Prelexical Decomposition of Compound and Pseudocompound Words

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ABSTRACT

Previous studies on morphologically complex words suggest early decomposition in the visual word process. In that case, morpheme-like constituents of pseudocompound words (e.g. *mushroom*) should also be decomposed during the early stage of visual recognition, although such effects should disappear quickly, as the decomposition does not help in the identification of the whole word. Experiment 1 assessed priming effects of compound words and pseudocompound words on their constituents at SOAs of 150ms and 500 ms, using masked primes. At the short SOA, both word types primed their first constituents (e.g., *blackboard* primed *black*, *mushroom* primed *mush*), supporting the hypothesis of early decomposition. At the long SOA, the compound words primed both of their constituents, while the pseudocompound words continued to prime their first constituents. Experiment 2 repeated Experiment 1 with the long SOA condition changed to 300ms. The results were the same for compound words, but priming effects disappeared for the pseudocompound words at 300ms SOA. These findings suggest an early segmentation of morpheme-like word parts based on the orthographical structure of multisyllabic words.

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Prelexical decomposition of compound and pseudocompound words

In the study of visual word recognition, many levels of how a word may be represented in the mental lexicon have been identified. The unique sequence of letters associated with each word makes up the orthography, and the distinct pattern of sounds linked to each word makes up the phonology. The meanings of the words form the semantic level of their lexical representation and influence the activation of related words in the mental dictionary. Also, how often these forms appear in print or how many similarly spelled or sounding words exist are known to affect how fast a given word is recognized. Most computational models of reading use these three levels of representation for speculating how written words are processed. For example, connectionism suggests that the three levels serve as layers of networks with different units from which lexical representations arise as learned patterns (Plaut, McClelland, Seidenberg, & Patterson, 1996). The Dual Route Cascaded model suggests that orthography, phonology, and semantics are different levels of the mental lexicon among which the corresponding items are interconnected (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). These models tend to focus on explaining how the proper phonological information is identified from a given letter string that may employ regular or irregular spelling.

However, there is another level of consistency that can be found in words that is not fully addressed in such models of visual word recognition. Morphology governs many word forms that carry multiple aspects or combinations in their meanings. Linguistically, morphemes are identifiable as the smallest unit of meaning, but whether such an abstract structure is indeed represented in the mental lexicon is still debatable. For example, since morphologically related words share both similar meaning and sound or spelling, morphological effects may be explained as arising from a mere overlap of form (phonology or orthography) and meaning (semantics).

Support for such a reductionist view comes from connectionist theories that consider the mental lexicon to be distributed patterns of activation across the levels of form and meaning (Seidenberg & Gonnerman, 2000). Empirical support comes from a priming study that found that the magnitude of priming between morphologically related word pairs was proportional to the degree of semantic and phonological similarity between the items (Gonnerman, Seidenberg, & Andersen, 2007). Also, an fMRI study (Devlin, Jamison, Matthews, Gonnerman, & McClelland, 2004) that compared the brain activation levels across different priming conditions found that morphologically related priming reduced the blood oxygenation level-dependent (BOLD) signal in the left fusiform gyrus, which also happened in the orthographically related condition, and also in the middle temporal gyrus, which happens in a semantically related condition as well, suggesting a functional localization of these brain areas, with morphological processing as a sum of the two functions, orthographic processing and semantic processing.

However, results from other studies suggest that there may be more to morphology than just a sum of form and semantics. Feldman (2000) conducted immediate- and delayed-priming experiments using morphologically, orthographically, and semantically related pairs of words. In immediate priming, the effects of semantics and orthography did not add up to equal the morphological effects as morphological priming was greater than semantic priming and orthographic priming resulted in inhibition. In delayed priming, where an average of 10 items intervened between the prime and the target, only morphologically related items showed priming, whereas orthographic and semantic effects did not survive the long lag. Feldman's (2000) results from the immediate priming are mirrored in the results of MEG studies where the latency for the M350 component (which is considered to be a signal of lexical access) was inhibited by onset-matching phonological primes (Pylkkänen, Gonnerman, Stringfellow, & Marantz, accepted, pending revision) and facilitated by semantic primes (Pylkkänen, Llinás, & Murphy, 2006). If morphology is merely a combination of form and meaning, the magnitude of its effects should also be diminished as the effects of form and meaning overlap and cancel out each other, but again, morphologically related pairs were found to result in facilitation (Fiorentino & Poeppel, in press), suggesting that morphology is not a mere addition of form and semantics.

Accepting morphology as a viable property of words in the mental lexicon, the question arises as to whether multimorphemic words are stored as separate entries or are always computed from single morphemes whenever needed. Inflected morphemes (e.g. the plural indicator –*s* in *cups* and the third person singular indicator –*s* in *runs*) have been the source of much debate for how the past tenses of irregular verbs are processed (see Bybee, 1995). However, as they do not change the category or meaning of the lexical item, their effects are not of interest in this study. On the other hand, derivational morphemes such as affixes and free morphemes that can stand alone as words can produce various combinations of multimorphemic words with different meanings, and examining how they are represented and processed in the mental lexicon is the aim of this study.

If multimorphemic words have their own lexical representations in the mental dictionary, their processing should be influenced by whole-word characteristics. On the other hand, if properties of the constituent morphemes affect word recognition, it would indicate morphological decomposition as part of the procedure of lexical access. Eye-movement studies with Finnish compound words have found both kinds of effects, where whole-word frequency and second constituent frequency influenced gaze duration and first constituent frequency influenced first fixation duration (Bertram & Hyönä, 2003; Hyönä & Pollatsek, 1998; Pollatsek, Hyönä, & Bertram 2000). Comparable results have been found in studies using English compound words as well (Andrews, Miller, & Rayner, 2004; Juhasz, Starr, Inhoff, & Placke, 2003).

Based on these findings, Pollatsek et al. (2000) suggested a race model where both whole-word and constituent morphemes are processed in parallel for the identification of compound words. The fact that the first constituent frequency influences first fixation duration while whole-word and second-constituent frequencies influence the total gaze duration indicates that the first constituent is accessed before the whole-word representation or the second constituent. Also, when

Bertram and Hyönä (2003) manipulated the length of the compound words, the first constituent frequency effect disappeared for short words, whereas the whole-word frequency effect also extended to the first fixation duration, suggesting that when the compound word is short enough, it is processed via the whole-word route, but if it is long, the decomposition route may be more effective.

In this sense, the mental lexicon has separate entries for multimorphemic words, but the lexical representations of their constituent morphemes are also linked to the whole-word representations, and activation of one can lead to the other. If such linkage is based on the semantic association between the two representations, decomposition would only be beneficial to those complex words where the meanings of the constituent morphemes are directly related to the meaning of the whole word. For example, *blackboard* derives its meaning from both of its constituents *black* and *board*, while *strawberry* shares part of its meaning with only its second constituent *berry*, and *buttercup* does not have anything to do with the meaning of either *butter* or *cup*. If decomposition is based on semantic transparency, only words like *blackboard* and *strawberry* would be decomposed into their constituents because they have relevant meanings. On the other hand, if decomposition is based on the structure of the word before any semantic influences, even words like *buttercup* would be fully decomposed.

Effects of semantic transparency have been found in some priming studies involving Dutch compound words (see Sandra, 1990; Zwitserlood, 1994; Zwitserlood, Bolwiender, & Drews, 2005). Semantic associates of either the first or the second constituent primed semantically transparent compound word targets but not opaque word targets (Sandra, 1990). In partial repetition priming where the compound words served as primes to the constituent targets (e.g. *kerkorgel-KERK*, where *kerk* means *church* and *orgel* means *organ*), both semantically transparent and opaque conditioned showed priming, but when the targets were semantic associates of either of the constituents (e.g. *kerkorgel-priester*, where *priester* means *priest*), only transparent pairs showed priming (Zwitserlood, 1994).

