew
litterize	litizeter	izelitter	litterime	litimeter	imelitter
lizardize	lizizeard	izelizard	lizardime	lizimeard	imelizard
mammalize	mamizemal	izemammal	mammalime	mamimemal	imemammal
pencilize	penizecil	izepencil	pencilime	penimecil	imepencil
anchorly	anlychor	lyanchor	anchorla	anlachor	laanchor
blisterly	blislyter	lyblister	blisterla	blislater	lablister
chapterly	chaplyter	lychapter	chapterla	chaplater	lachapter
humorly	hulymor	lyhumor	humorla	hulamor	lahumor
robotly	rolybot	lyrobot	robotla	rolabot	larobot
scandally	scanlydal	lyscandal	scandalla	scanladal	lascandal
appearment	apmentpear	mentappear	appearmant	apmantpear	mantappear
competement	commentpete	mentcompete	competemant	commantpete	mantcompete
createment	crementate	mentcreate	createmant	cremantate	mantcreate
forbidment	formentbid	mentforbid	forbidmant	formantbid	mantforbid
forgetment	formentget	mentforget	forgetmant	formantget	mantforget
swallowment	swalmentlow	mentswallow	swallowmant	swalmantlow	mantswallow
lilacness	linesslac	nesslilac	lilacnels	linelslac	nelslilac
mammothness	mamnessmoth	nessmammoth	mammothnels	mamnelsmoth	nelsmammoth
minorness	minessnor	nessminor	minornels	minelsnor	nelsminor
ostrichness	osnesstrich	nessostrich	ostrichnels	osnelstrich	nelsostrich
trebleness	trenessble	nesstreble	treblenels	trenelsble	nelstreble
vandalness	vannessdal	nessvandal	vandalnels	vannelsdal	nelsvandal
adaptory	aorydapt	oryadapt	adaptody	aodydapt	odyadapt
affordory	aforyford	oryafford	affordody	afodyford	odyafford
allowory	alorylow	oryallow	allowody	alodylow	odyallow
informory	inoryform	oryinform	informody	inodyform	odyinform
mentionory	menorytion	orymention	mentionody	menodytion	odymention
publishory	puborylish	orypublish	publishody	pubodylish	odypublish
ambushous	amousbush	ousambush	ambushoes	amoesbush	oesambush
districtous	disoustrict	ousdistrict	districtoes	disoestrict	oesdistrict
dollarous	dolouslar	ousdollar	dollaroes	doloeslar	oesdollar
guitarous	guioustar	ousguitar	guitaroes	guioestar	oesguitar
hiccupous	hicouscup	oushiccup	hiccupoes	hicoescup	oeshiccup
sloganous	sloousgan	ousslogan	sloganoes	slooesgan	oesslogan

Appendix C

Critical stimuli for Experiment 3.

Stem$_1$+Stem$_2$ +Suffix	**Stem$_1$+Sufix +Stem$_2$**	**Suffix+Stem$_1$ +Stem$_2$**	**Stem$_1$+Stem$_2$ +Control**	**Stem$_1$+Control +Stem$_2$**	**Control+Stem$_1$ +Stem$_2$**
explainance	exanceplain	anceexplain	explainolge	exolgeplain	olgeexplain
furnishance	furancenish	ancefurnish	furnisholge	furolgenish	olgefurnish
listenance	lisanceten	ancelisten	listenolge	lisolgeten	olgelisten
offendance	ofancefend	anceoffend	offendolge	ofolgefend	olgeoffend
remainance	reancemain	anceremain	remainolge	reolgemain	olgeremain
suggestance	sugancegest	ancesuggest	suggestolge	sugolgegest	olgesuggest
gingerary	ginaryger	aryginger	gingeroli	ginoliger	oliginger
onionary	onaryion	aryonion	onionoli	onoliion	olionion
picnicary	picarynic	arypicnic	picnicoli	picolinic	olipicnic
tattooary	tatarytoo	arytattoo	tattoooli	tatolitoo	olitattoo
walrusary	walaryrus	arywalrus	walrusoli	walolirus	oliwalrus
yogurtary	yoarygurt	aryyogurt	yogurtoli	yooligurt	oliyogurt
adjustence	adencejust	enceadjust	adjusturve	adurvejust	urveadjust
aggressence	agencegress	enceaggress	aggressurve	agurvegress	urveaggress
cancelence	canencecel	encecancel	cancelurve	canurvecel	urvecancel
finishence	finenceish	encefinish	finishurve	finurveish	urvefinish
happenence	hapencepen	encehappen	happenurve	hapurvepen	urvehappen
obsessence	obencesess	enceobsess	obsessurve	oburvesess	urveobsess
abhorer	aberhor	erabhor	abhoril	abilhor	ilabhor
acquainter	acerquaint	eracquaint	acquaintil	acilquaint	ilacquaint
astounder	asertound	erastound	astoundil	asiltound	ilastound
deterer	deerter	erdeter	deteril	deilter	ildeter
exerter	exerert	erexert	exertil	exilert	ilexert
tamperer	tamerper	ertamper	tamperil	tamilper	iltamper
answerful	anfulswer	fulanswer	answertep	antepswer	tepanswer
compassful	comfulpass	fulcompass	compasstep	comteppass	tepcompass
degreeful	defulgree	fuldegree	degreetep	detepgree	tepdegree
grizzleful	grizfulzle	fulgrizzle	grizzletep	griztepzle	tepgrizzle
lessonful	lesfulson	fullesson	lessontep	lestepson	teplesson
supremeful	sufulpreme	fulsupreme	supremetep	suteppreme	tepsupreme
contentic	conictent	iccontent	contentom	conomtent	omcontent
daughteric	daughicter	icdaughter	daughterom	daughomter	omdaughter
doctoric	docictor	icdoctor	doctorom	docomtor	omdoctor
expertic	exicpert	icexpert	expertom	exompert	omexpert
ketchupic	ketchicup	icketchup	ketchupom	ketchomup	omketchup
orchardic	oricchard	icorchard	orchardom	oromchard	omorchard
behalfish	beishhalf	ishbehalf	behalferk	beerkhalf	erkbehalf
conceitish	conishceit	ishconceit	conceiterk	conerkceit	erkconceit
desertish	deishsert	ishdesert	deserterk	deerksert	erkdesert
jacketish	jackishet	ishjacket	jacketerk	jackerket	erkjacket
portalish	porishtal	ishportal	portalerk	porerktal	erkportal
tennisish	tenishnis	ishtennis	tenniserk	tenerknis	erktennis
butterism	butismter	ismbutter	butterard	butardter	ardbutter
digitism	digismit	ismdigit	digitard	digardit	arddigit
iglooism	igismloo	ismigloo	iglooard	igardloo	ardigloo
kidneyism	kidismney	ismkidney	kidneyard	kidardney	ardkidney

