MORPHOLOGICAL PRODUCTIVITY AND THE DECOMPOSITION OF COMPLEX WORDS

By

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Abstract

This thesis addresses the role that morphological productivity plays in the process of morphological decomposition. Understanding the role of productivity is crucial, as previous literature has shown words to be decomposable across-the-board into their morphemic parts or employing both decomposition into morphemic parts and whole-word storage. Previous research has also shown that in a masked priming experiment, morphologically complex words are decomposed in terms of morphological parts (e.g., *cleaner*; *clean* + -*er*) and potential morphological parts (e.g., *corner*; *corn* + -*er*). However, the extent to which properties beyond morpho-orthographic segmentation, such as productivity, constrains this process remains unclear.

In a masked priming experiment, we examined the role of productivity in morphologically complex word processing, testing whether both morphologically complex words with productive (e.g., *-ness*) and unproductive (e.g., *-ity*) suffixes are decomposed into morpheme-level constituents or whether only productive suffixes are decomposed while unproductive are stored. Our response time results did not support morpheme-level processing, as all of our conditions showed similar priming results. However, our accuracy results argue for a decomposition process sensitive to potential morphologically-complex and potential morphological words. We conclude based on the response time and accuracy differences that the priming effects in our experiment were not modulated by our productivity manipulation. Therefore, productivity is not a factor that constrains the initial stages of lexical access.

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1 Introduction

A wide array of psycholinguistic literature discusses the nature of complex word recognition (e.g., cleaner, humidity, abruptness). The past several years have shown us ample evidence that these types of items are actually "decomposed" into their constituent morphemes (e.g., *clean* + *er*). However, what still remains unclear is what constraints there are on the decomposition process, particularly at the early stages of lexical processing. What kind of items decompose? Are there items that are not decomposed because of a particular morphological constraint? This thesis attempts to answer these questions based on the types of suffixes that are attached to a root, or base of a word. Specifically, we will investigate whether or not productivity plays a role in the early stages of decomposition.

Literature on the morphological decomposition of complex words is divided into two theories, or approaches. The first being that words are accessed as non-decompositional items, or whole-word chunks or Atoms (Butterworth, 1983; Devlin, Jamison, Matthews, & Gonnerman, 2004); the other states words are retrieved as separate morphological constituents (Baayen, 1994; Fiorentino & Poeppel, 2007; Marslen-Wilson, Tyler, Waksler, & Older, 1994; Taft & Forster, 1975). Some researchers claim decomposition occurs only with semantically transparent words (Marslen-Wilson et al., 1994), while others claim that semantics does not play a role and the role of morphology, or the appearance of a morphological structure (e.g., corner−CORN), is what aids in decomposition (Rastle, Davis, & New, 2004).

In this thesis I will address whether morphologically complex affixed words that include a productive (e.g., *-ness*) or unproductive (e.g., *-ity*) suffix will decompose into their constituent morphemes, which include root + suffix, at the early stages of lexical processing.

Lexical access models make distinct predictions regarding the role of particular properties of morphology and lexical retrieval. The Dual-Route model posits that words are decomposed into their constituent parts and retrieved as whole-word chunks (e.g., Pinker & Ullman, 2002). The full-decomposition approach (e.g., Taft, 2004) posits complex words will be decomposed into their constituent morphemes. Finally, a Storage model (e.g., Butterworth, 1983; Bybee, 1995), or non-decompositional model, posits there is no abstract representation in this or other morphologically complex structures. All words, whether inflected or derived, are listed in the mental lexicon.

Background studies
Evidence for morphological decomposition

Taft and Forster (1975) were among the first to perform a lexical decision task testing morphological access of derivational affixes. They conducted a lexical decision experiment in which subjects were presented with each item for 500 ms and an intertrial interval (ITI) of four seconds. Subjects were presented with either nonword stem of a derived word (e.g., *juvenate*), a free morpheme and also has a lexical feature of a bound morpheme (e.g., *vent* is either an outlet for air or a morpheme in *prevent*), pseudo-stem word (e.g., *pertoire*), prefixed word (e.g., *rejuvenate*), or a pseudo-prefixed word (e.g., *dejuvenate* or *depertoire*). Taft and Forster conclude that subjects would strip off the affix of polymorphemic words encountered as the method to determine whether the word they are presented is a word in English or not. In doing so, they found real-word stem items would provide a longer response time than non-word stem items because there is an extra step in the search in the mental lexicon. Their study concluded that morphological decomposition occurs prior to a mental lexical search, based on response times of (pseudo)stems (e.g., pseudo-stem: *pertoire*; real stem: *juvenate*) of either prefixed (e.g., *rejuvenate*) or pseudo-prefixed words (e.g., *dejuvenate* or *depertoire*).

Similarly, Taft (1979) tested whether the base frequency had a role in the response times (RTs) of inflected and derived words. He hypothesized that if complex words are accessed as a whole unit, then the frequency of the base should not have an effect on the RT in a lexical decision task. If complex words were accessed by morphemes, the frequency will play a role and either slow (low frequency) or speed up (high frequency) the RT. Taft's results confirmed his hypothesis: words with a high frequency base were responded to more quickly than low frequency base words.

Marslen-Wilson et al. (1994) tested the decomposition of morphologically complex words and whether there is any relationship between a word's semantic and/or phonological transparency when the derivation and the stem are presented. The task used in their experiment was cross-modal repetition priming. In this task, the subject is aurally presented with the prime (e.g., happiness) through headphones and the target is visually presented on a computer screen (e.g., HAPPY) immediately at the offset of the prime. The subjects were to make a decision as to whether or not the word they saw was a word in English. The prime and target may or may not be related semantically, phonologically, or orthographically. The unrelated condition, where the prime and target were *not* related in any way (e.g., penniless−EDGE), was considered to be the control condition and this was used to compare the response times with the experimental related conditions.

The results of Marslen-Wilson et al. showed that for decomposition to occur in morphologically complex words, the prime and target must be semantically related, regardless of any phonological transparency. Semantically opaque forms (e.g., apartment−APART) were found to be retrieved as whole-words, i.e., monomorphemic words or atoms, based on response times. Opaque pairs such as apartment−APART do not show a priming effect because they do not share morphemes, and therefore behave like monomorphemic words. Conversely, word pairs such as friendly—FRIEND and elusive—ELUDE will produce a priming effect because they do in fact share a morphological relationship, although one pair (friendly—FRIEND) has a phonological relationship while the other pair (elusive—ELUDE) does not have as strong of one.

Rastle et al. (2004) performed a similar experiment but utilized a masked priming paradigm investigating morphologically complex words wherein they attempted to determine the information that is required in order for a word to be decomposed. They used three conditions to test how, and whether, complex words were decomposed: *Semantically transparent* condition (e.g., cleaner−CLEAN), *Apparent morphological* condition (e.g., corner−CORN), and *Nonmorphological* condition (e.g., brothel−BROTH). In the semantically transparent condition, the prime and target are related semantically and there is a clear and unambiguous semantic relationship between them, as in the example cleaner−CLEAN. The Apparent morphological condition (e.g., corner−CORN) hosts primes which are full, non-decomposable lexical items, but they have the *potential* to be decomposed further because they posses a root and what appears to be a legal suffix, as in the example of *corn* + *er*. However, unlike the Semantic transparent condition, the prime and target pairs have no semantic relatedness in this condition (e.g., a *corner* is not someone who *corns*). Finally, the Nonmorphological condition contains items which consist of only letter overlap without any semantic or morphological relationship. Moreover, unlike in the Apparent morphological condition, the items in the Nonmorphological condition cannot be further decomposed into root + suffix since doing so will result in an existing English root, but a nonexistent suffix, as in the example brothel−BROTH where *–el* is a nonexistent suffix in English.

Rastle et al.'s results showed that both the semantically transparent and apparent morphological conditions produce significant priming results when compared to unrelated control words. When the response times are compared to one another, they produced no significant differences. This, then, suggests that a semantic similarity argument cannot be the sole reason for decomposition because if it were, we would only see priming for the semantically transparent condition (cleaner−CLEAN) and not the apparent condition (corner−CORN). The nonmorphological condition produced no priming and therefore suggests that orthographic overlap cannot be used as an argument for why priming occurred in the other conditions, leaving us with morphology as the important factor in the early decomposition process.

What Rastle et al.'s study then shows is that morphemes and pseudo-morphemes play a role in the early stages of lexical processing, but the morphemes must be orthographically identical to legal English morphemes. If the string of letters constitutes a legal morpheme, regardless of whether the morpheme is a real or pseudo-morpheme, then decomposition does occur.