In fact, when it comes to partial repetition priming, several studies show equal effects of both transparent and opaque constituents (Dohmes, Zwitserlood, & Bölte, 2004; Fiorentino, submitted; Libben, Gibson, Yoon, & Sandra, 2003; Rastle & Davis, 2003; Rastle, Davis, & New, 2004;), similar to the results of Zwitserlood (1994) mentioned above. Also, an eye-movement study on compound words found no difference between semantically transparent and opaque words on fixation durations (Pollatsek & Hyönä, 2005). These findings suggest early segmentation of morphemes even before semantic influences.

For example, Rastle et al. (2004) compared priming effects between pairs that had a transparent morphological relationship (e.g. *cleaner-clean*), pairs that looked like they were morphologically related but were not in meaning (e.g. *brother-broth*), and pairs that overlapped in form only (e.g. *brothel-broth*) and found about equal magnitude of priming for the first two pairs but no priming for the last condition. Even though there is no morphological relationship between *brother* and *broth*, *brother* seems to have been decomposed into *broth* and *er* as *–er* is a valid morpheme. This result is replicated in an ERP study with the same conditions where the N400 component showed significant attenuation for both semantically transparent and opaque pairs (Lavric, Clapp, & Rastle, 2007). The N400 component is a negative peak in EEG measures usually occurring around 300-500ms after stimulus presentation whose amplitude is correlated with the semantic incongruency of the stimulus and is generally considered to reflect the amount of processing resources required for semantic integration of the stimulus with the context. Hence its attenuation in priming studies would reflect facilitation of target processing due to a related prime, and in Lavric et al. (2007), the apparent morphological relationship was enough to find such an effect even when such decomposition did not make sense, as in the case of *brother*.

The possibility of such structure-based decomposition has been suggested in lexical decision data on nonwords that contain word parts (Monsell, 1985; Taft & Forster, 1975; Taft & Forster, 1976; van Jaarsfeld & Rattink, 1988). Taft and Forster (1975) found that nonwords that are stems of existing prefixed words (e.g. *juvenate* from *rejuvenate*) take longer in lexical decision than regular nonwords, and nonwords produced by mismatching existing prefixes and stems (e.g. *dejuvenate*) are also identified slower than prefixed nonwords. Compound nonwords in which one or both of the constituents are words also take longer in their rejection, taking the longest when both are words (e.g. *dustworth*), then when the first part is a word (e.g. *footmilge*), then when the second part is a word (e.g. *trowbreak*), with bysyllabic nonwords containing no word part being the fastest for rejection as a word (van

Jaarsfeld & Rattink, 1988). Such results suggest that the morphemic parts of any letter string become segmented and are used to identify a stimulus as a potential lexical item.

Support for this view is found in an MEG study by Fiorentino and Poeppel (in press), where the M350 component (considered to signal the initial activation of lexical candidates) showed equally short latencies for nonwords starting with a word part as for compound words. The original design of this study was to compare both the behavioral and neural responses on lexical decisions to compound words and comparable monomorphemic words, and found that reaction time and M350 latencies were shorter for compound words, possibly because of the higher frequency of the constituents than the whole word. While reaction time to the word-nonword nonwords in this study was longer than other nonwords, the M350 component latency was comparable to that of the compound words, suggesting that the initial word part was decomposed and lexically accessed, thus taking longer to reject its nonword status.

If decomposition of morphemes happens early in the visual word recognition process, then it may be speculated that it would even happen for monomorphemic words that look like they are compound words (e.g. *brandish*, which is not a dish of bran, but looks like it could be). In fact, Taft (1981) showed that words that look like they are prefixed but are not (e.g. *relish*) are identified slower than genuinely prefixed words (e.g. *repay*) because they would be incorrectly prefix-stripped and mislead lexical search. Likewise, pseudocompound words may also show initial decomposition into their pseudo-constituents and later correct themselves in the process.

Additional support for prelexical parsing comes from Libben, Derwing, and de Almeida (1999) who found that when novel compound words with ambiguous morphological boundaries (e.g., *clamprod* can be parsed into *clam* and *prod* or *clamp* and *rod*) are presented, they seem to activate all constituent representations from the possible parsing rather than merely dividing the initial wordstring into two parts. They also cited results from an unpublished study that found that such ambiguous compounds take longer to process than their reversed forms (e.g. *prodclam* or *rodclamp*) and suggest that the increase in processing time is due to the additional amount of work load during the prelexical parsing and also the extra stage of choosing which parsing to accept.

Shoolman and Andrews (2003) included monomorphemic pseudocompound words (e.g. *hammock*) as one of the target conditions when assessing priming effects of constituents on their compound words. While compound word constituents primed their respective compound words regardless of whether their relationship was semantically transparent or opaque, the effect of pseudocompound words was not significantly different from that of monomorphemic words, thereby distinguishing the effects of morphological structure from those of mere orthographic segmentation. However, the design of using constituents as primes and the compound words as targets necessarily hides any decompositional effect that may be found from pseudocompound words, as the activation of the pseudoconstituent (e.g. *ham*) does not aid the activation of the target (e.g. *hammock*). On the other hand, if the pseudocompound words themselves are used as primes and their apparent constituents as targets, priming may occur at short SOAs, while such effects would die away quickly as the whole word is activated and declares the constituents as false components. Compound words should continue to prime their constituents at longer SOAs if their meaning is still linked to their constituents or if decomposition happens after lexical access. In fact, Feldman (2000) showed such a result, where at the short prime duration of 66ms, orthographically related pairs *vowel-vow* showed 18ms of facilitation, while at longer prime durations (116ms and 300ms, including 50ms of ISI), the orthographic effects changed into inhibition.

However, the fact that the prime was visible for most of the SOA duration makes it possible for the reader to consciously develop a strategy for lexical decision. In order to deal with this problem, the present studies used the masked priming technique with a short prime duration so that the subject could not identify the prime. Thus, we can examine how different amounts of prime processing influence constituent processing in both compound words and pseudocompound words.

Mathias (2006) used this method with compound words and found partial identity priming for the first and second constituents at 100ms SOA, increased priming for the first constituent at 300ms SOA, and decreased priming for both constituents at 700ms SOA. In his second experiment, he found semantic priming of the first constituent (e.g. *grapefruit – vines*) at 100ms SOA, inhibition of the first constituent and priming of the second constituent at 300ms SOA, and priming of the second constituent at 700ms SOA. These results seem to suggest that over the time course, resource allocation shifts between constituents when processing compound words depending on the semantic contribution of the constituent to the whole-word meaning.

First constituents do play a role in compound word identification, as Taft and Forster (1976) found that nonwords that start with words take longer to be rejected in LDT regardless of whether the rest of the nonword was another word (e.g. *dustworth*), nonword with clear syllable boundary (e.g. *footmilge*), or nonword with unclear syllable boundary (e.g. *trucerin*). Taft and Forster (1976) suggested that the first part of a word may serve as an index key in lexical search, narrowing down the possible candidates among the entries in the lexicon. Taking this view, the contribution of the first constituent seems to be primarily based on form rather than semantics, at least in the beginning stages of word recognition.

On the other hand, second constituents seem to play a bigger role in semantics, as they serve as the semantic head in most English compound words. For example, a blackboard is a board that is black, and a blueberry is a berry that is blue. Support for this comes from Zwitserlood (1994) who found greater priming effects (54ms vs. 26ms) for second constituents than for first constituents when primed by semantically transparent compound words. Further support comes from a study by Libben, Gibson, Yoon, and Sandra (2003), where compound words with semantically transparent second constituents were recognized faster than compound words with semantically opaque second constituents regardless of whether the first constituent was semantically transparent or opaque.

In the current studies, the aim is to extend the results of Mathias (2006) regarding partial identity priming with compound words and to compare this priming to that for pseudocompound words. The compound words are expected to continue to prime their constituents at later SOAs, whereas pseudocompound words are expected to show initial priming, which should diminish at later SOAs. The first constituent priming effects were maintained for the partial-repetition priming in Mathias (2006) whereas they disappeared at later SOAs in the semantic priming experiments, which may indicate a phonological or orthographic influence. If that is the case, such an effect may be found for the pseudocompound words in this experiment as well, as the orthographic structure is the same for both types of words.

