The representation and processing of derived words: exploration of a morpheme recognition task

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The Representation and Processing of Derived Words:
Exploration of a Morpheme Recognition Task

by

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Abstract

Theories of morphological representation tend to one of two extremes. Strict morphological decomposition theories argue for automatic, prelexical decomposition of complex words during recognition. They also argue that decomposition is indiscriminate, applying to pseudoaffixed words as well as truly affixed words. These theories claim that the representations of complex words in the lexicon are decomposed: They are represented by their stems plus rules for applying appropriate affixes. Full listing theories, on the other hand, argue that all familiar words are represented in whole-word form in the lexicon, and that decomposition occurs only as a fall-back procedure for unfamiliar words. Although much research has examined the issue of decomposed representation and processing, the issue remains unsettled. Some evidence indicates that the decomposition is indiscriminate, while other evidence indicates that it is not. Evidence against indiscriminate decomposition suggests that word characteristics such as semantic compositionality determine the form of morphological representation.

To address the questions of indiscriminate decomposition and the influence of word characteristics, a new morpheme recognition task was developed. In this task, a word is presented briefly, followed by a target (a prefix or suffix), and the subject must confirm or deny the presence of the target in the word. The morpheme recognition task differs from the tasks used in many previous studies in that it addresses morphology directly. Experiments 1 and 2 examined prefix and suffix recognition for truly affixed and pseudoaffixed high frequency words. The
experiments were inconclusive, because there were no differences between truly affixed and pseudoaffixed words. The two word types were treated alike during recognition, but it is unclear whether decomposition occurred for both types or for neither type. Experiment 3 investigated the influences of semantic compositionality and word frequency on processing of prefixed and suffixed words. There was evidence of an interaction between compositionality and affix type, but no frequency effect. The interaction suggests that morphological decomposition occurred only for semantically compositional words.
I. Introduction

Significance

A goal of psycholinguistics is to understand the use of language and the mechanisms responsible for skillful acquisition and performance of linguistic tasks. Nearly all of these tasks require that the person has, at minimum, some implicit knowledge of the morphology of the language (Spencer, 1991). Morphological analysis entails parsing a word into its morphemes, or smallest meaningful units, and interpreting the meaning of the whole word from the combined meanings of its morphemes. Although a person may simply retrieve or identify a previously encountered morphologically complex word from his or her lexicon, generating or interpreting a previously unencountered multimorphemic word logically would demand morphological analysis. Evidently, we have available the morphological knowledge needed to perform such analysis. The ability to perform morphological analysis has prompted knowledge of morphology to be explained and described as a set of rules for properly understanding and generating complex words. For example, plurals of nouns are formed by adding an "s", and regular past tenses are formed by adding "ed" to the verb stem.

The importance of understanding morphology is further emphasized by clinical evidence indicating that the morphological components of words are psychologically real aspects of language. Most evidence in support of this claim comes from agrammatic patients -- patients whose speech does not follow grammatical rules. Caramazza and Hillis (1989) described an interesting case of agrammatism in which
the patient’s disorder was specific to misuse or non-use of grammatical morphemes. The patient, M.L., suffered damage to the right parietal and frontal regions, and the right basal ganglia. The ensuing deficits were marked by omission of articles, auxiliaries, and both free and bound grammatical morphemes. The deficits were evident in a wide range of production tasks: unconstrained oral production, sentence repetition, sentence writing, and free written production. Performance on oral single word repetition and written and auditory comprehension was not affected. Cases with similarly specific deficits were also reported by Badecker, Hillis and Caramazza (1990), Kolk, van Grunsven and Keyser (1985), Miceli and Caramazza (1988), Miceli, Mazzucchi, Menn and Goodglass (1983) and Nespoulous et al. (1988).

Garrett (1980) provided more evidence that morphology is a psychologically real aspect of language. Garrett reviewed much of Fromkin’s (1973) speech error evidence, as well as providing a corpus of his own. He noted in both collections a large number of morpheme stranding errors. A morpheme stranding error is one in which the stem of a word is exchanged with another word, but the affixes are left behind and attached to the new word (e.g., "fancy getting your model renosed" where the intended utterance was "fancy getting your nose remodeled"). He argued that not only is it plausible that the lexicon consists of stems and affixes, but also that, due to the high probability that prefixes and suffixes are involved in speech errors, stems and affixes are represented separately.