McCormick, Rastle, and Davis (2008) also performed a masked priming study testing morpho-orthographic segmentation of complex words with orthographic alternations, i.e., words that do not parse perfectly into their constituent morphemes without any changes to the root or suffix, as in the previous studies (Lavric, Clapp, & Rastle, 2007; Longtin, Segui, & Halle, 2003; Rastle et al., 2004). For their study, three conditions were tested in which there existed different orthographic alternations. Experiment 1 tested words that had a missing 'e', as in adorable−ADORE. Experiment 2 tested words that shared an 'e', as in lover−LOVE. Experiment 3 tested words that duplicated a consonant, as in metallic−METAL. McCormick et al. also included an Experiment 4 which tested the whether priming could be obtained for words that exhibit an orthographic alternation but are, in fact, pseudo-morphological pairs, as in corner−CORN. To do this, they compared priming effects elicited by orthographically opaque but semantically transparent stimuli (e.g., lover−LOVE), orthographically and semantically opaque stimuli (e.g., badger−BADGE), and non-morphological form controls (e.g., shovel−SHOVE). McCormick et al.'s results of Experiments 1 − 4 clearly showed that even in morpho-orthographic segmentation of complex words, priming still occurs as significantly as it does in morphological pairs that can be parsed perfectly into their constituent morphemes.

The supralexical model (Diependaele, Sandra, & Grainger, 2005; Giraudo & Grainger, 2000) claims that lexical processing at the initial stages is primarily activated by whole-words. This is similar to atomist approach, but the difference is that the supralexical model is not strictly a whole-word only model like the atomist approach and it relies on a hierarchical process. In other words, the model claims that after we reach the whole-word level, if the word can be further decomposed based on how easily the word is understood based on its parts (i.e., how semantically transparent it is), the word moves to the next level of the decomposition process. If the word is not easily understood based on its parts, it remains at the whole-word stage and is accessed in that fashion.

This occurs because morphology does exist in this model, unlike in atomist approaches, but it is located between whole-word form and higher-level semantic representations. The importance of this model is that they are like an intermediate model that claims we access words as whole-words, but the process is more complex and we can access the internal morphology of certain words. Which words, exactly, depends on its semantic transparency.

What is important for the current study is the fact that the supralexical model does make a prediction as to what kind of words will be taken down the path to potential decomposition, namely transparent morphological pairs. If productivity also affects whether words are decomposed, then this model may also be consistent with findings that show productivity affects constituent access.

Productivity and decomposition

Defining productivity

This leads us to our current research on the morphological processing of complex words with productive and unproductive suffixes. The way previous research has defined productivity is best defined as the potential to create new words within a membership of a particular suffix (Baayen, 2008; Marslen-Wilson, Ford, Older, & Zhou, 1996; Plag, 2004). To clarify, what is meant by a *membership* is essentially the physical number of members that belong to one morphological category. Some morphological categories have a large, growing membership, while others have a small, declining membership. The growing membership category (e.g., *-ness* in *tardiness* and nominal compounding) is considered to be productive, while declining membership categories (e.g., *-th* in *warmth* or *strength*) are said to be unproductive because they are not growing (i.e, no addition of new words added to the lexicon, or words that are not as easily created as they are in the productive categories).

Another way productivity has been defined is by either relative frequency of occurrence in a particular language or by the frequency speakers use a particular form to produce nonce-formations (Cutler, 1980). Other restrictions on the definition also posit that phonology is the determining factor whether a morphological affix is decomposable or not (Vannest & Boland, 1999; Vannest, Polk, & Lewis, 2005). One criterion that Vannest et al. (2005) use for determining decomposability is whether the affix changes the pronunciation of the word (e.g., serene—SERENITY). If so, the claim is that there is a smaller degree of orthographic and phonological overlap and therefore is not as likely to be decomposed since the lexical association between the prime and target are presumed to be "broken." Another major criterion is frequency on response times to suffixed words. The reasoning behind this is that if morphemes are always accessed separately, then the frequency of the base should also matter in all complex word forms and would therefore have an effect on the response times in a lexical decision task.

Vannest et al. (2005) propose the following decomposable and non-decomposable suffixes, shown in Table 1.

Table 1. Decomposable and non-decomposable suffixes.

Decomposable	Non-decomposable
-able	-ity
-ness	-ation
-less	—
-ed	—
-ing	—

Vannest and Boland's (1999) study makes reference to Kiparsky's (1982) theory of Lexical Phonology and Morphology, which describes affixes as being broken into two "levels": those which are *Level 1* suffixes, meaning those that are more idiosyncratic in nature and semantically opaque; and *Level 2* which are more semantically transparent and more productive. Another criterion is also interaction with phonological processes, which when it does occur and changes the pronunciation of the word (stress assignment included), then it is likely to be associated with a Level 1 affix. This, then, goes back to the earlier point they stated in which Level 1 suffixes are idiosyncratic in nature. In this case the changes in the pronunciation of the word, and stress assignment, makes the word more unproductive than one that does not change pronunciation or stress assignment.

Baayen (2008) defines productivity in terms of categorical membership based on three terms: *Realized Productivity*, *Expanding Productivity*, and *Potential Productivity*. Realized productivity is simply restricted to "past achievements," so to speak. So a category with many members has produced many words and is therefore considered to be productive in this sense. *Expanding productivity* measures the extent to which a category is expanding and attracting new members. A category that is expanding at a high rate is considered productive, while a category that is stagnant or not expanding at all is considered unproductive. The way this is measured is by hapax legomena, i.e., the number of words in a morphological category that occur only once in a corpus of N tokens. This measure is referred to as hapax-condition degree of productivity. Finally, *Potential productivity* measures the sensitivity to the potential of expansion of a particular affix. In other words, if an affix is saturated (e.g., the unmarked *–er* in Dutch, as opposed to the *–ster* affix and therefore can more easily and freely attached to verbs than *–er*), the potential productivity for that affix will be low (this is a high-risk affix). A low-risk affix is one that is not saturated and therefore has a greater chance for expansion. This can be measured by its hapax legomena in the corpus divided by the total number of tokens in the corpus. This ratio is known as category-conditioned degree of productivity.

Productivity studies

Some early studies that addressed the role of productivity include Aronoff (1978) and Aronoff & Anshen (1988; 1981). In both of these early productivity studies, Aronoff and colleagues tested people's intuition about productive- and unproductive-suffixed words. They investigated whether suffixes such as *–ness* are more productive, and therefore more easily used in novel-word constructions, than unproductive *–ity* suffixes.[1]

In their 1978 study, a lexical decision task, participants divided into three groups were asked to respond to whether the stimuli presented were (1) *Words*, which consisted of real words consisting of the *Xivity* structure; (2) *Possible Words*, which consisted of *Xive*-structured words that take the form of *Xivity* and *Xiveness*; and (3) *Nonwords*, which consisted of nonwords of the form *Xive* and again included the forms *Xivity* and *Xiveness*. Regardless of the instructions given to participants, but especially in the Potential Words, their responses showed the form *Xiveness* to be judged as words or possible words more than the form *Xivity*, displaying a preference for productive words more so than unproductive words.

[1] It should be noted here that almost all of their studies include suffixes in succession, e.g., *Xivity*, *Xiveness*, *Xibility*, and *Xibleness*. However, the heart of the matter was still investigating how easily the productivity of one particular suffix is attached to a word.

Their 1981 study was almost identical to their previous 1978 study. However, the difference was that they used forms other than *Xive*, and included *Xible*. The idea was the same as with the *Xive* experiment: will participants respond more positively, i.e., likely to say that certain groups of words were possible words or not, towards *Xibleness* than *Xibility* forms? In all conditions, participants preferred the form *Xibility* rather than *Xibleness*. This was measured by participants responding yes to whether a presented word was a word in English even if they were not familiar with the word. Because the result is not expected based on the less productive suffix *–ity* as opposed to the more productive -*ness*, one explanation they give for this result is that of prosody. The form *Xibleness*, they claim, ends in three unstressed syllables and therefore are more awkward than *Xibility*, which has an alternating stress pattern. Therefore, phonology has the potential to influence participant decisions, but it does not hold in all cases.

Anshen and Aronoff (1988) again studied all the forms available in the previous two studies mentioned above. The difference in their 1988 study was that the experiment was not a lexical decision task. Instead, participants were given specific instructions such as, "List as many words as you can think of with the suffix *–ment*." The same would be true of instructions asking participants to construct *–ibility*, *-ionary*, and *–iveness* suffixed words. They concluded that *–ness* words are created as they are needed, while *–ity* words have a specific set of words that it can attach to. In other words, participants were more likely to include nonce words when creating them with a *–ness* suffix than words with the *–ity* suffix.