Experiment 1:

If morphological decomposition happens prelexically and automatically, the basis for such segmentation would be orthographical, and since no structural difference should exist between compound words and pseudocompound words, both types of words would prime their constituents or pseudoconstituents. As time passes, the constituents of compound words should stay activated, as they lead to the activation of the compound word. The activation of the pseudoconstituents, however, would dissipate, as they do not lead to the lexical representation of the pseudocompound word. Experiment 1 examines whether pseudocompound words prime their “constituents,” and whether the pattern is identical to that of the compound words.

Method

Participants

Eighty undergraduate students from the University of Kansas participated in the study in order to fulfill an introductory psychology course requirement. They were all native English speakers, right-handed, and had normal or corrected to normal vision. Students who did not meet these criteria were allowed to participate but their data were not included in the analysis. Participants were randomly assigned to one of eight lists of stimuli.

Stimuli

Eighty compound words (e.g. *bathrobe*) and 80 pseudocompound words (e.g. *mushroom*) were selected as primes for this study. Most of the words came from the English Lexicon Project database (Balota, Cortese, Hutchison, Neely, Nelson, Simpson, & Treiman, 2002). Compound words were chosen from a list of words from the ELP database that met the criteria of consisting of six to nine letters, two morphemes, and two syllables. Words were screened by the researcher for having two free morphemes and their meanings being transparent with respect to the meanings of the whole word. Pseudocompound words also were between six and nine letters and constisted of two syllables; however, each comprised only one morpheme. Pseudocompound words consisted of word parts that could work as free morphemes and their pronunciations were mostly preserved in the whole word. Then, half of the compound words and half of the pseudocompound words were selected to be paired with word targets, and the other half were paired with nonword targets.

The word targets were created by splitting the primes into their constituents or pseudoconstituents (e.g., *bath* and *robe* from *bathrobe*, *mush* and *room* from *mushroom*). Initially, four lists were created, where each list had 4 conditions with 10 words per condition: first-constituent related (*bathrobe-bath*), second-constituent related (*bathrobe-robe*), first-constituent unrelated (*bathrobe-dew*, where *dew* is the first-constituent of another compound word prime *dewdrop*) and second-constituent unrelated (*bathrobe-drop*, again, *drop* is the second-constituent of *dewdrop*). For the related conditions, targets were the first or second constituents or pseudoconstituents of their respective primes, and for the unrelated conditions, targets were the unused first or second constituents or pseudoconstituents from the primes used in the related conditions. These conditions rotated among four groups of compound and pseudocompound words so that, among lists, each prime was used in all four conditions and each target served as its own control. Then, for each condition, half of the words were assigned to the short SOA of 150 ms, and the other half assigned to the long SOA of 500 ms, and another set of four lists were created with the SOA conditions reversed, resulting in a total of eight lists.

The nonword targets were created in a similar manner as the word targets by splitting the primes and assigning each quarter to different conditions and their halves to different SOAs, and were converted into nonwords by changing a letter from the original constituent or pseudoconstituent. Only one version of the list was created and was used as nonword controls for all the 8 lists of word pairs.

The Kucera-Francis frequency of the primes did not differ significantly between the compound words (mean = 2.44) and the pseudocompound words (mean = 4.69), t (158) = -1.636, $p > .05$. A 2 x 2 (prime type x constituent position) ANOVA was conducted on the frequency value of the first and second constituents of compound words (means = 131.65 and 141.35) and of pseudocompound words (means= 160.83 and 143.83). The main effect of prime type was not statistically significant, F (1, 156) = .109 $p > .05$. The main effect of constituent position was not statistically significant, F (1, 156) = .006, $p > .05$. The interaction between the two factors was also not significant, F (1, 156) = .078, $p > .05$. The frequency values that were not available from the ELP database were substituted with 0 for the calculation.

The difficulty of obtaining enough stimuli with the right conditions inevitably resulted in using some constituents that appeared in more than one prime (e.g. *warlock* and *warden* share *war*; *mushroom* and *classroom* share *room*). Primes were chosen so that such overlapping would not occur more than once between them (i.e. each word part appears no more than twice among the primes) and the assignment of conditions among targets made sure that no target appeared more than once (e.g. in the case of *war*, *warden* is paired with an unrelated nonword pair; in the case of *room*, when *mushroom* is paired with *room*, *classroom* is paired with *class* or an unrelated word and vice versa).

Procedure

Stimulus presentation and data collection were performed by E-prime software. Participants sat in front of the computer and received verbal instruction on how to participate in the study. When they were ready, they could commence the practice part of the experiment by pressing any key on the keyboard. The practice consisted of 20 trials that had similar conditions as the actual experiment with words that were not used during the stimulus selection. After the practice section, another instruction screen appeared on the screen, and the participants were given another chance to ask the researcher any questions. Again, any key stroke prompted the program to proceed to the next stage in the experiment where the real trials began. Each trial consisted of a blank screen with a fixation cross at the center for a duration of 500ms. Then the fixation cross was replaced by a series of hashmarks (########) that served as a forward mask for the prime and lasted for 50ms. Either a compound or pseudocompound word prime was then presented for 50ms and then replaced again by the same series of hashmarks that served as a backward mask this time. For the short SOA condition, this second mask lasted for 100ms to complete the 150ms SOA, and for the long SOA condition, it lasted for 450ms to complete the 500ms SOA. The target was then presented and stayed on the screen until a response was made by either pressing the *a* key or the *l* key. If the presented target was a real word in English, the participants were asked to press the *l* key, and if the target was not a real word, they were asked to press the *a* key as quickly and accurately as possible. Both reaction times and accuracy data were collected from this procedure. The order of the trials was randomized for each participant.

Results

Before analyzing the data, error rates by items revealed that 10 pseudoconstituents had been incorrectly identified as nonwords more than 30% of the time, and consequently, data from those trials were excluded from further analysis. Also, reaction times to incorrect responses and those beyond 2.5 standard deviations from the mean were also removed from the data, removing less than 5% of the data. The responses to nonword stimuli were also excluded from the analysis.

A four-way ANOVA was conducted using prime type (compound, pseudocompound), constituent position (first, second), relatedness (related, unrelated), and SOA (150ms, 500ms) as independent variables and mean reaction time as the dependent variable. For analysis by subjects (F_1), all four variables were treated as repeated measures, and for analysis by items (F_2), only relatedness and SOA were treated as repeated measures. Table 1 shows the mean reaction times and error rates under each condition for the subjects analysis.

The main effect of prime type was significant by subjects, F_1 (1, 79) = 153.15, $p < .001$ and by items, F_2 (1, 145) = 37.60, $p < .001$. Targets to compound words had faster reaction times than targets to pseudocompound words. The main effect of relatedness was also significant by subjects, F_1 (1, 79) = 25.46, $p < .001$, and by items, F_2 (1, 145) = 33.76, $p < .001$. When the target was a partial repetition of the prime, the reaction time was faster. SOA also had a significant main effect by subjects, F_1 (1, 79) = 46.55, $p < .001$ and by items, F_2 (1, 145) = 73.18, $p < .001$. Target words were more quickly identified when the SOA was longer.

The main effects were qualified by a 2-way interaction between prime type and constituent that was significant by subjects, F_1 (1, 79) = 8.31, $p < .01$ but not significant by items, F_2 (1, 145) = 2.04, $p = .156$. In the case of compound word primes, the first constituents (*M* = 639.47, *SD* = 77.80) had faster reaction times than the second constituents (*M* = 648.01, *SD* = 82.51), t_1 (79) = -1.70, $p = 0.09$. On the other hand, pseudocompound word first constituents (*M* = 698.50, *SD* = 76.73) had slower reaction times than second constituents (*M* = 681.90, *SD* = 75.71), t_1 (79) = 2.85, $p < 0.05$.

Also, the 2-way interaction between constituent and relatedness approached significance by subjects, F_1 (1, 79) = 3.61, $p = .061$ although not significant by items, F_2 (1, 145) = 1.66, $p = .200$. The priming effect for the relatedness condition was greater for first constituents (*M* = 28.91, *SD* = 45.12) than for second constituents (*M* = 16.20, *SD* = 59.60), although their difference was not significant, t_1 (79) = 1.50, $p =$ 0.14.