Clearly, morphology is a psychologically real aspect of language, with implications for both comprehension and production. Although most of the past
empirical morphology research has dealt with comprehension, theories about representation and processing must take into account production evidence such as that of Caramazza and Hillis (1989), Fromkin (1973), and Garrett (1980). The separate representations of affixes in production implies one of three possibilities. The first possibility is that there is a common lexicon for comprehension and production that contains decomposed representations of morphologically complex words. The second possibility is that the lexicon contains whole-word entries, but that decomposition occurs prelexically during comprehension and postlexically during production. The third possibility is that the comprehension and production systems simply operate differently, which leaves unclear the question of lexical representation.

As I noted above, most experimental evidence comes from comprehension research. A central issue within the literature is whether or not morphological decomposition is a fundamental subprocess of word recognition. Some researchers have developed categorical positions on these issues, such as strict decomposition (Taft & Forster, 1975, 1976) and full-listing (Butterworth, 1983), while others propose mixed models (Caramazza, Miceli, Silveri and Laudanna, 1985).

Strict decomposition, as proposed by Taft and Forster (1975), means that a morphologically complex word is represented in the lexicon by its stem, and that the lexical entry consists of the stem itself plus retrievable information about acceptable affixes. Taft and Forster argued for this type of representation even for complex words containing bound stems (which can only appear as a subpart of a word), not just free stems (which can stand alone), (see Spencer, 1991). For example, Taft and
Forster argued that "juv" is the stem lexical entry for both "rejuvenate" and "juvenile" despite the fact that "juv" is a bound stem, not a word. Furthermore, they claimed that recognition of a complex word entails prelexical decomposition, or stripping of affixes and accessing the representation via the stem. For example, "re-" would be stripped from "rejuvenate" before lexical access occurred. This process is called "prefix stripping." An important aspect of the theory is that prefix stripping is an automatic, indiscriminate process. This means that morphological decomposition is also attempted on pseudoprefixed words -- words that begin with letters resembling a prefix, like "repertoire." Although Taft and Forster did not discuss language production, decomposed lexical representation suggests that production of complex words would involve, at some point in the process, concatenating the constituent morphemes of the decomposed representation.

Full-listing theories, in contrast to decomposition theories, claim that all familiar words are represented in whole-word form. For instance, "rejuvenate" and "juvenile" would have individual, whole-word listings. But full-listing does not preclude the use of morphological information during recognition or production. As Butterworth (1983) stated, even though words are listed in whole-word form, morphological information may still be available postlexically.

Mixed models incorporate morphological decomposition within a framework that specifies whole-word processing and representation. For instance, Caramazza, Miceli, Silveri and Laudanna (1985) describe a model that allows lexical access via decomposition for novel words and via whole-word activation for familiar words.
Another possible mix is a model in which word characteristics determine whether whole-word or decomposed representation and processing will occur. There are a number of relevant word characteristics. One is the type of complex word -- whether it is an inflection or derivation. Inflections are variants of a single word that belong to the same syntactic category, but derivations create new words from old, typically causing a shift in syntactic category. Another characteristic is the type of affix (prefix or suffix). Semantic compositionality, or the predictability of whole-word meaning from the meanings of the morphemes, may also affect processing and representation. Word frequency is another possible influencing factor, and there may be others.

Within the three standpoints -- strict decomposition, full listing, and mixed models -- researchers make additional assumptions about lexical access. Although every theory does not present lexical access the same way, alternative assumptions about lexical access would not generally change the underlying claims for morphology. I will, however, describe two general models of lexical access for the purpose of providing background for the evaluation of evidence to be presented below. The two models are lexical search and direct access.