Marslen-Wilson et al. (1996) performed a cross-modal priming lexical decision task testing the productivity of suffixes and prefixes. They performed two experiments. The first experiment tested productive and unproductive suffixes and prefixes (e.g., *productive suffix* darkness−toughness; *unproductive suffix* development−government; *productive prefix* rearrange−rethink; *unproductive prefix* enslave−encircle). The reason they used affixed words for both the prime and target is because although they believe that affixes are not free morphemes (i.e., they cannot stand alone as separate entities), they do believe that, in terms of cognitive elements, affixed words are *represented* as free morphemes. Therefore, if true, they should behave similarly to primes that contain an affix, e.g., *darkness*, and a monomorphemic target, e.g., *dark*. The results for Experiment 1 were as they expected. The productive prefixed words were responded to faster, and on par with prime-stem pairs, than when compared to unproductive words which were considered a marginal effect ($p < .10$). In contrast, the productive suffixed words produced a significant effect, as in the prefixed words, but the unproductive suffixed words did not produce a significant effect.

Experiment 2 tested phonological overlap to ensure that the results in Experiment 1 were not due to a phonological effect. It also included a pseudo-affix condition for both word-initial pairs (e.g., *rearrange−recent*) and word-final pairs (e.g., *darkness−harness*). The phonological pairs were also tested for both word-initial pairs (e.g., *pilgrim−pilfer*) and word-final pairs (e.g., *jacket−bucket*). The results for this experiment were also as expected and did not differ very much from Experiment 1. They still showed significant priming for productive affixes when compared to stems, and weaker, but still significant, effects for unproductive affixes. The pseudo-affixed condition, word-initial overlap, showed an interference effect while the word-final overlap was not as strong of an interference, but nevertheless an interference effect.

Marslen-Wilson et al.'s (1996) results play a role in motivating the current study by showing that in an overt priming experiment, productivity plays a role in morphological processing. If productivity matters at the (conscious) overt level (as shown in Marslen-Wilson et al.'s experiment), then it stands to reason that it can possibly have some effect on productivity at a (unconscious) masked level of presentation. This study is designed to test this exact question: Do we see productivity effects in the initial stages of lexical processing?

Silva and Clahsen (2008) is one study that has addressed the priming effects of two nominalizing suffixes (e.g., *-ness* in Experiment 3; and *–ity* in Experiment 4) for Chinese and German L2 speakers of English and native English speakers using a masked priming paradigm. Their results showed that productive- and unproductive-suffixed word pairs (e.g., bitterness−BITTER for the *–ness* Productive condition, and humidity−HUMID for the *–ity* Unproductive condition) in native English speakers did show significant priming when compared with the control/unrelated words. While their results are consistent with Rastle et al. (2004) with regard to morphological priming, one drawback is that they did not ensure their results were indeed morphological in nature in a similar way to Rastle et al. (2004). However, Silva and Clahsen did explain how they addressed these concerns without including these conditions. They reason that since they did not obtain any significant results from Experiments 1 and 2, which tested past-tense forms (e.g., boiled−BOIL) and are semantically related, the results in Experiment 3 and 4 could not be due to semantics. Moreover, they posit that the results cannot be due to orthography as the words in Experiment 3 and 4 differed significantly in terms of orthographic overlap. Therefore, they claim their results must be related to morphology. Broadly speaking, this thesis will extend Silva and Clahsen's experiment including additional item controls and testing a wider range of affixes. In doing so, we hope to have a better understanding of the role productivity plays at early stages of lexical processing.

If productivity at the early stages of lexical processing does not matter, as Rastle et al. (2004) would predict, then we will see significant response time differences between the experimental and control conditions for Productive, Unproductive, and Apparent morphological conditions, while no significance for the Nonmorphological condition. If productivity does play a role, then we will see significant response time differences in the Productive condition and no significance in the Unproductive condition.

For the experiment in this thesis, we use a masked priming paradigm to discover whether morphologically complex words with productive suffixes (e.g., *-ness* words) or unproductive suffixes (e.g., *-ity* words) are decomposed in the earliest stages of visual word recognition. The reason we chose masked priming as opposed to an overt priming paradigm is because masked priming has been shown to tap into the very early (unconscious) stages of word processing and therefore produce different results than overt priming since primes are known to be consciously processed in overt priming tasks (Forster, Mohan, & Hector, 2003; Taft & Nguyen-Hoan, 2009). For example, *Apparent morphological* pairs (e.g., corner—CORN) and *Semantically transparent/morphologically complex pairs* (e.g., hunter—HUNT) show a significant priming effect when compared to an unrelated control (e.g., sludge—CORN) in a masked priming task (Longtin et al., 2003; Rastle et al., 2004). Pairs that share an orthographic overlap (e.g., brothel—BROTH) show no priming effects and are therefore thought to be accessed as whole-words. Conversely, in overt priming paradigm studies (Longtin et al., 2003, Experiment 2; Marslen-

Wilson et al., 1994), the only condition showing a significant priming effect is the semantically transparent condition (e.g., hunter−HUNT), while the apparent and nonmorphological conditions showed no priming effects.

Current study

As depicted in the figures below, each word pair in each condition in our experiment will be tested against a non-related control word to determine whether priming is observed. This unrelated word is matched for length to ensure that confounding variables do not negatively affect our results.

Figure 1. Depiction of Productive and Unproductive prime and target word pairs.

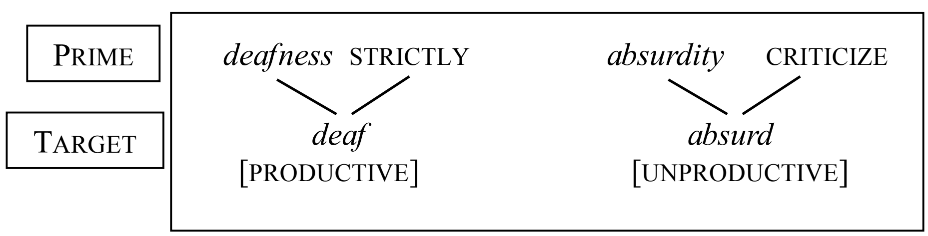
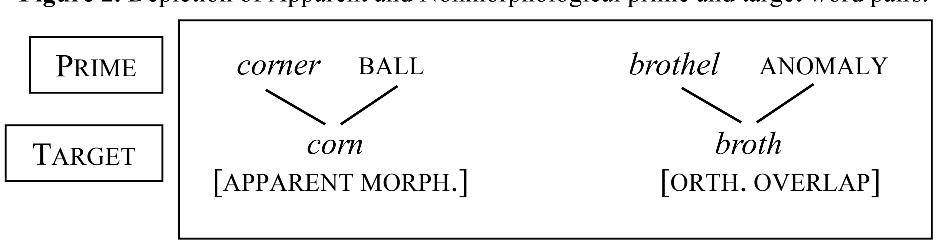


Figure 2. Depiction of Apparent and Nonmorphological prime and target word pairs.



In the *Productive* condition, word pairs such as darkness—DARK will be presented to participants. All items in this condition will all be semantically and orthographically related. Words in the *Unproductive* condition will include an unproductive suffix, e.g., absurdity—ABSURD and will also be semantically and orthographically related. Words in the *Apparent morphological* condition (e.g., corner—CORN) are not semantically related and do not have an etymological relationship (e.g., department—DEPART). The *Nonmorphological* condition will include words such as brothel—BROTH, which are not related semantically but instead share a letter-string overlap; the prime will include a non-existent English suffix (e.g., *–el*).

Priming results in the masked priming paradigm for the morphologically and apparent morphologically related conditions would allow us to investigate whether the productive/unproductive suffix distinction affects the early stages of lexical processing, i.e., whether productivity is the factor that matters first in the early stages. For example, if all morphologically and potential morphological words are aggressively decomposed, we would predict that the masked priming effect of words such as darkness—DARK, absurdity—ABSURD, and corner—CORN, to be significantly greater than its unrelated control. If productivity does matter, then we will only show significant results for the productive-suffixed items.

If we obtain these types of results, there are three possibilities that we are confronted with for why we see a priming effect: (i) the priming is due to a semantic similarity (*darkness* and *dark* are semantically related); (ii) the priming is due to the orthographic overlap of the string of letters in *dark* being contained within *darkness*; or (iii), the priming is due only to morphological relatedness, i.e., morphology is the cause of aggressively parsing existent stems and suffixes. To find the cause of the priming, we must test different morphological conditions.

The reasons for Productive and Unproductive conditions are straight-forward, since we are investigating productivity effects in morphologically complex words. If productivity matters, then we will see robust priming for the productive condition in contrast to the unproductive condition. If productivity does not matter, then we will see both productive and unproductive conditions behave similarly in response times when compared to their unrelated primes.

The Apparent condition is needed so that we can ensure that semantics is not necessary in the decomposition of morphologically complex words. What is important in this condition is the *appearance* of a morphological relationship between the root and suffix, as in the example corner−CORN. If our masked priming experiment produces significant effects of this condition, we can say with some confidence that semantics does not play a role in the decomposition process or that semantics is not the primary source of decomposition.