Since the priming pattern was the main interest of the experiment, planned comparisons were conducted between the related and unrelated trials for each condition. The resulting priming effects are reported in Table 1. For the compound word trials, significant priming was found for the first constituent at the short SOA (t_1 (79) = 3.93, $p < 0.05$; t_2 (39)= 3.95, $p < 0.05$) and for the second constituent at the long SOA (t_1 (79) = 2.10, $p < 0.05$; t_2 = (39) 2.15, $p < 0.05$), with marginally significant priming found for the first constituent at the long SOA as well (t_1 (79) = 1.94, $p = 0.06$; t_2 (39) = 1.86, $p = 0.07$). For the pseudocompound word trials, significant priming was found for the first constituent only at both short SOA (t_1 (79) = 2.34, $p < 0.05$; t_2 (33) = 1.01, $p = 0.32$) and long SOA (t_1 (79) = 3.00, $p < 0.05$; t_2 (39) = 2.90, $p < 0.05$) at least in the subject analysis.

The same ANOVA analyses were conducted with the error rates, and revealed that compound word targets (*M* = 1.6%, *SE* = .3%) were responded with fewer errors than pseudocompound words targets (*M* = 4.8%, *SE* = .5%), F (1, 79) = 43.46, $p < .001$. A 2-way interaction between SOA and constituent was also significant, F (1, 79) = 5.84, $p < .05$. At the short SOA, first constituents had more errors than second constituents, but at the long SOA, there was no difference between the two constituents in error rates.

Discussion

The significant priming for the first constituents for both compound and pseudocompound word primes at the early SOA support the view of prelexical decomposition of morpheme-like units based on orthography. The fact that both constituents for the compound words are primed at the late SOA also supports the view that constituent morphemes are involved in whole-word processing of compound words. The result for compound words somewhat replicate that of Experiment 1 in Mathias (2006), where greater priming was found for the first constituent at early SOAs (100ms and 300ms) and comparable priming for both constituents at a late SOA (700ms). Upon seeing a compound or pseudocompound word, the word-initial constituent is rapidly segmented and activated. When the remainder of the word is also processed, if the activation of the constituents helps access the whole-word representation in the lexicon, the links between the constituents and the whole word stay active even after lexical access, hence the priming of both constituents at the late SOA.

However, it is harder to interpret the continued priming for the first constituents for the pseudocompound words at the late SOA. According to our initial hypothesis, the initial activation of the first constituent should diminish as the lexical search for the whole word representation deems it as a false lead. One possible explanation could be that the priming of the first constituent at the late SOA is purely form-related regardless of its semantic relationship to the compound or pseudocompound word preceding it. The fact that first constituent priming disappeared at 300ms and 700ms SOA in semantic priming for Mathias (2006) may support this view. Since the reversal of priming effects between constituents was found between 100ms and 300ms SOAs for Mathias (2006), the current studies chose to reduce the interval between the two SOAs in the experiment. A second experiment was conducted, with identical procedure as the first, with only an alteration to the long SOA from 500ms to 300ms.

Experiment 2:

Participants

Sixty-four undergraduate students from the University of Kansas participated in the study in order to fulfill an introductory psychology course requirement. They were all native English speakers, right-handed, and had normal or corrected to normal vision. Students who did not meet these criteria were allowed to participate but their data were not included in the analysis. Participants were randomly assigned to one of the eight lists of stimuli.

Stimuli and procedure

The same sets of stimuli and procedure were used as in Experiment 1 with the only change of the long SOA duration from 500ms to 300ms. This change was implemented by replacing all conditions with 450ms ISI to 250ms ISI in the E-prime program.

Results

Twelve of the pseudoconstituent targets were removed before analysis because their error rates were higher than 25%. Reaction times to incorrect responses and those beyond 2.5 standard deviations from the mean were also removed from the data, removing less than 5% of the data. The responses to nonword stimuli were also excluded from the analysis.

A four-way ANOVA was conducted using prime type (compound, pseudocompound), constituent position (first, second), relatedness (related, unrelated), and SOA (150ms, 300ms) as independent variables and mean reaction times as the dependent variable. For analysis by subjects (F_1), all four variables were treated as repeated measures, and for analysis by items (F_2), only relatedness and SOA were treated as repeated measures. Table 2 shows the mean reaction times and error rates under each condition for the subject analysis.

The main effect of prime type was significant by subjects, F_1 (1, 63) = 128.48, $p < .001$ and by items, F_2 (1, 141) = 56.16, $p < .001$. Targets following compound words had faster reaction times than targets following pseudocompound words. The main effect of relatedness was also significant by subjects, F_1 (1, 63) = 11.14, $p < .01$ and by items, F_2 (1, 141) = 15.23, $p < .001$. When the target was a partial repetition of the prime, the reaction time was faster. SOA also had a significant main effect by subjects, F_1 (1, 63) = 44.42, $p < .001$, and by items, F_2 (1, 141) = 36.3, $p < .001$. Target words were more quickly identified when the SOA was longer.

The main effects were qualified by a 2-way interaction between prime type and relatedness that was significant by subjects, F_1 (1, 63) = 5.74, $p < .05$, and by items, F_2 (1, 141) = 5.53, $p < .05$. The priming effect of the related condition was significant for targets of compound words (M_1 = 25.78, SD_1 = 40.48; M_2 = 26.11, SD_2 = 47.09), t_1 (63) = 5.10, $p < 0.05$; t_2 (79) = 4.96, $p < 0.05$; but not significant for targets of pseudocompound words (M_1 = 5.22, SD_1 = 52.98; M_2 = 6.61, SD_2 = 54.22), t_1 (63) = 0.79, $p = 0.43$; t_2 (64) = 0.98, $p = 0.33$).

Also, another 2-way interaction between constituent and relatedness was found to be significant by both subjects, F_1 (1, 63) = 8.01, $p < .01$ and items, F_2 (1, 141) = 89.2, $p < .01$. The priming effect of the related condition was significant for first constituents (M_1 = 31.33, SD_1 = 55.92; M_2 = 28.98, SD_2 = 51.79), t_1 (63) = 4.48, $p < 0.05$; t_2 (72) = 4.78, $p < 0.05$; but not significant for second constituents (M = 3.47, SD = 49.34; M_2 = 5.59, SD_2 = 47.54), t_1 (63) = 0.56, $p = 0.58$; t_2 (71) = 1.00, $p <$ 0.32.

As in Experiment 1, planned comparisons were conducted between the related and unrelated trials for each condition. The resulting priming effects are reported in Table 2. For the compound word trials, significant priming was found for the first constituent at both short SOA (t_1 (63) = 3.93, $p < 0.05$; t_2 (39) = 3.22, $p <$ 0.05) and long SOA (t_1 (63) = 3.44, $p < 0.05$; t_2 (39) = 3.24, $p < 0.05$), and for the second constituent at the long SOA (t_1 (63) = 2.15, $p < 0.05$; t_2 (39) = 1.47, $p = 0.15$) by subjects. For the pseudocompound word trials, significant priming was found for the first constituent only at the short SOA (t_1 (63) = 2.39, $p < 0.05$; t_2 (32) = 2.14, $p <$ 0.05).

Another ANOVA was conducted with the error rates of the data and revealed that compound word targets (M = 1.9%, SE = .3%) were responded with fewer errors than pseudocompound words targets (M = 4.9%, SE = .5%), F (1, 63) = 38.02, $p <$ .001. A main effect of constituent also approached significance, F (1, 63) = 3.86, p = .054, with the first constituents having more errors (M = 3.9%, SE = .5%) than the second constituents (*M* = 2.8%, *SE* = .4%). A 2-way interaction between prime and constituent was significant, $F(1, 63) = 6.81$, $p < .05$. For the compound word targets, the error rates did not differ significantly between the two constituents, but for the pseudocompound word targets, the first constituents had more errors than the second constituents.