Stem$_1$+Stem$_2$ +Suffix	**Stem$_1$+Sufix +Stem$_2$**	**Suffix+Stem$_1$ +Stem$_2$**	**Stem$_1$+Stem$_2$ +Control**	**Stem$_1$+Control +Stem$_2$**	**Control+Stem$_1$ +Stem$_2$**
meterism	meismter	ismmeter	meterard	meardter	ardmeter
silverism	silismver	ismsilver	silverard	silardver	ardsilver
chimneyist	chimistney	istchimney	chimneyerf	chimerfney	erfchimney
harvestist	haristvest	istharvest	harvesterf	harerfvest	erfharvest
monsterist	monistster	istmonster	monstererf	monerfster	erfmonster
mountainist	mounisttain	istmountain	mountainerf	mounerftain	erfmountain
paperist	paistper	istpaper	papererf	paerfper	erfpaper
pumpkinist	pumpistkin	istpumpkin	pumpkinerf	pumperfkin	erfpumpkin
abruptity	abityrupt	ityabrupt	abruptuba	abubarupt	ubaabrupt
certainity	ceritytain	itycertain	certainuba	cerubatain	ubacertain
correctity	corityrect	itycorrect	correctuba	corubarect	ubacorrect
openity	oitypen	ityopen	openuba	oubapen	ubaopen
robustity	roitybust	ityrobust	robustuba	roubabust	ubarobust
suddenity	sudityden	itysudden	suddenuba	sudubaden	ubasudden
basketize	basizeket	izebasket	basketabe	basabeket	abebasket
curfewize	curizefew	izecurfew	curfewabe	curabefew	abecurfew
litterize	litizeter	izelitter	litterabe	litabeter	abelitter
lizardize	lizizeard	izelizard	lizardabe	lizabeard	abelizard
mammalize	mamizemal	izemammal	mammalabe	mamabemal	abemammal
pencilize	penizecil	izepencil	pencilabe	penabecil	abepencil
anchorly	anlychor	lyanchor	anchorta	antachor	taanchor
blisterly	blislyter	lyblister	blisterta	blistater	tablister
chapterly	chaplyter	lychapter	chapterta	chaptater	tachapter
humorly	hulymor	lyhumor	humorta	hutamor	tahumor
robotly	rolybot	lyrobot	robotta	rotabot	tarobot
scandally	scanlydal	lyscandal	scandalta	scantadal	tascandal
appearment	apmentpear	mentappear	appearponk	apponkpear	ponkappear
competement	commentpete	mentcompete	competeponk	componkpete	ponkcompete
createment	crementate	mentcreate	createponk	creponkate	ponkcreate
forbidment	formentbid	mentforbid	forbidponk	forponkbid	ponkforbid
forgetment	formentget	mentforget	forgetponk	forponkget	ponkforget
swallowment	swalmentlow	mentswallow	swallowponk	swalponklow	ponkswallow
lilacness	linesslac	nesslilac	lilaclisk	lilisklac	lisklilac
mammothness	mamnessmoth	nessmammoth	mammothlisk	mamliskmoth	liskmammoth
minorness	minessnor	nessminor	minorlisk	milisknor	liskminor
ostrichness	osnesstrich	nessostrich	ostrichlisk	oslisktrich	liskostrich
trebleness	trenessble	nesstreble	treblelisk	treliskble	lisktreble
vandalness	vannessdal	nessvandal	vandallisk	vanliskdal	liskvandal
adaptory	aorydapt	oryadapt	adaptifa	aifadapt	ifaadapt
affordory	aforyford	oryafford	affordifa	afifaford	ifaafford
allowory	alorylow	oryallow	allowifa	alifalow	ifaallow
informory	inoryform	oryinform	informifa	inifaform	ifainform
mentionory	menorytion	orymention	mentionifa	menifation	ifamention
publishory	puborylish	orypublish	publishifa	pubifalish	ifapublish
ambushous	amousbush	ousambush	ambushiag	amiagbush	iagambush
districtous	disoustrict	ousdistrict	districtiag	disiagtrict	iagdistrict
dollarous	dolouslar	ousdollar	dollariag	doliaglar	iagdollar
guitarous	guioustar	ousguitar	guitariag	guiiagtar	iagguitar
hiccupous	hicouscup	oushiccup	hiccupiag	hiciagcup	iaghiccup
sloganous	sloousgan	ousslogan	sloganiag	sloiaggan	iagslogan