Finally, the Nonmorphological condition is needed to ensure that *any* results we find are not due to an orthographic overlap between the root and suffix. In other words, the argument can be made that the reason we find priming effects for hunter−HUNT and corner−CORN, for example, is because the prime and target share orthographic features (*hunt* is in both the prime and the target, therefore this causes a speed-up in the reaction time). If we do not find any significant effects for this condition, then orthographic overlap does not, and did not, play a role in the decomposition of the other conditions. If, on the contrary, we do find significant effects in this condition, then further studies would be needed to determine the exact cause of the priming effect.

Semantic similarity. If our results are indeed semantic in nature, then when compared to unrelated primes, we should see *Productive* and *Unproductive* conditions (e.g., darkness—DARK for Productive; absurd—ABSURDITY for Unproductive) producing a significantly faster response time when compared to the *Apparent* condition (e.g., corner—CORN, since there is no semantic relationship between *corner* and *corn*), and the *Nonmorphological* condition (e.g., brothel—BROTH). If masked priming is blind to semantics, then priming found for productive or unproductive suffixes cannot be due to semantics.

If the semantic-similarity explanation is right:

Condition	Facilitation predicted?
Productive vs. control	yes
Unproductive vs. control	yes
Apparent vs. control	no
Nonmorphological vs. control	no

Orthographic overlap. If the claim is that our prime-target relationship results in priming due to an orthographic overlap, then we should see priming effects for *Productive* (darkness—DARK) and *Unproductive* (absurdity—ABSURD) conditions, *Apparent morphological* (corner—CORN), and *nonmorphological* (brothel—BROTH), conditions when compared to their unrelated controls.

If the orthographic-similarity explanation is right:

Condition	Facilitation predicted?
Productive vs. control	yes
Unproductive vs. control	yes
Apparent vs. control	yes
Nonmorphological vs. control	yes

Whether a suffix is a legal suffix in English or not, priming will occur simply due to the letter overlap shared by the prime and target.

Morphological decomposition. If we believe priming effects in this experiment is the results of morphology, we should see a priming effect for *Productive*, *Unproductive* and *Apparent* conditions. If we can show that our productive- and unproductive-suffixed words prime, we can say with a high degree of confidence that the priming effect we have is due to morphological decomposition and not, say, semantic or orthographic relatedness, for reasons argued above.

If the morphological decomposition explanation is right:

Condition	Facilitation predicted?
Productive vs. control	yes
Unproductive vs. control	yes
Apparent vs. control	yes
Nonmorphological vs. control	no

Predictions

If the results follow Rastle et al. (2004) and Silva & Clahsen (2008), we reason that in the early stages of visual word recognition, words will be decomposed into their constituent parts, including productive, unproductive, and pseudo-affixed words. If productivity constrains the initial stages of visual word recognition, then we will see significant priming results only for the Productive condition.

2 Methods

Stimuli and Design

There were two hundred fifty-six prime-target pairs selected from the CELEX English database (Baayen, Piepenbrock, & van Ruh, 1993), sixty-four in each of the following four conditions. The materials included four conditions of prime-target pairs, *productive, unproductive, apparent morphological,* and *nonmorphological* conditions. In the *productive* and *unproductive* conditions the primes were morphologically and semantically related to their targets (e.g., abruptness-ABRUPT; brutality-BRUTAL). The primes in these two conditions were also constructed so that they can be exhaustively parsed into the target plus the English suffix, i.e., there were no orthographic changes in the root of the prime as in happiness−HAPPY, where the 'y' becomes orthographically changed to 'i'.[2] Primes in the *apparent morphological* condition appear to contain two morphemes—the "root" morpheme (i.e., the target) and its derivative, but are not related in meaning (e.g., plumage−PLUM),[3] and would not be considered morphologically complex according to morphological theory. In order for a word to be considered for this category, the apparent morpheme or suffix, e.g., *-age* in *plumage*, must form a legitimate and legal suffix in the English language. Furthermore, as in the productive and unproductive case, the root must remain orthographically unaltered when the apparent morpheme or suffix is removed. In the *nonmorphological* condition, targets were also embedded in the primes,

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[2] Although it has been recently shown by McCormick, Rastle, and Davis (2008) that this kind of derivation in prime and target, e.g., adorable−ADORE, where the 'e' is dropped, does not prevent a priming effect. They also tested items that share an 'e', e.g., lover−LOVE, and duplicate a consonant, e.g., dropper−DROP, and found equally robust effects.

[3] It was not the case that *all* our primes in the apparent condition were apparent derivational suffix equivalents. A few were inflectional, e.g., grueling−GRUEL.

but the remaining letters did not form an English suffix (e.g., gazelle-GAZE; *-lle* is not a legal suffix in English), and thus do not appear to have an exhaustive morphological parse even at the orthographic level.

All target words were matched as closely as possible for target frequency, prime frequency, target length, prime length, form overlap,[4] and target neighborhood size (Medler & Binder, 2005). The means for each property across the four conditions as well as the mean log frequencies can be found in Table 2. A one-way 4 X 6 ANOVA (4 conditions X 6 properties) was performed for all conditions. There were no significant differences across all the conditions for any of the variables across the board (of all *p*-values, the closest to any significance was Target Neighbors with $F(3,252) = 1.148$, $p = .330$).

Table 2. Mean values across four conditions

Property	*Productive*	*Unproductive*	*Apparent Morphological*	*Nonmorphological*
Log Frequency (P)	.468	.531	.585	.435
Log Frequency (T)	1.478	1.306	1.331	1.304
Neighbors (T)	4.500	3.218	4.187	4.406
Length (P)	8.703	8.546	8.296	8.656
Length (T)	5.203	5.046	5.015	5.000
Overlap	.597	.588	.603	.586

Another variable we controlled for was grammatical category. Previous masked priming studies dealing with the issue of morphological processing and decomposition (Longtin et al., 2003; Rastle et al., 2004; Silva & Clahsen, 2008)[5] had not controlled for gram-

[4] This is defined as the number of letters that overlap from prime to target, e.g., massive−MASS have a four letter overlap of the seven letters in the prime.
[5] Longtin et al. (2003) did in fact control for grammatical category. However, the control was only among the prime-target triplet pairs, not across all four of their conditions, as in our experiment. For example, a triplet pair consisted of a transparent, opaque, and pseudo-derived condition that all shared the same *suffix*, or the appearance of a suffix. The main difference among the three conditions was their morphological relationship, e.g.,

matical category, and thus it remains unclear whether or not to what extent this affects the observed priming results. We explicitly controlled for this, ensuring that any priming effects could not be due to this factor. Our grammatical category control can be found in the Table 3. All the root grammatical categories as well as the derivational grammatical category were evenly split in the Productive and Unproductive categories (e.g., Productive roots = Adjective, Noun, Verb, Verb; Unproductive roots = Adjective, Noun, Verb, Verb), as shown in Table 3. This was done to ensure that any results we obtain were not an effect of grammatical category.

Table 3. Root-to-Derivation Grammatical category

Productive		*Unproductive*	
-ness	A→N	-ity	A→N
-ship	N→N	-ment	V→N
-able	V→A	-ous	N→A
-er	V→N	-ance	V→N

The suffixes for the productive and unproductive conditions were carefully chosen based on previous research on English morphological productivity (Baayen, 2008; Marslen-Wilson et al., 1996; Plag, 2004; Silva & Clahsen, 2008; Vannest et al., 2005). The suffixes chosen for either condition in this study were classified as productive or unproductive throughout all of the chosen previous productivity papers in order to sort the

the transparent condition prime–target pair shared an etymological and semantic relationship, opaque condition shared an etymological but no semantic relationship, and pseudo-derived did not share an etymological nor a semantic relationship. Now, their grammatical category control was among these triplets. Moreover, these triplets shared the appearance of the same suffix, e.g., plumeau/PLUME “feather duster/feather” (transparent), rideau/RIDE “curtain/wrinkle” (opaque) and pinceau/PINCE “paintbrush/pliers” (pseudo-derived). Within this triplet of prime–target pairs is where the grammatical category and orthographic overlap was controlled.

least controversial classifications, considering the slightly divergent articulations of what productivity means.

For each of the suffixes in the productive and unproductive conditions, we controlled for the number of repetitions of each suffix − 16 items per respective suffix, 64 per condition (Longtin et al., 2003; Rastle et al., 2004). In the apparent and nonmorphological condition we simply used 64 items but ensured that the appearance of suffixes did not overlap with our productive or unproductive conditions, i.e., the apparent or nonmorphological condition never used any words with *–ness*, *-ship*, *-able*, *-er*, *-ity*, *-ment*, *-ous*, or *–ance* suffixes (Longtin et al., 2003; Rastle et al., 2004). Moreover, we ensured that the frequency, overlap, and length in these conditions was not statistically different from the productive and unproductive conditions.