Discussion

The significant priming for the first constituent at the early SOA for both compound words and pseudocompound words was replicated in Experiment 2, supporting the view of early decomposition of constituents based on the orthographic structure. The compound words continued to prime their first constituents and also primed their second constituents at the 300ms SOA, suggesting that the decomposition activated both constituents of the compound words. On the other hand, neither constituent is primed for the pseudocompound words at the longer SOA, suggesting that the effects of the early decomposition at 150ms did not survive. These results support the hypothesis that, whereas decomposition at the early stage occurs equally for both compound and pseudocompound words, only the constituents of the real compound words continue to be active as they lead to the activation of the correct lexical representation. By 300ms, the whole-word form of the pseudocompound words has been processed and information from the pseudoconstituents is discarded, resulting in a loss of priming at the longer SOA.

General Discussion

The results of this study provide additional support for the early decomposition account based on the orthographic structure of multimorphemic words in English. Compound words primed their first constituent at an early SOA, and continued to prime it along with the second constituent at later SOAs, resulting in a similar pattern of findings as previous studies (Feldman, 2000; Mathias, 2006). Pseudocompound words showed initial priming of the first constituent at an early SOA but no priming at an intermediate SOA, supporting the hypothesis that structure-based decomposition happens early in the process, but is quickly overwritten when it does not aid the lexical search. The strong priming at the longest SOA for the first constituent of the pseudocompound words is rather enigmatic, and further research may be necessary to fully understand its source.

The SOAs used in this study provide some insight about the order of different stages in the process. By 150ms, the words are parsed into morpheme-like segments and the representation of the first constituent is already activated. Between 150 and 300ms, the second constituent is also accessed, and for the compound words, it consequently leads to the lexical access of the whole word. For the pseudocompound words, the constituent activation does not lead to the correct lexical representation, so their representations are discarded and the information from the prime is processed at its whole-word level. Between 300ms and 500ms, the constituents of the compound words continue to be primed as their lexical representations are also conceptually linked to the whole-word representations. On the other hand, the pseudocompound words have been accessed through their whole-word form, and do not have any basis to prime their constituents except for the form overlap between them. This whole-word form may even have been processed via the GPC route according to the DRC model (Coltheart, et al., 2001), priming the first constituent phonologically at the latest SOA. The fact that only the first constituent is primed may suggest a position effect where the first syllable of a word is used as a search index (Taft & Forster, 1976).

This interpretation is similar to that taken from the ERP results of Lavric et al. (2007). They compared word pairs with transparent morphological relationships (e.g. *cleaner-clean*), opaque morphological relationships (e.g. *corner-corn*), and mere orthographic overlap (*brothel-broth*). Even for the orthographic overlap condition, early positivity (hence more facilitative relationship) in waveforms between 140ms and 260ms was found, and although not as long-lived and robust as with the morphological pairs, an attenuation of the N400 component was found as well, revealing some form of facilitation compared to the completely unrelated condition. While the source and nature of these early and late signs of facilitation between merely orthographically related words are unclear at this point, they show a unique pattern that is distinguishable from the morphologically related pairs.

To understand the timecourse of priming found in the present studies, it may be useful to take the approach of the connectionists and suppose that the source of priming is the overlapping features between the prime and the target. In this sense, the compound word trials have orthography, phonology, and semantics as sources of facilitation while pseudocompound words have the former two, but lack semantics. One way of testing that semantics as a source of priming is only present for the compound word trials would be to conduct priming experiments using semantic associates of the constituents as targets following compound or pseudocompound primes. Evidence for influence of semantics has been found in Mathias (2006), where significant priming was produced for semantic associates of the first constituent at 100ms SOA and for the second constituent at 300ms and 700ms SOAs. Also, Sandra (1990) and Zwitserlood (1994) showed that, even for legitimate compound words, when the prime-target relationship was semantically opaque, no priming was found when semantic associates replaced, although the prime durations were long enough to allow for conscious processing in these studies. Likewise, replicating the current studies with semantic associates of the constituents as targets may only find priming for the compound word condition, similar to the results of Mathias (2006). There is also a possibility of priming for the pseudcompound word condition at short SOAs, if the early morphological segmentation involves active lexical search via the segmented morphemes. In such a case, the falsely activated constituents may prime the semantic associates at first, but as their activation does not lead to the correct lexical item, their effects would disappear at later SOAs, similar to the results of the current studies. If the parsing is purely orthographical and does not include efforts of lexical access according to the morphological constituents, no priming should be found between pseudocompound words and the semantic associates of their "constituents" even at short SOAs.

Teasing out the overlap between orthography and phonology can also be done by adding another type of pseudocompounds words, where the pronunciation of the constituents are not preserved in the whole word (e.g. *hatred*). Using such stimuli would help examine the curious presence of priming at 500ms for the first constituents of pseudocompound words found in the current studies. If the source of that effect is indeed late-surfacing phonology, it should not happen with phonologically opaque pseudocompound words. On the other hand, the priming of the first constituent found at the early SOA should remain the same if the parsing was indeed due to the orthographical structure of the whole word.

There may be other factors influencing the recognition of multimorphemic words versus monomorphemic words beyond form and meaning. For example, studies with suffixed or prefixed stimuli (e.g. Taft & Forster, 1975; Rastle et al., 2004) are subject to the criticism that the limited number and high regularity and frequency of affixes make their recognition procedure less generalizable to other complex words (Longtin, Segui, & Halle, 2003). In other words, how often a particular morpheme appears as part of a word can have an influence on how the word is recognized. For example, morphological family size (the number of morphologically related words) is found to have a facilitative effect on the recognition of a monomorphemic word (Schreuder & Baayen, 1997). This result was replicated in an MEG study in both lexical decision times and M350 latencies (Pylkkänen, Feintuch, Hopkins, & Marantz, 2004), suggesting an early influence of morphological family size on word recognition. Whether such effects are found in constituents of compound words and whether they affect the process of multimorphemic word recognition differently from monomorphemic words will need to be further examined.

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Table 1

Mean reaction times (in milliseconds) and error rates (in percentages) in Experiment 1

Condition		Related		Unrelated		U - R	
		RT	Error	RT	Error	RT	Error
Compound word							
150ms SOA	Const. 1	645 (101)	1.3 (5.1)	681 (97)	2.8 (8.3)	36*	1.4
	Const. 2	661 (99)	1.0 (4.4)	672 (89)	1.3 (4.9)	11	0.3
500ms SOA	Const. 1	608 (101)	1.1 (4.7)	630 (102)	1.3 (5.8)	22(*)	0.2
	Const. 2	620 (114)	2.1 (6.2)	644 (97)	2.0 (6.0)	23*	-0.1
Pseudocompound word							
150ms SOA	Const. 1	710 (110)	6.9 (12.1)	739 (121)	6.3 (16.3)	30*	-0.6
	Const. 2	689 (115)	3.1 (10.2)	707 (104)	3.9 (11.0)	18	0.8
500ms SOA	Const. 1	660 (109)	5.7 (12.6)	706 (130)	3.6 (8.2)	47*	-2.1
	Const. 2	671 (105)	3.5 (9.0)	683 (101)	5.7 (13.7)	12	2.2

(*) $p < .10$; * $p < .05$. $n = 80$.

Table 2

Mean reaction times (in milliseconds) and error rates (in percentages) in Experiment 2

Condition		Related		Unrelated		U - R	
		RT	Error	RT	Error	RT	Error
Compound word							
150ms SOA	Const.1	597 (95)	2.0 (6.1)	638 (89)	0.6 (3.5)	41**	1.3
	Const. 2	629 (99)	1.6 (6.5)	637 (86)	1.9 (6.9)	8	-0.3
300ms SOA	Const. 1	579 (92)	2.2 (7.2)	612 (86)	1.9 (6.9)	33**	0.3
	Const. 2	585 (79)	2.9 (7.2)	604 (78)	2.0 (6.1)	18*	0.9
Pseudocompound word							
150ms SOA	Const.1	664 (97)	8.0 (12.6)	697 (102)	5.6 (10.9)	33*	2.5
	Const. 2	679 (109)	4.0 (11.3)	670 (104)	4.7 (10.8)	-9	-0.7
300ms SOA	Const. 1	649 (116)	4.4 (11.4)	661 (97)	7.0 (13.5)	12	-2.6
	Const. 2	646 (107)	1.5 (5.8)	631 (95)	4.0 (9.9)	-15	-2.5

* p < .05; ** p < .01. n = 64.