**Lexical Access**

Lexical search in general is a process of searching through the lexicon for a needed lexical entry. In comprehension, a lexical search would be executed in order to find an entry that matches an orthographic input. Taft (1979) presented a detailed version of a lexical search model. He argued that the "Basic Orthographic Syllabic Structure" (BOSS) is the fundamental unit of storage and retrieval of all words. The
stored BOSS of a word is its first orthographic syllable, which Taft defined in this way: "include in the first syllable as many consonants following the first vowel of the word as orthotactic factors will allow without disrupting the morphological structure of the word." (p. 24) For example the BOSS of "lantern" is "lant", and the BOSS of "nearly" is "near." All familiar words are represented in the lexicon by their BOSS units, and the remainders of the words are specified as "tags" on the appropriate BOSSes, indicating that they are acceptable additions.

In Taft's view, words are represented by their BOSSes, and word recognition occurs as a series of searches through the lexicon for successively larger chunks of a word. So, a reader searches his or her lexicon for an entry corresponding to the first letter of a word, and if no lexical entry corresponding to that fragment is found, another letter is added in a left-to-right fashion, and the search is executed again. This process continues from left to right, until a string of letters matches a BOSS in the lexicon. The string will be found when the left to right concatenation of letters adds up to that particular word's BOSS unit. When the BOSS is located in the lexicon, the remaining portion of the word is checked for acceptability as an appropriate ending to the BOSS.

At first sight, the BOSS theory in which a word is accessed by its first syllable appears to conflict with Taft and Forster's (1975) prefix-stripping idea. However, Taft (1979) reconciled the two ideas by treating prefixed words as a special case. If a prefix is encountered during the search, it is stripped and the word is then accessed by its stem. Finally, Taft postulated that pseudoprefixed words like "repertoire" first
are recognized in two steps. First, the "prefix" is stripped. Then, when no entry for
the pseudostem is found, the search begins again with the first syllable, since it is not
a real prefix. In general, then, recognition time for pseudoaffixed words should be
long because two searches are required for recognition.

The primary alternative to lexical search is direct lexical access. In contrast to
the search model, direct access models describe lexical access as parallel activation of
word representations. Morton (1969, 1979) proposed a benchmark model of direct
lexical access called the "Logogen Theory." In this theory, lexical items are
represented as *logogens*. A logogen, in simple terms, is a representation that collects
"evidence" for the activation of a word. The system is parallel, and all logogens
simultaneously collect information. Each has a threshold, and as soon as one collects
enough evidence to exceed its threshold, it "fires," allowing recognition or selection.
McClelland and Rumelhart (1981) described and implemented a similar direct access
model. The basic principle is the same as Morton's logogen model. There are units
in the lexicon that represent words, and they are activated by visual input via feature
and letter units. Both models argue for direct activation of the representations of
words in the lexicon, so no lexical search is needed or performed. Most theorists
now assume some type of direct access, as opposed to lexical search.

**Morphological Processing and Representation**

**Decomposed Representation and Processing**

Taft and Forster (1975) offered three potential advantages for a representation
and recognition scheme that combines lexical search and morphological
decomposition. First, they suggested that it is more economical to store the stem for many words just once, and to use rules of morphology to construct complex forms when needed. Second, whether the lexicon is organized phonologically or orthographically, decomposed representations allow semantically related words such as "rejuvenate" and "juvenile" to appear "near each other" in the lexicon, since the prefix is removed (p. 645). Third, stripping off the prefixes of words allows alphabetical storage of words based on their stems rather than listing together all words beginning with the same prefix.