Table 4. Suffixes used per Productivity condition

Productive	*Unproductive*
-ness	-ity
-ship	-ment
-able	-ous
-er	-ance

Individually, each suffix was chosen in the following way. Although five separate studies similarly cited the suffixes in Table 5 as productive or unproductive, we ensured that our chosen suffixes also differed in terms of log potential productivity, a computational measure of productivity proposed by Baayen (2008). While we do not intend to take a strong position on alternative articulations of precisely what defines productivity, we wish to show that our affixes were both agreed upon in the psycholinguistic literature, and can be distinguished from one another also on a corpus-based measure of productivity. For the productive affixed words, *–ness* was referenced as a productive morpheme in

Baayen (2008), Vannest et al. (2005), Marslen-Wilson et al. (1996), Silva and Clahsen (2008) and Plag (2004); *–ship* was referenced in Baayen (2008); *-able* was tested in Baayen (2008), Vannest et al. (2005), Marslen-Wilson et al. (1996); and *–er* in Baayen (2008). For the unproductive suffixes, the process was similar to discovering affixes in the productive condition; *-ity* was referenced in Baayen (2008), Vannest et al. (2005), and Silva and Clahsen (2008) ; *-ment* in Baayen (2008) and Marslen-Wilson et al. (1996); -*ous* solely in Baayen (2008); and *–ance* also solely in Baayen (2008). All of the unproductive affixes were also matched with Baayen's chart to ensure agreement of classification among previous research.

Table 5. Suffixes in our study which were used in previous studies.

Baayen (2008)	*Vannest (2005)*	*Marslen-Wilson (1996)*	*Silva & Clahsen (2008)*	*Plag (2004)*
-ness	-ness	-ness	-ness	-ness
-ship	-able	-able	-ity	
-able	-ity	-ment		
-er				
-ity				
-ment				
-ous				
-ance				

The control primes were chosen to be equivalent to the experimental item primes in length, frequency, and orthographic overlap. They were also semantically and morphologically unrelated to the experimental primes and targets. The morphological structure of the control primes was either morphologically complex or simplex. For example, in the Productive and Unproductive condition controls, items were morphologically complex.[6] The Apparent and Nonmorphological condition control primes were all simplex items or

[6] And we maintained non-replication of a word from anywhere else in our study. We further ensured no suffix was repeated from the Productive and Unproductive experimental primes.

if they are capable of being fully decomposed, they "contain" an illegal English suffix (e.g., *cartoon*, where we can tease it apart as cart−oon. However, the *–oon* suffix is illegal in English). Nonword targets were matched for length with real-word targets and were pronounceable. Like our experimental conditions, half of our nonword stimuli had some orthographic overlap with their primes. We ensured that they shared the same proportion of prime-target overlap in number of letters as our experimental conditions.

In the presentation of the our stimuli, we utilized a Latin-square design with two lists to ensure that all subjects saw all 256 targets in each of the four conditions, and no subject saw the same target twice. For example, a subject presented with list 1 would see the pair aloofness−ALOOF, while the person using list 2 would see detective−ALOOF. Within each list, each condition was matched as closely as possible using the properties listed in Table 6 and tested using a paired *t*-test between the two Latin-squared lists (e.g., Productive Related-List 1 vs. Productive Related-List 2) and among the Latin-squared list conditions (e.g., Productive Related-List 1 vs. Unproductive Related-List 1) in order to ensure that they are not statistically different, i.e., as similar as possible.[7] The figures among this condition can be found in Table 6. There were no significant differences among any of the measured conditions or across any of the variables.

Table 6. *p*-values across Latin square list 1 and 2 (List 1 vs. List 2 data)

Cond	Rel Freq (P)	Rel Freq (T)	Unr Freq (P)	Unr Freq (T)	Rel Ngh (T)	Unr Ngh (T)	Rel Len (P)	Rel Len (T)	Unr Len (P)	Unr Len (T)	Rel Ovrlp	Unr Ovrlp
Prod	0.474	0.851	0.488	0.851	0.535	0.535	0.750	0.649	0.849	0.649	0.739	0.739
Unpr	0.333	0.553	0.982	0.553	0.692	0.692	0.729	0.674	0.729	0.674	0.735	0.735
App	0.409	0.456	0.319	0.456	0.364	0.364	0.922	0.560	0.922	0.560	0.414	0.414
Non	0.134	0.911	0.490	0.911	0.729	0.729	0.755	1.000	0.755	1.000	0.640	0.640

[7] All are at a minimum *p*-value of $p > .10$ or better.

Procedure

Stimulus presentation was controlled by DMDX software (Forster & Forster, 2003). A Microsoft SideWinder® Plug & Play gamepad controller was used as the two-button response box, while the stimuli was presented on a cathode ray tube (CRT) monitor with a refresh rate of 100 Hz. Subjects were asked to respond as quickly and accurately as possible to the stimuli presented on the screen as to whether the word they saw was a word in English or not. They were not told of the masked prime. The index finger of the dominant hand was always positioned on the "yes" (i.e., "*the item I saw was a word in English*") response button, while the middle finger was always positioned on the "no" (i.e., "*the item I saw was not a word in English*") response button. There were six practice trials of pairs of words which were not included in the experimental or control conditions in order for the participants to familiarize themselves with the task. The morphological structure of the practice trial items consisted of either a real word with a morphological overlap (e.g., professor−PROFESS) or pronounceable nonword prime−target pairs with a real-word prime (e.g., population−CLEPSE). None of the words used in the practice trial were used in the actually experiment. They were seated in a quiet, dimly lit room.

Each trial began with a series of hashmarks as a mask ("######"), which was presented in the center of the screen for 500 ms. The number of the hashmarks were determined by the number of letters of the masked prime. Immediately following the hashmarks, the masked prime was presented in lower case for 50 ms in the identical area the hashmarks were presented. Following the masked prime, the target, in uppercase letters, was presented in the center of the screen for 3000 ms or until a response was registered. A typical trial looks like this (########−darkness−DARK). Participants were given three, untimed, rest periods (on 128-trial intervals). Response times for each stimulus was recorded from the onset of the target stimulus display. The total duration of the experiment was approximately 20 minutes.

256 pronounceable prime-nonword pairs were also included in order for the subject to respond “no” to the items half of the time. When we look at our four real-word conditions, i.e., Productive, Unproductive, Apparent, and Nonmorphological, 128 of the 256 real words were related and had an orthographic overlap with the prime, e.g., abruptness−ABRUPT. We also made sure that among the nonwords, 128 of the 256 had some amount of overlap between the prime and target.

Participants

Sixty-eight undergraduate students (39 female; mean age: 19 yrs old) from the University of Kansas Lawrence campus participated in this experiment for course credit or a payment of $5. All participants were native speakers of English and had normal or corrected-to-normal vision, and provided their written informed consent to participate in this study. All participants were not trained in linguistics. Six participants were excluded from our analysis for reporting seeing the masked primes. The remaining data from the sixty-two participants were carried forward for data analysis.

3 Results

Results for response times were collected and cleaned to remove outliers. Outliers were determined by using a cutoff of 2.5 above and below the standard deviation of the mean of each participant's data (2.5% of our data). 8% of our data was removed for incorrect responses. The remaining data were carried forward for statistical analysis.

Response times

Our main goal of this experiment was to test whether productivity plays a role in the early stages of lexical processing using four conditions (Productive, Unproductive, Apparent, and Nonmorphological) and their controls. The response times and error rates are summarized in Tables 7 (By Subjects) and 8 (By Items). All response time (RT) data were analyzed using by-subjects and by-items repeated measures analysis of variance (ANOVA) with the following main factors: RELATEDNESS (related or unrelated) and CONDITION (Productive, Unproductive, Apparent, and Nonmorphological).

Table 7. Mean latencies, errors, and priming effects by subjects

	Condition							
	Productive		Unproductive		Nonmorphological		Apparent	
Relatedness	Mean	% error	Mean	% error	Mean	% error	Mean	% error
Related	683.63	5.9	691.70	11.3	710.27	9.6	689.8	10.2
Unrelated	708.79	5.9	716.86	11.5	729.28	12.1	705.8	11.5
Priming	25.16	0	25.16	0.2	19.01	2.5	16.02	1.3

Table 8. Mean latencies, errors, and priming effects by items

	Condition							
	Productive		Unproductive		Nonmorphological		Apparent	
Relatedness	Mean	% error	Mean	% error	Mean	% error	Mean	% error
Related	686.59	5.9	694.83	11.3	712.46	9.6	693.65	10.2
Unrelated	708.99	5.9	723.68	11.5	736.57	12.1	711.25	11.5
Priming	23.69	0	32.98	0.2	24.66	2.5	16.60	1.3

In all conditions, related pairs were responded to significantly faster than the unrelated pairs in both by-subjects and by-items analysis ($F_1(1,61) = 35.796$, $p < 0.001$; $F_2(1,63) = 12.784$, $p < 0.01$), as well as there being a significant effect of condition, which was only observed in by-subjects analysis ($F_1(3,183) = 14.820$, $p < 0.001$; $F_2(3,189) = 1.772$,

$p > 0.100$). The Condition * Relatedness did not reach significance in either by-subjects or by-items analysis ($F_1 < 1$; $F_2 < 1$).