Appendix 1: Consent Form for Experiments 1 and 2.

INFORMED CONSENT STATEMENT

TITLE OF STUDY: Morphological processing of compound and pseudocompound words

INTRODUCTION

The Department of Psychology at the University of Kansas supports the practice of protection for human subjects participating in research. The following information is provided for you to decide whether you wish to participate in the present study. You may refuse to sign this form and not participate in this study. You should be aware that even if you agree to participate, you are free to withdraw at any time. If you do withdraw from this study, it will not affect your relationship with this unit, the services it may provide to you, or the University of Kansas.

PURPOSE OF THE STUDY

The purpose of this study is to look at the influence of word structure on word reading.

PROCEDURES

You will be asked to read a list of words and nonwords. Each will be presented, one at a time, on a computer screen, and you will decide whether each item presented is either a word or a nonword. Reaction times will be recorded. The experiment will take approximately 20 minutes to complete.

RISKS

It is not anticipated that there are any risks associated with your participation in this study.

BENEFITS

Participating in this study will not benefit you directly. However, understanding how words are processed may help us understand the type of information people use as they learn to read, and may therefore help us understand reading and difficulties in learning to read.

PAYMENT TO PARTICIPANTS

By participating in this study, you will receive credit in your General Psychology course.

PARTICIPANT CONFIDENTIALITY

In this study, information will be collected only from the study activities listed in the Procedures section of this consent form. Your name will not be associated in any way with the research findings from this study. The researcher will use a study number instead of your name. The information collected about you will be used only by Un So Park, or Dr. Greg B. Simpson. The researchers will not share information about you with anyone not specified above unless required by law or unless you give written permission. Permission granted on this date to use and disclose your information remains in effect indefinitely. By signing this form you give permission for the use and disclosure of your information for purposes of this study at any time in the future.

REFUSAL TO SIGN CONSENT AND AUTHORIZATION

You are not required to sign this Consent and Authorization form and you may refuse to do so without affecting your right to any services you are receiving or may receive from the University of Kansas or to participate in any programs or events of the University of Kansas. However, if you refuse to sign, you cannot participate in this study.

CANCELLING THIS CONSENT AND AUTHORIZATION

You may withdraw your consent to participate in this study at any time. You also have the right to cancel your permission to use and disclose information collected about you, in writing, at any time, by sending your written request to: Dr. Greg B. Simpson or Un So Park, 1415 Jayhawk Blvd., Lawrence, KS 66045.

QUESTIONS ABOUT PARTICIPATION

Questions about procedures should be directed to the researcher(s) listed at the end of this consent form.

PARTICIPANT CERTIFICATION:

I have read this Consent and Authorization form. I have had the opportunity to ask, and I have received answers to, any questions I had regarding the study. I understand that if I have any additional questions about my rights as a research participant, I may call (785) 864-7429 or (785) 864-7385 or write the Human Subjects Committee

Lawrence Campus (HSCL), University of Kansas, 2385 Irving Hill Road, Lawrence, Kansas 66045-7563, email dhann@ku.edu or mdenning@ku.edu.

I agree to take part in this study as a research participant. By my signature I affirm that I am at least 18 years old and that I have received a copy of this Consent and Authorization form.

_______________________________ _____________________

Type/Print Participant's Name Date

____

Participant's Signature

Researcher Contact Information

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Appendix 2: Instructions for Experiments 1 and 2.

Focus on the fixation mark (+) at the center of the screen for the whole experiment duration. At times the mark will change into a string of hashmarks (###..), and then into a string of letters. If those strings of letters make a word in English, press the letter l on the keyboard as accurately and fast as possible. If those strings of letters do not make a word in English, press the letter a as accurately and fast as possible.

Appendix 3: Stimuli used in Experiments 1 and 2.

For the word-word pairs, 40 compound words and 40 pseudocompound words were divided into 4 groups and were assigned a different code. For each list, each code represented a different condition. The 1st constituent related condition was assigned to code 1 in lists 1 and 5, to code 2 in lists 2 and 6, to code 3 in lists 3 and 7, and to code 4 in lists 4 and 8. The 2nd constituent related condition was assigned to code 2 in lists 1 and 5, to code 1 in lists 2 and 6, to code 4 in lists 3 and 7, and to code 3 in lists 4 and 8. The 1st constituent unrelated condition was assigned to code 3 in lists 1 and 5 (by pairing the targets with the 1st constituents from the primes of code 2), to code 4 in lists 2 and 6 (by pairing the targets with the 1st constituents from the primes of code 1), to code 1 in lists 3 and 7 (by pairing the targets with the 1st constituents from the primes of code 4), and to code 2 in lists 4 and 8 (by pairing the targets with the 1st constituents from the primes of code 3). The 2nd constituent unrelated condition was assigned to code 4 in lists 1 and 5 (by pairing the targets with the 2nd constituents from the primes of code 1), to code 3 in lists 2 and 6 (by pairing the targets with the 2nd constituents from the primes of code 2), to code 2 in lists 3 and 7 (by pairing the targets with the 2nd constituents from the primes of code 3), and to code 1 in lists 4 and 8 (by pairing the targets with the 2nd constituents from the primes of code 4). The SOA condition alternated within each list, starting with the short SOA for the first four lists and starting with the long SOA for the last four lists.

Compound words and their constituents			**code**
bathrobe	bath	robe	1
classroom	class	room	1
doorbell	door	bell	1

downfall	down	fall	1
firefight	fire	fight	1
headband	head	band	1
lipstick	lip	stick	1
necktie	neck	tie	1
sandstorm	sand	storm	1
teacup	tea	cup	1
beefsteak	beef	steak	2
earwax	ear	wax	2
junkyard	junk	yard	2
matchbox	match	box	2
meatball	meat	ball	2
nosebleed	nose	bleed	2
playmate	play	mate	2
roadkill	road	kill	2
sawdust	saw	dust	2
tollgate	toll	gate	2
bellboy	bell	boy	3
blindfold	blind	fold	3
eyewear	eye	wear	3
fireplace	fire	place	3
landmine	land	mine	3
lifelong	life	long	3
moonlight	moon	light	3
pancake	pan	cake	3
sleepwalk	sleep	walk	3
toothpick	tooth	pick	3
dewdrop	dew	drop	4
flashbulb	flash	bulb	4
leafstalk	leaf	stalk	4
nailbrush	nail	brush	4
playtime	play	time	4
racehorse	race	horse	4
railroad	rail	road	4
snowball	snow	ball	4
sunshine	sun	shine	4
watchdog	watch	dog	4

Pseudocompound words and their constituents			**Code**
brandish	bran***	dish	1
capsize	cap	size	1
carbide	car	bide***	1
content	con*	tent	1
furlong	fur	long	1

hemlock	hem***	lock	1
mandrill	man	drill	1
profile	pro	file	1
shamrock	sham***	rock	1
tadpole	tad**	pole	1
brimstone	brim**	stone	2
cartridge	cart	ridge	2
fanfare	fan	fare	2
margin	mar***	gin	2
napkin	nap	kin**	2
rampart	ram	part	2
ransack	ran	sack	2
scarlet	scar	let	2
sirloin	sir	loin	2
target	tar	get	2
bulldoze	bull	doze**	3
carpet	car	pet	3
cashmere	cash	mere***	3
furrow	fur	row	3
handsome	hand	some	3
mayhem	may	hem***	3
mushroom	mush	room	3
parsnip	par***	snip	3
rickshaw	rick	shaw***	3
sublime	sub	lime	3
canteen	can	teen	4
castrate	cast	rate	4
hoodlum	hood	lum***	4
palmate	pal	mate	4
penchant	pen	chant	4
pumpkin	pump	kin**	4
rampage	ram	page	4
sexton	sex	ton	4
tablet	tab	let	4
warlock	war	lock	4

* excluded from analysis in Experiment 1;
** excluded from analysis in Experiment 2;
*** excluded from analysis in Experiment 1 and Experiment 2.