Taft and Forster (1975) performed a series of experiments that strongly supported prelexical decomposition during word recognition. In particular, they argued for a process of "prefix stripping." Prefix stripping means that prefixes of complex words are stripped from the stems, and lexical access is achieved by a search for the remainder of the word. Their experiments focused on the representation and processing of prefixed words. In their first experiment, they had subjects make lexical decisions to nonwords like "juvenate" and "pertoire." Both of these differ from real words by only two letters, "re-." Taft and Forster hypothesized that, because "rejuvenate" is a complex word, it would be listed in the lexicon without its prefix, even though its stem cannot stand alone. Like Taft and Forster, I will refer to word fragments like "juvenate" as bound stems, although such fragments may still have suffixes. Bound stems are nonwords formed by stripping a real prefix from a word like "rejuvenate." As a control, they included pseudostems like "pertoire." Pseudostems are nonwords that are formed by stripping a pseudoprefix from a word
like "repertoire" (see Experiment 1 methods for a specific definition of a pseudoaffix). They argued that pseudostems provide an appropriate control because they are as similar to actual words as are bound stems, i.e., they both differ from actual words by the letters "re-". Taft and Forster predicted that subjects would more quickly reject pseudostems than bound stems, based on the hypothesis that subjects would find a lexical entry for the bound stem but not for a pseudostem. Checking time would be required to determine whether or not the bound stem (e.g. "juvenate") could stand alone. If this test failed (as it inevitably would when checking a bound stem), the search would continue until the lexicon was exhausted. Only then would the bound stem be rejected. The search for a pseudostem would also be exhaustive, but no entry needing evaluation time would be found. The response to a bound stem, thus, would be slower than to a pseudostem by the amount of time elapsed in evaluating and rejecting the discovered lexical entry. The results supported the hypothesis. Reaction times for real bound stems were significantly longer than for pseudostems, and error rates were significantly higher.

Taft and Forster's (1975) second experiment involved lexical decisions to letter strings that correspond to both a free standing word and a bound morpheme, such as "vent." In this case, although "vent" is a word, it is also the stem of "prevent." They argued that lexical search is frequency based, with higher frequency words being encountered earlier than low frequency words. So, if the bound stem had a higher frequency than the free form, it would be encountered earlier in the lexical search, incurring some delay for evaluation which would be reflected as a cost in
reaction time. After the evaluation and rejection of the bound stem, the search would continue until the free form was encountered. On the other hand, if the free form had a higher frequency, it would be encountered first, and confirmation would be rapid. These predictions were confirmed.

Taft and Forster (1975) postulated that, in general, if a stem is not found, a whole-word lexical search would occur as a last resort. This would occur so that words like "repertoire" could be identified after the initial stripping process. So, in a third experiment they added inappropriate prefixes to items similar to those used in their first experiment (e.g. "dejuvenate", "depertoire"). The reason for this manipulation was to guard against the interpretation that a delay in reaction time occurred because of subjects' uncertainty as to whether or not the bound stems could stand alone. According to Taft and Forster, the presence of the inappropriate prefix should not change the results. The lexical search would occur first for the stems, exactly as if only the stems were presented. The bound stem "juvenate" would be found, and "de" would be checked as a prefix. After rejection, a whole-word search would commence. But for "depertoire", the pseudostem would not be found. The whole-word search would begin without the delay for checking the prefix. Results were as they expected. Bound stem nonwords were rejected more slowly than pseudostem nonwords.

On the basis of these results, Taft and Forster argued for "prefix stripping" during identification of a word. They claimed that word recognition involves parsing the word into prefix and stem, and searching for the stem in the lexicon. Failure to
find the stem, or failure to affirm compatibility of a stem and the stripped prefix (as in the "dejuvenate" example), would result in a lexical search for the whole word. So, a whole-word search would be made only as a last resort to identify pseudoprefixed words. Consequently, recognition time should be long, in general, for pseudoprefixed words.

**Whole-word Representation and Processing**

Taft and Forster presented strong arguments and evidence, but their case is not without flaws. Butterworth (1983) made several important points in defense of the full-listing theory of representation. He first suggested that, although knowledge of rules of morphology in principle could allow speakers to maintain a smaller list of words in the lexicon, the main concern is not the theoretically minimal type of listing, but what type of listing is actually used. He further argued that a full-listing hypothesis is difficult to disprove, since evidence of knowledge and use of morphological rules does not force abandonment of the position. In other words, one need not contend that the rules are unknown to speakers, but only that the rules are not necessarily used in all circumstances. He suggested that the rules may "come into play in fall-back procedures," much as described earlier, when a person must recognize or produce a complex, novel word. Henderson (1986) strengthened the criticism. He argued that, although nonword evidence may be useful in making inferences about the processing of unfamiliar words, the issue of interest is processing of familiar words. That morphological analysis is performed on unfamiliar words is generally uncontested.
Butterworth's and Henderson's arguments raise a very important question. Perhaps in Taft and Forster's (1975) experimental setting, subjects are forced into using fall-back procedures due to the nature of the task. Rubin, Becker and Freeman (1979) made just such a case. They first quarreled with the use of evidence obtained from nonwords to draw conclusions about morphological decomposition of real words. They suggested the possibility that nonword processing depends on morphological similarity to words, but that processing time for real words is unaffected by morphological structure. They also noted that the materials used by Taft and Forster contained a far higher percentage of prefixed words than normal reading sources such as periodicals. This introduces the possibility that subjects adopt a prefix-stripping strategy in lexical decision tasks when prefixed words are overrepresented.