We also conducted a planned comparisons *t*-test of relatedness, both by-items and by-subjects, within each condition, as shown in Table 9. For by-subjects data, relatedness was significant, reflecting faster response times for related vs. unrelated prime-target pairs within each condition (Productive related vs. unrelated, $t(61) = -4.166$, $p < 0.001$; Unproductive related vs. unrelated, $t(61) = -3.949$, $p < 0.001$; Apparent related vs. unrelated, $t(61) = -3.003$, $p < 0.010$; Nonmorphological related vs. unrelated, $t(61) = -3.832$, $p < 0.001$ paired *t*-test). For by-items data, a paired *t*-test was significant for unproductive and nonmorphological conditions (Productive related vs. unrelated, $t(63) = -1.716$, $p > 0.090$; Unproductive related vs. unrelated, $t(63) = -2.266$, $p < 0.028$; Apparent related vs. unrelated, $t(31) = -1.211$, $p > 0.230$; Nonmorphological related vs. unrelated, $t(63) = -2.015$, $p = 0.048$).

Table 9. By-subjects and by-items *t*-test among relatedness

Comparison	By-subjects *p*-value	By-items *p*-value
Productive-related vs Productive-unrelated	0.000	0.004
Unproductive-related vs Unproductive-unrelated	0.000	0.000
Apparent-related vs Apparent-unrelated	0.004	0.010
Nonmorphological-related vs Nonmorphological-unrelated	0.000	0.007

We next wanted to test whether strengths of the priming effects are larger across any of the conditions by performing paired *t*-tests on the magnitude of priming (related *minus* unrelated), in the by-subjects data. This test was necessary in order to distinguish whether there exist any effects among conditions. This test will show whether the amount of priming found in, say, Productive-related/unrelated is statistically different from Unproductive-related/unrelated. No significance was found among any of the condition priming effects (Productive-related/unrelated vs. Unproductive-related/unrelated $t(61) = -.001$, $p > 0.999$; Productive-related/unrelated vs. Apparent-related/unrelated $t(61) = 1.282$, $p > 0.205$; Productive-related/unrelated vs. Nonmorphological-related/unrelated $t(61) = .955$, $p > 0.343$; Unproductive-related/unrelated vs. Apparent-related/unrelated $t(61) = 1.264$, $p > 0.211$; Unproductive-related/unrelated vs. Nonmorphological-related/unrelated $t(61) = .763$, $p > 0.448$; Apparent-related/unrelated vs. Nonmorphological-related/unrelated $t(61) = -.409$, $p > 0.684$).

Accuracy

Accuracy rates show a significant effect of condition by subjects and by items ($F_1(3,183) = 42.618$, $p < 0.001$; $F_2(3,189) = 3.218$, $p < 0.025$). Relatedness showed significance only by subjects ($F_1(1,61) = 4.066$, $p = 0.048$; $F_2 < 1$). A 2 (Relatedness) X 4 (Condition) repeated measures ANOVA revealed no significant effect of Condition * Relatedness ($F_1(3,183) = 1.148$, $p > 0.330$; $F_2 < 1$). A paired *t*-test on relatedness within each condition showed Nonmorphological related was responded to more accurately than unrelated by subjects ($t(61) = 2.800$, $p < 0.008$; all other conditions, including all by-items analysis, $p > 0.299$). Specific *p*-values on accuracy rates for by-subjects and by-items data can be found in Tables 10 below.

Table 10. *t*-test on accuracy, by subjects

Comparison	By subject *p*-value	By items *p*-value
Productive-related vs Productive-unrelated	1.000	1.000
Unproductive-related vs Unproductive-unrelated	0.817	0.944
Apparent-related vs Apparent-unrelated	0.412	0.741
Nonmorphological-related vs Nonmorphological-unrelated	0.007	0.300

We next went on to test whether our accuracy results yielded different levels of accuracy among the different conditions. Paired *t*-tests revealed a significant difference among the Productive and Nonmorphological conditions by-subjects ($t(61) = 2.237$, $p = 0.029$), and a marginal difference among the Unproductive and Nonmorphological conditions ($t(61) = 1.815$, $p = 0.074$). See Table 10 for the *t*-test results for every comparison across conditions.

Further exploration

Although we have focused our main analyses on the experimental conditions (e.g., Productive, Unproductive, Apparent, and Nonmorphological), because there are very few trials given per affix type − eight trials related, eight trial unrelated per subject, not including apparent and nonmorphological − we also provide an exploratory analysis of each affix per condition below.

A 2 (Condition: Productive and Unproductive) X 2 (Relatedness: related and unrelated) X 4 (suffixes per condition) repeated measures ANOVA was conducted on response times in order to establish any significant differences among suffixes within each condition.

Our analysis revealed a significant effect of relatedness ($F_1(1,61) = 28.674$, $p < 0.001$; $F_2(1,15) = 5.702$, $p < 0.05$), suffix type ($F_1(3,183) = 34.595$, $p < 0.001$; $F_2(3,45) = 12.350$, $p < 0.001$), and condition X suffix type for by-subjects analysis ($F_1(3,177) = 14.803$, $p < 0.001$) for Productive and Unproductive.

A by-subjects and by-items paired *t*-test on relatedness for each suffix type per condition was also conducted. One of the by-items *t*-test comparisons reached significance, Productive-related vs. Unrelated *–er* ($t(15) = -2.364$, $p < 0.05$). All other *p*-values for each relatedness pair was $p > 0.10$. The by-subjects *t*-test, however, showed a relatedness effect for only *two* Productive and *two* Unproductive suffixes (Productive *–ness*: $t(61) = -2.505$, $p < 0.05$; *-er*: $t(61) = -4.372$, $p < 0.001$; Unproductive *–ment*: $t(61) = -2.370$, $p < 0.05$; *–ous*: $t(61) = -4.077$, $p < 0.001$).

Table 11. By-Subjects and by-items *t*-test among suffixes

	Affix comparison	By subject *t*-test	By items *t*-test
Productive	related-ness vs unrelated-ness	0.015	0.195
	related-ship vs unrelated-ship	0.111	0.680
	related-able vs unrelated-able	0.136	0.705
	related-er vs unrelated-er	0.000	0.032
Unproductive	related-ity vs unrelated-ity	0.168	0.369
	related-ment vs unrelated-ment	0.021	0.289
	related-ous vs unrelated-ous	0.000	0.149
	related-ance vs unrelated-ance	0.140	0.356

Discussion

All conditions patterned similarly in response times, the Productive, Unproductive, Apparent, and Nonmorphological conditions all yielded similar response time priming. However, we observed a different pattern of results in accuracy priming. We found no accuracy priming for the Productive, Unproductive, and Apparent morphological conditions (i.e., for any of the three conditions which has potential morphological structure), but the Nonmorphological condition showed significant accuracy priming, distinguishing between morphological and orthographic priming. Unlike previous research, our pattern which distinguishes between morphological and orthographic priming, stemmed from accuracy and not response times, and we show an effect for *only* the Nonmorphological condition while other studies show effects for *all but* the Nonmorphological condition. Although this particular pattern was unexpected, it is an indicator that our data did in fact dissociate the conditions with a (potential) morphological structure from purely orthographic overlap, e.g., twinkle−TWIN. Moreover, we emphasize that even in this comparison, the Productive and Unproductive conditions patterned alike.

We turn to the implications of these findings for morphological processing, and we further evaluate the unexpected result in which the nonmorphological condition provided robust priming, in the general discussion below.

4 General Discussion

The goal of this paper was to investigate the properties of morphological decomposition, and more specifically, whether productivity has an active role in the decomposition process. Recent studies on decomposition (Bozic, Marslen-Wilson, Stamatakis, Davis, & Tyler, 2007; Longtin et al., 2003; McCormick et al., 2008; Rastle et al., 2004) have shown using a masked priming paradigm that decomposition does in fact occur at the very early stages of lexical processing for both transparent morphologically complex words, e.g., *cleaner*, and Apparent morphological ones, e.g., *corner*, but have the potential to be further decomposed. The majority of previous literature focuses on whether semantics is a necessary condition for decomposition to occur.