Only one list was created for the nonwords. Code 1 represents 1st constituent related condition, code 2 represents 2nd constituent related condition, code 3 represents 1st constituent unrelated condition, and code 4 represents 2nd constituent unrelated condition. This time, the swapping of constituents for the unrelated condition was done between compoundwords and pseudocompound words (e.g. pseudocompound prime *bargain* is paired with nonword *birt* which comes from compound prime *birthday*).

Compound primes and their nonword targets		**Code**	**Pseudocompound primes and their nonword targets**		**Code**
armchair	arn	1	banking	bal	1
bookcase	bool	1	centrum	ceng	1
coastline	coasp	1	cocktail	cuck	1
drugstore	drux	1	crawfish	crar	1
flaxseed	flac	1	hammock	hom	1
lambskin	lomb	1	putrid	pum	1
paycheck	pai	1	rattan	ral	1
popcorn	pon	1	scabbard	scap	1
raincoat	raen	1	vanguard	ven	1
schoolbag	schoul	1	buckthorn	thurn	2
snakebite	snace	1	claybank	benk	2
birdcage	caze	2	cordwain	wein	2
cheekbone	bome	2	cudbear	baar	2
crossword	wurd	2	portray	fut	2
eggshell	shel	2	rarebit	tal	2
lakeshore	shure	2	reptile	barp	2
molehill	holl	2	stubborn	nant	2
peephole	hule	2	whippet	luss	2
postmark	malk	2	bargain	birt	3
sailboat	boet	2	bumper	cheet	3
seafood	foud	2	confine	criss	3
swimsuit	suid	2	dewlap	agg	3
birthday	buct	3	farrow	lage	3
daybreak	clat	3	partridge	mohl	3
earpiece	coid	3	perform	peap	3
endnote	cux	3	sonnet	bost	3
fistfight	purt	3	tendon	sael	3
lamplight	rart	3	windlass	seaf	3
nightcap	rel	3	winsome	swin	3
oilcloth	stup	3	barrack	cheir	4

washcloth	whib	3	cantrip	cese	4
clipboard	keng	4	cultrate	lile	4
doorplate	trum	4	donkey	sture	4
endmost	taim	4	parson	sead	4
eyedrop	figh	4	penstock	stin	4
keyboard	meck	4	profit	chack	4
lifeguard	bik	4	tenant	corl	4
nightgown	tyle	4	warden	coet	4
tombstone	nat	4	winnow	bak	4
woodpile	det	4	woodruff	bibe	4

Appendix 4: Mean reaction times by subject for each condition in Experiment 1.

	Compound words							
	150ms SOA				500ms SOA			
	C 1		C 2		C 1		C 2	
Subject	**U**	**R**	**U**	**R**	**U**	**R**	**U**	**R**
1	660	569	717	678	576	584	627	545
2	586	520	650	594	613	564	628	650
3	661	591	641	645	606	642	602	705
4	684	658	650	852	531	706	530	663
5	605	595	559	664	618	544	538	590
6	541	630	560	615	566	490	508	544
7	692	681	658	556	603	569	727	615
8	549	533	534	540	464	481	470	502
9	602	600	612	651	517	711	565	572
10	721	738	680	717	650	748	590	726
11	782	741	863	757	662	717	728	703
12	583	520	554	518	543	462	542	401
13	596	559	620	544	555	530	571	558
14	652	633	660	685	650	807	720	686
15	887	777	946	755	828	716	820	936
16	710	676	751	793	615	703	708	749
17	528	443	466	498	502	484	492	428
18	592	562	635	522	574	581	643	640
19	650	696	774	844	634	668	500	805
20	725	776	611	657	678	511	700	508
21	618	650	743	652	641	620	688	672
22	1053	895	855	1006	709	604	757	647
23	704	614	627	683	520	797	760	740
24	546	551	561	572	693	481	643	548
25	647	604	621	686	678	531	702	565
26	642	528	628	616	517	521	534	549
27	765	609	656	678	688	584	639	582
28	830	863	679	733	634	690	698	772
29	837	568	775	754	667	691	651	609
30	653	530	662	561	934	593	718	697
31	804	764	714	702	700	669	718	676
32	578	593	578	624	657	536	512	671
33	697	723	801	752	658	583	658	845
34	631	679	626	577	689	625	535	600
35	707	691	740	642	648	613	727	546
36	705	660	738	619	523	575	572	705
37	601	526	582	644	451	454	526	455
38	608	712	689	745	866	685	892	709

39	622	497	679	595	606	496	709	555
40	679	610	695	674	620	612	592	513
41	811	839	862	928	814	871	980	947
42	753	617	697	608	594	626	607	577
43	905	1002	900	875	837	922	855	1019
44	554	607	547	519	496	438	525	477
45	651	571	652	643	538	673	547	581
46	667	681	635	757	710	648	670	601
47	754	593	648	723	662	605	619	678
48	607	700	730	734	736	666	736	632
49	720	687	829	764	749	696	744	564
50	620	757	624	670	530	592	610	539
51	648	581	631	555	663	552	678	518
52	717	668	682	647	582	502	800	586
53	798	590	643	616	625	687	677	598
54	661	569	658	547	478	506	585	486
55	829	689	632	763	685	566	720	550
56	584	590	586	550	658	574	561	596
57	551	560	675	559	540	503	600	545
58	666	672	824	723	664	666	717	622
59	653	639	638	801	623	547	641	631
60	624	534	584	552	631	443	475	494
61	789	777	738	686	731	816	715	747
62	688	577	708	551	523	545	707	517
63	574	551	555	565	564	573	623	579
64	731	689	722	696	628	593	612	568
65	700	604	624	639	529	506	633	593
66	684	757	561	629	580	613	599	456
67	565	492	585	489	417	509	470	508
68	801	622	653	788	536	536	598	524
69	635	632	691	669	691	720	652	647
70	735	616	721	741	619	509	613	597
71	672	810	643	595	645	727	590	653
72	571	559	582	569	551	492	562	543
73	781	617	683	639	653	771	662	701
74	629	634	718	554	719	601	571	540
75	794	838	770	632	942	684	730	838
76	634	691	618	637	820	662	696	627
77	806	794	713	660	677	598	628	713
78	628	648	589	711	604	600	602	567
79	788	579	778	676	561	540	732	694
80	583	638	654	654	543	613	704	594

Pseudocompound words								
	150ms SOA				500ms SOA			
	C 1		C 2		C 1		C 2	
Subject	U	R	U	R	U	R	U	R
1	728	744	612	714	739	897	551	558
2	644	636	616	667	781	713	663	732
3	658	636	560	686	854	731	642	631
4	746	641	599	788	713	672	522	871
5	682	692	576	732	734	535	612	607
6	632	698	605	544	516	590	535	595
7	654	767	618	682	749	543	585	631
8	643	588	566	580	537	471	525	712
9	621	588	649	616	648	526	564	608
10	769	852	750	679	621	573	679	724
11	795	777	861	695	770	837	721	727
12	634	561	659	604	664	547	525	611
13	553	675	671	544	691	674	550	522
14	762	776	658	717	805	839	824	738
15	802	938	806	888	643	857	728	782
16	754	782	784	676	1021	584	718	705
17	604	526	517	462	499	557	524	482
18	846	652	668	795	874	670	907	598
19	715	698	703	961	1028	680	758	814
20	872	1014	697	693	586	729	762	646
21	838	670	684	666	901	772	845	643
22	928	1006	805	678	1004	932	784	618
23	721	648	611	621	652	581	717	688
24	678	515	570	501	642	818	575	654
25	832	733	894	683	694	660	664	640
26	618	656	640	635	942	506	779	624
27	727	830	772	716	610	718	680	637
28	857	844	710	779	716	737	676	802
29	987	721	707	697	824	612	718	722
30	699	855	718	791	661	670	860	705
31	770	744	705	778	711	765	751	732
32	567	700	566	798	600	664	639	638
33	831	717	860	787	823	825	895	789
34	653	647	753	647	621	644	632	536
35	718	637	686	683	952	713	797	667
36	748	737	696	716	685	523	649	598
37	736	731	692	542	551	550	590	569
38	926	754	909	705	652	740	854	712
39	587	768	630	637	642	725	574	577
40	718	731	703	738	686	586	662	659