In addressing their concerns about the Taft and Forster results, Rubin et al. showed that prelexical decomposition does not always occur. They compared reaction times in lexical decision to prefixed and pseudoprefixed words, in the contexts of either prefixed filler trials or non-prefixed filler trials. The non-prefixed context condition contained the same total percentage (15%) of prefixed words as their sample from normal reading sources. As expected, they found a significant effect of word type in the prefixed filler context (as did Taft and Forster), but in the non-prefixed context there was no significant effect. These results are inconsistent with the decomposition model presented by Taft and Forster (but see Taft, 1981, for criticisms). Rubin et al. proposed that subjects have multiple strategies available, and
in a situation with overrepresentation of prefixed words, they may find it beneficial to adopt a prefix-stripping strategy. They concluded that "morphological decomposition may be more the exception than the rule for word recognition" (p. 765).

Caramazza et al. also partially replicated Taft and Forster (1975). They used lexical decision on Italian words, and extended the manipulations to include nonwords that mimic a variety of Italian morphological complexities. In their replication, they confirmed Taft and Forster’s results and supported the conclusion that constituent morphemes become activated during recognition of the stimuli. Specifically, they found the longest latencies for nonwords that consisted of a real stem with incompatible affixes, somewhat shorter latencies for nonwords with a real stem but non-affix like letters attached, and still shorter latencies for nonwords with no real stem or affix. But, they also found evidence related to the "morphological structure" of nonwords that contradicts indiscriminate affix stripping processes. They found that subjects rejected prefixed nonwords more quickly than bound stems without affixes. An affix stripping model makes a clear prediction here -- the bound stem ought to be rejected more quickly than a prefixed nonword. The bound stem would require only one attempt at lexical access. But the prefixed nonword would be first stripped of its prefix so that lexical access for the remainder could be attempted. When that search failed, the prefix would be recombined with the remainder and whole-word access would be attempted. Caramazza et al.’s results are clearly at odds with this description.

Henderson’s (1986) criticism regarding generalizations from nonwords to
familiar real words applies to Caramazza et al.'s findings as well. However, evidence against decomposition of familiar real words also exists. In phoneme monitoring tasks, Schriefers, Zwitserlood and Roelofs (1991) asked subjects to identify a particular phonological segment in a stream of auditorily presented words. Critical words were stems or prefixed forms of the same stems. There were two types of prefixed forms, which differed in their uniqueness points. The uniqueness point is the point at which a word diverges from all other words beginning with the same sound sequence (Schriefers et al., p. 27). The first type (EQUAL) had a uniqueness point equal to that of the stem alone (STEM), and the second type (EARLY) had an earlier uniqueness point than the stem. In the STEM and EQUAL conditions, the target phoneme corresponded to the uniqueness point. In the EARLY condition, however, the uniqueness point occurred earlier than the target phoneme. A continuous left-to-right processing model predicts faster reaction times in the EARLY condition, because the word can be recognized prior to the perception of the target phoneme, allowing some anticipation, or a "head start", in responding. Although recognition of the word is not necessary for phoneme detection, it can facilitate detection by allowing anticipation of the target (Marslen-Wilson & Welsh, 1978). Prefix stripping, however, predicts equal reaction times, since the prefixes would be recognized and ignored until the stem is identified. Once prefixes are stripped, stems from all conditions have equal uniqueness points, meaning that none of the conditions would have an advantage of early word recognition. Results showed faster reaction times in the EARLY conditions -- a result incompatible with affix stripping models.
Schriefers et al. found similar results with pseudoprefixed words.