Our goal was to investigate whether productivity constrains decomposition. We hypothesized that if productivity plays a role in the early stages of lexical processing, we would see response time differences among affixes of different productivity levels. We chose productivity as a possible constraint on decomposition because previous literature (Aronoff, 1978; Aronoff & Anshen, 1981; Marslen-Wilson et al., 1996) suggests productivity plays an active role in the later stages of decomposition of morphologically complex words. However, these studies used an overt-priming method and a lexical decision task which has been shown to be sensitive to semantics.

Response Time data showed us that Productive- and Unproductive-affixed words pattern similarly in a masked priming paradigm. This result is consistent with the hypothesis that at the early stages of lexical processing, productivity does not play a major role in decomposition and what aids in decomposition is the potential for words to be exhaustively parsed. Therefore, response times among productive and unproductive should be relatively similar.

Unexpectedly, our findings for RT data suggest that we cannot identify morphology as the reason for priming in our Productive, Unproductive, or Apparent conditions. Although we show there being significant priming in these conditions, we also show significant priming in the Nonmorphological condition.

The accuracy data is consistent with previous literature on the processing of morphologically complex words in a masked priming paradigm (Longtin et al., 2003; Rastle et al., 2004) and supports an early decomposition model. We found that Productive, Unproductive, and the Apparent morphological conditions did not yield significant effects in accuracy. We did, however, find significant effects in the nonmorphological condition in our data. Although this is a surprising result, it is a result that makes our result fall in-line with previous studies since it *did* dissociate between morphological and orthographic priming effects. It is important to note that even though the result here in our accuracy results was surprising, the Productive and Unproductive conditions still behaved similarly (i.e., no significant effects).

In considering why the current study showed significant RT priming in the non-morphological condition, one possibility is that our nonmorphological words could stand to be more tightly controlled. Although we took careful precautions to ensure that the words chosen for our nonmorphological condition were in fact nonmorphological in nature, reinvestigation of the words showed that within some nonmorphological words exists the *potential* for further decomposition. A recent study on the decomposition of multiple morphemic words (Kazanina, Dukova-Zheleva, Geber, Kharlamov, & Tonciulescu, 2008) has shown that the process of decomposition in Russian is not only concerned with affix stripping (Taft & Forster, 1975, 1976), but also with the affixes, or potential affixes, contained within the word, i.e., preceding the "stripped" affix. Reviewing our nonmorphological words, we did find words that could follow this type of process, e.g., terminal−TERM; although the pseudo-suffix *–inal* does not exist in English, parsing *–inal* into *–in* and *–al* makes for two suffixes found in English. Furthermore, we have some other words that do not involve multiple morphemic parts, but they involve the overlap of letters as we have seen in McCormick et al. (2008), e.g., emergency−EMERGE and marinate−MARINA. Recall that McCormick et al. found significant response time effects in complex words that share a final letter in the stem and initial letter in the suffix, e.g., lover−LOVE. Therefore, although the suffixes *–ncy* and *–te* do not exist in English, taking McCormick et al.'s study into consideration shows us that our priming results could in fact be morphological in nature, e.g., -*ency* and *–ate* are legal suffixes.

Lexical Access Models and our Study

Because we found response time effects across all four conditions, we cannot conclude that our effects are morphological in nature. The accuracy results did support a morpheme-based, decomposition model, as we have seen in previous studies. Recall that we did not find that productivity constrains this early decompositional process.

The Dual-Route model (Marslen-Wilson & Tyler, 1997; Pinker, 1997; Pinker & Prince, 1988; Pinker & Ullman, 2002) contends that both a decomposition and a storage/whole-word route is available, with each accessed through various factors of a word's properties. While the focus of this model has typically been on the regular vs. irregular distinction in inflection, Clahsen, Sonnenstuhl, and Blevins (2003) and Hagiwara, Sugioka, Ito, Kawamura, and Shiota (1999) suggest that the dual-route model extends beyond inflection to productivity in derived words. Our results, however, show that productive and unproductive words are processed similarly in the initial stages of processing, consistent with an across-the-board early decompositional model.

When we consider our accuracy results, we show support for Rastle et al.'s (2004) proposal for decomposition based on a word's potential to be parsed into legal English parts. In Rastle et al. (2004), both semantically transparent and semantically opaque words decompose into their constituent (pseudo) parts (e.g., both semantically transparent *fleshy−flesh* and semantically opaque *ample−amp* showed to decompose based on response time data). In our study, the productive, unproductive, and apparent morphological condition show similar priming results. Although most literature shows this effect in RT data, our accuracy data is perhaps just as telling because it shows there are differences between the conditions that have the potential to be decomposed and the nonmorphological, monomorphemic condition without the possibility of further parsing.

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Appendix A

Primes and targets used in this experiment.

Condition	*Target*	*Related prime*	*Unrelated prime*
Productive	ABRUPT	abruptness	aldermanic
Productive	ILL	illness	soulful
Productive	FAIR	fairness	manually
Productive	BLIND	blindness	resentful
Productive	FOND	fondness	secretly
Productive	IDLE	idleness	meteoric
Productive	EAGER	eagerness	curiously
Productive	BOLD	boldness	marginal
Productive	ALOOF	aloofness	detective
Productive	DEAF	deafness	strictly
Productive	NAKED	nakedness	trackless
Productive	CALM	calmness	peaceful
Productive	COOL	coolness	validate
Productive	WEAK	weakness	clinical
Productive	NEAT	neatness	sadistic
Productive	SHY	shyness	hateful
Productive	AUTHOR	authorship	regressive
Productive	COMRADE	comradeship	progressive
Productive	CONSUL	consulship	neglectful
Productive	TOWN	township	mouthful
Productive	PREMIER	premiership	atmospheric
Productive	STEWARD	stewardship	statistical
Productive	CITIZEN	citizenship	thoughtless
Productive	COURT	courtship	objection
Productive	CENSOR	censorship	familiarly
Productive	FELLOW	fellowship	inspection
Productive	LADY	ladyship	properly
Productive	PARTNER	partnership	contraction
Productive	SPONSOR	sponsorship	courteously
Productive	TRUSTEE	trusteeship	didacticism
Productive	INTERN	internship	frictional
Productive	PARTISAN	partisanship	conventional
Productive	ADJUST	adjustable	disruptive
Productive	FISSION	fissionable	rudimentary
Productive	DETECT	detectable	delightful
Productive	PREDICT	predictable	elaborately
Productive	LAMENT	lamentable	projection

Productive	REDEEM	redeemable	resourceful
Productive	OBTAIN	obtainable	confession
Productive	ADAPT	adaptable	staunchly
Productive	PROFIT	profitable	officially
Productive	COMMEND	commendable	competently
Productive	ALTER	alterable	currently
Productive	RENEW	renewable	leisurely
Productive	FASHION	fashionable	missionary
Productive	REMARK	remarkable	dementedly
Productive	KNOWLEDGE	knowledgeable	substantially
Productive	PERISH	perishable	relentless
Productive	LOOT	looter	touchy
Productive	GOLF	golfer	hugely
Productive	BOX	boxer	soapy
Productive	CAMP	camper	frothy
Productive	SING	singer	evenly
Productive	BOMB	bomber	peachy
Productive	FARM	farmer	darkly
Productive	KILL	killer	sticky
Productive	BUST	buster	trashy
Productive	FIND	finder	quilty
Productive	STEAM	steamer	soberly
Productive	TEACH	teacher	ideally
Productive	BOWL	bowler	cystic
Productive	ROLL	roller	nicely
Productive	RENT	renter	gloomy
Productive	HUNT	hunter	warmly
Unproductive	ABSURD	absurdity	criticize
Unproductive	FORMAL	formality	patriotic
Unproductive	ACID	acidity	bluntly
Unproductive	FATAL	fatality	doubtful
Unproductive	LAX	laxity	poorly
Unproductive	LEGAL	legality	graceful
Unproductive	MORAL	morality	princely
Unproductive	AVID	avidity	prickly
Unproductive	MINOR	minority	expertly
Unproductive	ARID	aridity	locally
Unproductive	TIMID	timidity	betrayal
Unproductive	FINAL	finality	brightly
Unproductive	HUMID	humidity	suddenly
Unproductive	LIQUID	liquidity	terrorist
Unproductive	MORTAL	mortality	alcoholic
Unproductive	STUPID	stupidity	affection