41	941	1005	829	1181	1003	734	804	1078
42	711	654	685	650	603	689	733	701
43	1256	1024	965	959	860	833	863	917
44	595	636	600	582	561	539	663	578
45	771	802	699	664	650	646	612	630
46	811	550	785	858	723	730	750	735
47	687	617	713	787	909	804	624	569
48	730	734	776	650	777	858	708	611
49	676	743	819	741	654	605	656	702
50	735	699	739	693	521	554	650	539
51	658	645	842	594	728	676	682	700
52	708	800	731	712	624	819	807	669
53	705	846	718	650	629	563	784	796
54	712	613	604	593	469	542	604	504
55	675	613	911	798	677	426	539	473
56	624	741	845	626	764	654	631	555
57	669	615	866	499	582	583	600	619
58	742	658	864	703	761	674	741	773
59	705	709	704	691	540	663	636	677
60	566	615	555	537	659	533	556	584
61	799	706	963	832	829	700	636	722
62	890	684	633	560	576	683	721	597
63	651	691	576	546	588	743	643	669
64	715	726	741	727	639	733	713	687
65	709	643	611	559	523	587	620	596
66	659	546	671	612	729	637	666	755
67	648	627	569	610	699	566	575	550
68	691	769	656	619	655	568	668	796
69	586	752	625	653	680	616	763	639
70	814	703	720	706	798	593	698	711
71	677	644	712	697	746	665	717	707
72	650	563	583	738	560	569	567	596
73	730	644	639	700	907	519	656	757
74	660	552	604	652	505	542	600	516
75	866	852	791	923	721	801	870	912
76	808	806	637	743	820	581	586	733
77	975	657	759	749	741	629	669	878
78	831	589	771	572	722	567	707	659
79	1128	764	873	551	688	792	945	632
80	743	681	728	693	647	597	722	653

Appendix 5: Mean reaction times by subject for each condition in Experiment 2.

	Compound words							
	150ms SOA				300ms SOA			
	C 1		C 2		C 1		C 2	
Subject	**U**	**R**	**U**	**R**	**U**	**R**	**U**	**R**
1	730	682	740	517	741	717	829	629
2	683	589	706	744	683	640	603	604
3	659	783	621	742	640	698	604	728
4	621	554	605	591	619	605	585	610
5	551	506	596	506	506	442	448	506
6	942	757	743	747	717	636	716	729
7	544	546	605	695	666	458	635	502
8	599	628	615	558	611	448	488	474
9	623	605	712	658	658	578	660	702
10	660	552	730	780	637	590	618	688
11	596	542	650	593	565	470	587	642
12	564	585	610	614	603	520	633	607
13	635	569	562	583	617	551	561	598
14	595	635	569	604	483	535	629	622
15	732	764	736	737	760	678	787	720
16	659	767	837	743	646	661	659	738
17	508	598	572	525	618	549	657	520
18	521	530	550	566	548	593	531	443
19	625	697	700	697	642	591	685	587
20	514	532	550	536	519	474	556	539
21	575	539	564	649	557	617	610	531
22	570	586	532	773	578	480	626	564
23	731	770	718	899	684	824	681	644
24	650	581	534	543	530	590	654	514
25	676	568	715	630	587	546	589	654
26	621	668	634	741	869	652	640	672
27	718	606	691	698	678	643	583	631
28	620	612	661	657	561	590	625	664
29	694	536	619	582	591	548	512	526
30	673	573	610	554	656	666	569	584
31	869	890	871	855	779	725	718	733
32	642	618	715	588	597	552	612	527
33	773	613	687	670	806	587	680	623
34	628	515	595	489	537	470	524	502
35	488	434	491	443	567	476	478	474
36	552	503	584	611	552	667	534	569

37	660	579	616	666	630	599	636	543
38	505	471	565	553	443	448	510	458
39	706	511	638	668	586	550	583	577
40	675	567	766	690	586	589	578	567
41	679	547	534	569	530	479	507	460
42	697	708	748	711	657	700	686	635
43	697	575	676	662	641	621	636	583
44	665	580	607	605	613	556	590	564
45	576	550	547	575	610	551	540	532
46	570	617	566	547	479	479	631	486
47	608	541	634	512	544	552	606	486
48	619	533	604	568	521	508	549	585
49	623	590	655	608	561	551	574	555
50	617	625	703	589	738	635	531	569
51	507	543	566	562	558	438	534	501
52	690	574	690	754	625	571	512	585
53	532	536	586	504	577	627	542	517
54	661	477	621	589	573	558	539	581
55	656	657	530	589	594	548	595	545
56	692	501	567	598	501	470	564	605
57	599	512	606	618	580	712	605	672
58	595	553	581	672	583	606	637	533
59	538	564	593	503	527	433	477	565
60	830	901	917	901	812	771	844	793
61	751	722	713	718	692	829	682	678
62	538	475	597	509	570	565	666	495
63	780	509	543	493	722	513	616	608
64	521	659	551	611	491	507	549	571

Pseudocompound words								
	150ms SOA				**300ms SOA**			
	C 1		**C 2**		**C 1**		**C 2**	
Subject	**U**	**R**	**U**	**R**	**U**	**R**	**U**	**R**
1	835	693	675	962	709	804	627	783
2	747	656	542	798	802	656	670	667
3	649	590	716	667	866	567	733	763
4	720	902	670	681	636	729	649	892
5	667	598	577	564	633	463	459	487
6	620	807	732	607	618	777	740	632
7	907	650	647	667	654	549	596	588
8	600	691	590	616	713	671	686	543
9	807	719	661	778	675	769	664	630
10	628	689	689	866	568	689	707	707

11	675	615	618	519	623	502	576	541
12	730	702	1032	679	589	653	649	714
13	681	625	618	602	574	591	630	659
14	684	584	704	664	566	610	529	619
15	918	684	819	743	704	706	674	821
16	628	704	571	753	665	896	830	732
17	712	682	719	555	578	609	674	522
18	558	652	567	494	628	661	616	537
19	648	786	681	595	803	611	705	697
20	667	598	862	526	524	531	550	665
21	675	671	624	669	587	582	662	549
22	783	589	605	716	679	521	582	557
23	792	818	735	868	779	791	639	957
24	538	584	825	594	718	646	652	645
25	809	905	614	767	770	816	673	716
26	746	737	808	700	763	862	640	648
27	844	653	682	768	678	770	637	679
28	731	773	721	576	631	679	564	639
29	697	624	656	624	621	553	711	589
30	651	680	629	775	596	702	533	691
31	817	710	941	776	684	869	904	834
32	745	582	735	650	849	893	653	711
33	801	721	735	759	893	864	684	738
34	637	670	578	610	510	543	677	583
35	577	523	550	613	698	467	486	510
36	640	715	616	577	557	691	673	549
37	803	644	610	777	795	798	555	656
38	512	470	527	518	603	419	467	512
39	793	843	604	584	759	748	647	729
40	644	705	633	789	741	709	621	641
41	601	644	667	557	531	606	623	488
42	650	744	790	666	566	672	662	653
43	740	711	609	672	632	757	657	650
44	677	598	583	871	684	589	677	676
45	626	481	593	613	612	508	529	594
46	816	544	629	661	517	530	556	538
47	642	619	641	691	562	511	579	538
48	652	709	606	728	677	549	584	541
49	621	846	663	810	604	637	646	567
50	759	609	652	732	668	659	790	803
51	559	511	548	581	550	614	710	772
52	907	725	776	814	621	623	508	720
53	580	523	712	583	508	599	509	532
54	651	593	583	604	648	722	692	533

55	514	614	733	682	621	569	441	592
56	771	531	530	831	678	474	606	657
57	540	548	747	582	808	634	599	604
58	628	635	585	609	631	634	600	588
59	687	592	692	633	613	600	476	544
60	876	844	958	1008	910	785	898	858
61	689	717	713	703	800	666	700	834
62	581	532	625	544	566	503	562	489
63	895	680	574	617	650	539	704	664
64	613	681	546	623	589	564	463	573