Overall, the evidence above indicates that experimental tasks may induce morphological decomposition, but that it may not normally occur. Tasks that involve a large number of nonwords force decomposition because such letter strings are unknown to subjects. Also, overrepresentation of affixed words appears to induce decomposition. Evidently, decomposition is available, but the evidence for indiscriminate decomposition is weak.

**Possible Compromises**

The existence of evidence both for and against decomposition indicates that the issue is quite complicated, and that a single, broad explanation will not suffice. Current evidence falsifies the strict decomposition account, but full-listing accounts are brought into question by evidence that decomposition sometimes occurs. A compromise between the two opposing theories could take one of two forms. First, a dual route may exist. A complex word may be available via both a decompositional and a whole-word access procedure, and both may operate simultaneously. As explained below, this means that whole-word representations exist, but they may not always be used. The second possibility is that some words are represented wholistically, and others decompositionally. Word characteristics like frequency and semantic compositionality, among others, may determine whether the word is represented and recognized in decomposed or whole-word form.
Dual Routes

Caramazza, Miceli, Silveri and Laudanna (1985) proposed a model of lexical representation that embodies the first type of compromise noted above. They have developed a model that they called "Augmented Addressed Morphology" (AAM). The AAM model reflects in its name the basic assumptions of the model: "addressed" means that familiar words can be accessed directly without decomposition, and "augmented" means that the model allows access of words through decomposition. Both whole-word and decompositional processes operate simultaneously, and access is complete when one process sufficiently activates the representation of the word. The assumption on which the model is based is that letter strings that correspond to familiar words activate both a whole-word representation and the morphemes (stems and affixes) that comprise the word. Further, activation of a whole-word representation proceeds more rapidly than the activation of its morphemic constituents. For an unfamiliar word, there would be no activation of a whole-word representation to supersede that of the constituents, so the individual morphemes would be analyzed and interpreted. The appeal of this system is that it allows recognition, interpretation, and production of previously unencountered words through activation of constituent morphemes, yet does not sacrifice the benefits of full-listing, such as ease of processing for familiar words.

Dual route models such as this are difficult to disprove. Evidence against decomposition effects supports the idea of faster whole-word activation. Evidence for decomposition can be interpreted as induced by experimental demands.
**Word Characteristics**

There is evidence that various characteristics of a complex word may influence its representation and the process by which it is recognized or produced. Among the possibilities are 1) the type of complex word (inflection or derivation); 2) the word’s whole-word and stem frequency; 3) the type of affix (prefix or suffix); and 4) the word’s semantic compositionality.

**Inflections and Derivations.** Spencer (1991) describes inflections as variants of a single word that belong to the same syntactic category. For example, "walks" and "walked" are inflected forms of "walk." Derivational morphemes create new words from old, typically causing a shift in syntactic category. For instance, the word "fear," a noun, combines with "-less" to form the adjective "fearless." The difference in the relation between the stem and the affixed form for inflections and derivations means that it is possible that they are represented and processed differently.

Observations in the clinical evidence discussed previously (e.g., the agrammatic patient, M.L.) supports the idea that inflections are processed differently than derivations. Caramazza and Hillis (1989) noted that M.L.’s omissions and errors involving bound morphemes always involved inflectional errors. Similar distinctions between inflections and derivations were noted by Badecker, Hillis, & Caramazza (1990).

Fromkin’s (1973) and Garrett’s (1980) speech error data also supported the idea that inflections are psychologically distinct from derivations. An important
footnote to Garrett's review regarded inflectional versus derivational morphemes. He stated, "In the MIT corpus, 64% of the stranding errors involve only inflectional morphemes, while 23% involve an inflectional morpheme and a derivational morph or a non-morph that is positionally and prosodically appropriate (and often phonetically identical) to an inflection" (p. 198). Nearly 90% of the total collection of morpheme stranding errors involved inflectional, or inflection-like derivational, affixes. So again, as with the agrammatic patients, inflections behaved differently than derivations.