Unproductive	AMAZE	amazement	sublimely
Unproductive	ENJOY	enjoyment	despotism
Unproductive	SHIP	shipment	burglary
Unproductive	ALLOT	allotment	ominously
Unproductive	ADORN	adornment	presently
Unproductive	STATE	statement	adversely
Unproductive	AIL	ailment	endless
Unproductive	AMEND	amendment	poisonous
Unproductive	ABASE	abasement	pointless
Unproductive	PAY	payment	coastal
Unproductive	ALIGN	alignment	specialty
Unproductive	ENDOW	endowment	symbolize
Unproductive	PAVE	pavement	secondly
Unproductive	PLACE	placement	prudently
Unproductive	AMUSE	amusement	initially
Unproductive	MOVE	movement	original
Unproductive	CANCER	cancerous	injection
Unproductive	RIOT	riotous	eagerly
Unproductive	VAPOR	vaporous	eruption
Unproductive	RUIN	ruinous	quietly
Unproductive	ZEAL	zealous	vaguely
Unproductive	PERIL	perilous	tropical
Unproductive	VIGOR	vigorous	sculptor
Unproductive	VENOM	venomous	idealism
Unproductive	COVET	covetous	intently
Unproductive	JOY	joyous	watery
Unproductive	BULB	bulbous	magical
Unproductive	MOMENT	momentous	eminently
Unproductive	RIGOR	rigorous	absently
Unproductive	RESIN	resinous	caffeine
Unproductive	CAVERN	cavernous	dentistry
Unproductive	DANGER	dangerous	enigmatic
Unproductive	ACCEPT	acceptance	slatternly
Unproductive	ASSIST	assistance	attractive
Unproductive	AVOID	avoidance	addiction
Unproductive	CONVEY	conveyance	neutralize
Unproductive	INHERIT	inheritance	principally
Unproductive	SUFFER	sufferance	fanaticism
Unproductive	REPENT	repentance	vehemently
Unproductive	SEVER	severance	dubiously
Unproductive	ALLOW	allowance	scholarly
Unproductive	ATTEND	attendance	amateurish
Unproductive	ACCORD	accordance	breathless

Unproductive	CLEAR	clearance	childless
Unproductive	GOVERN	governance	punctually
Unproductive	TEMPER	temperance	arrogantly
Unproductive	RESIST	resistance	vocational
Unproductive	UTTER	utterance	minimally
Apparent morphological	FACT	faction	bouquet
Apparent morphological	GRAPH	graphite	delegate
Apparent morphological	DORM	dormant	esquire
Apparent morphological	FLEET	fleeting	geranium
Apparent morphological	FABRIC	fabrication	precipitate
Apparent morphological	OVERT	overture	pentagon
Apparent morphological	METHOD	methodist	diffident
Apparent morphological	CONFIDENT	confidential	stratosphere
Apparent morphological	DESIGN	designation	superlative
Apparent morphological	BRIG	brigade	shuttle
Apparent morphological	EVER	eversion	imbecile
Apparent morphological	SECRET	secretary	fragrance
Apparent morphological	ADULT	adultery	obsolete
Apparent morphological	PLUM	plumage	ecology
Apparent morphological	CHAR	charade	travail
Apparent morphological	EARN	earnest	capsule
Apparent morphological	BUZZ	buzzard	bollard
Apparent morphological	MARSH	marshal	twitter
Apparent morphological	TOIL	toilet	ferret
Apparent morphological	BRAND	brandish	solitary
Apparent morphological	COAL	coalition	parochial
Apparent morphological	TEXT	textile	decline
Apparent morphological	LABOR	laboratory	lieutenant
Apparent morphological	LIST	listless	ultimate
Apparent morphological	PAGE	pageant	typhoon
Apparent morphological	MANIC	manicure	republic
Apparent morphological	FACET	facetious	pseudonym
Apparent morphological	GLOSS	glossary	syllable
Apparent morphological	ROUGH	roughage	thorough
Apparent morphological	FLOUR	flourish	shrapnel
Apparent morphological	HOST	hostage	animate
Apparent morphological	MISS	missive	prosper
Apparent morphological	GRUEL	grueling	sentence
Apparent morphological	DIPLOMA	diplomacy	architect
Apparent morphological	POTENT	potentate	construct
Apparent morphological	FOUND	foundation	dilettante
Apparent morphological	SATURN	saturnine	persevere
Apparent morphological	RAMP	rampage	pontoon

Apparent morphological	FLOW	flowery	papyrus
Apparent morphological	STRING	stringent	synthesis
Apparent morphological	CASUAL	casualty	describe
Apparent morphological	QUOTA	quotation	alligator
Apparent morphological	POSIT	positive	defecate
Apparent morphological	CONTENT	contentious	serendipity
Apparent morphological	CORPORA	corporation	qualitative
Apparent morphological	GRAD	gradation	nostalgia
Apparent morphological	ACCESS	accessory	retaliate
Apparent morphological	COMPLEX	complexion	propensity
Apparent morphological	COMB	combative	incentive
Apparent morphological	PASS	passion	trouble
Apparent morphological	LAMB	lambent	condone
Apparent morphological	MUST	mustard	confuse
Apparent morphological	INVENT	inventory	porcelain
Apparent morphological	TENT	tentative	plutonium
Apparent morphological	MEDIA	mediation	ludicrous
Apparent morphological	COLON	colonize	deviance
Apparent morphological	FALL	fallible	vignette
Apparent morphological	BOUND	boundary	creature
Apparent morphological	INFANT	infantry	ignorant
Apparent morphological	STALL	stallion	prestige
Apparent morphological	COMPASS	compassion	opalescent
Apparent morphological	MAXIM	maximize	cockatoo
Apparent morphological	INFER	inferior	saturate
Apparent morphological	SURGE	surgery	distant
Nonmorphological	BROTH	brothel	anomaly
Nonmorphological	TWIN	twinkle	launder
Nonmorphological	EMERGE	emergency	intellect
Nonmorphological	EXTRA	extrapolate	controversy
Nonmorphological	STAMP	stampede	metaphor
Nonmorphological	SQUAD	squadron	reticent
Nonmorphological	SCOUR	scourge	cartoon
Nonmorphological	APPEND	appendix	flamenco
Nonmorphological	HARM	harmonica	petroleum
Nonmorphological	WICK	wicket	beware
Nonmorphological	ELECT	electron	semolina
Nonmorphological	PLAIN	plaintiff	repertory
Nonmorphological	WAIT	waitress	pheasant
Nonmorphological	MINUS	minuscule	rheumatic
Nonmorphological	SOLVE	solvent	glisten
Nonmorphological	COMMA	commander	hypocrite
Nonmorphological	EXPECT	expectorate	conspicuous

Nonmorphological	SPIN	spinach	antenna
Nonmorphological	STERN	sternum	harmony
Nonmorphological	REFER	referendum	compensate
Nonmorphological	SOLE	solecism	cavalier
Nonmorphological	DELETE	deleterious	clandestine
Nonmorphological	SALMON	salmonella	vocabulary
Nonmorphological	PARENT	parenthesis	pontificate
Nonmorphological	BAMBOO	bamboozle	matriarch
Nonmorphological	PLAN	plankton	circular
Nonmorphological	CHAMP	champagne	terminate
Nonmorphological	COLLATE	collateral	vertebrate
Nonmorphological	MOUNT	mountain	populate
Nonmorphological	REND	rendezvous	providence
Nonmorphological	TRAMP	trampoline	incinerate
Nonmorphological	SCAN	scandal	devious
Nonmorphological	SHIN	shingle	facture
Nonmorphological	COMPETE	competent	intrinsic
Nonmorphological	SHALL	shallow	flutter
Nonmorphological	VASE	vasectomy	paragraph
Nonmorphological	PROP	prophecy	expedite
Nonmorphological	CHANCE	chancellor	aristocrat
Nonmorphological	LINGER	lingerie	duration
Nonmorphological	TRAP	trapezoid	sovereign
Nonmorphological	FLAME	flamenco	nuisance
Nonmorphological	TEMPO	temporal	probable
Nonmorphological	DIME	dimension	stipulate
Nonmorphological	GAZE	gazelle	freight
Nonmorphological	SIGN	significant	terrestrial
Nonmorphological	DEMON	demonstrate	equilateral
Nonmorphological	CANDID	candidacy	chocolate
Nonmorphological	REGIME	regiment	cohesion
Nonmorphological	BASIL	basilica	pamphlet
Nonmorphological	DISCO	discombobulate	cardiovascular
Nonmorphological	ETHER	ethereal	fragrant
Nonmorphological	MARINA	marinate	heritage
Nonmorphological	TERM	terminal	monument
Nonmorphological	MIST	mistress	amputate
Nonmorphological	TALL	tallow	volley
Nonmorphological	PATH	pathetic	decipher
Nonmorphological	DISCOUNT	discountenance	phantasmagoria
Nonmorphological	CRUST	crustacean	beneficial
Nonmorphological	PROVIDE	provident	apprehend
Nonmorphological	NEIGH	neighbor	discrete

Nonmorphological	CARD	cardinal	crescent
Nonmorphological	FORCE	forceps	counsel
Nonmorphological	RATIO	rational	momentum
Nonmorphological	FALSE	falsetto	sporadic