Stanners, Neiser, Hernon and Hall (1979) supported the idea as well. Using a repetition priming paradigm, they found that inflected words primed their unaffixed stems as strongly as the unaffixed words primed themselves. Derived words also primed their unaffixed stems, but not as effectively as inflections did. Stanners et al. argued that inflections share a common lexical entry, so priming is strong. Derivations only prime through semantic and orthographic relatedness. They concluded that inflections do not have separate representations within the lexicon, but derivations do.

Fowler, Napps, and Feldman (1985) weakened Stanners et al.'s evidence, however. They noted that Stanners et al. separated the prime-target pairs in their repetition priming paradigm by an average of only 10 items. Fowler et al. replicated the findings, but then increased the average number of intervening items to forty-eight. The increased lag between primes and targets resulted in equal priming of unaffixed words by themselves, by inflected relatives, and by derived relatives.
Fowler et al. explained this in terms of a reduction in the episodic contribution to the priming. They claimed that, when the lag is short, semantic and formal relatedness may add to the priming effect. Because derived relatives are less semantically and formally similar to the unaffixed stems than are inflected relatives, they would prime less at a short lag. When the lag was increased to 48 items, the episodic activation of the prime was lost, so the semantic and formal relationships did not contribute to the effect. They claim that the only effect that remained after the episodic memory of the prime was lost was the effect of repeated access to a shared stem. Because inflections and derivations primed their stems equally at the longer lag, Fowler et al. claimed that inflections and derivations shared a common stem within the lexicon.

So, it is still unclear how morphological relationships are represented and how the relationships affect activation in the lexicon. However, specificity of M.L.’s and others’ deficits suggests that inflections and derivations are to some extent processed differently.

**Whole-word and Stem Frequency.** Both whole-word and stem frequency have been shown to affect processing of morphologically complex words. Specifically, Stemberger and MacWhinney (1986) showed that inflected forms with a low stem frequency are involved in more speech errors than inflected forms with a high stem frequency. They arrived at a conclusion compatible with Caramazza et al.’s AAM model. "It appears that there are two routes leading to regularly inflected forms in language production: (1) direct access of the separately stored form, and (2) application of an inflectional rule to the base form." (p. 24). They argued that high
frequency forms may be lexicalized, and therefore accessed directly from a separately stored form, but that low frequency forms may require application of a rule to a base form.

Cole, Beauvillain, and Segui (1989) examined frequency effects for derived words, and found that whole-word frequency accurately predicted latency to prefixed but not suffixed words. Stem frequency, on the other hand, determined latencies for suffixed words. They attributed this finding to the different ordering of the morphemes in prefixed and suffixed words. Specifically, they claimed that a suffixed word is accessed by its stem because the stem is at the beginning of the word. Thus stem frequency affects access to suffixed words. But, they claim that prefixes must be integrated with the stem for lexical access because the prefix is at the beginning of the word. So whole-word frequency affects access to prefixed words.

Recall, though, that Taft and Forster (1975) showed that the frequency of a homographic bound stem (e.g. "vent" of "prevent") relative to the frequency of the free form (e.g. the word "vent") affects lexical decision time for the homograph. This result suggests that stem frequency also affects access to prefixed words. The combination of evidence from Taft and Forster, Stemberger and MacWhinney (1986), and Cole, Beauvillain, and Segui (1989) indicates that both whole-word and stem frequency are important factors influencing morphological processing. The effects, however, may differ for prefixes and suffixes.

**Prefixes and Suffixes.** Although Taft and Forster (1975) labeled their morphological decomposition theory "prefix-stripping," the model actually assumes
that both prefixes and suffixes are stripped. However, even though both types of affixes are stripped, the process is somewhat different for each. Prefix stripping can be characterized as an active process -- first recognizing a prefix, then temporarily ignoring it. Suffixes, on the other hand, are stripped as a by-product of the stem recognition process. That is, as elaborated by Taft (1985), word recognition occurs through a series of searches for a stem, based on left-to-right concatenation of letters. The search process terminates prior to encountering the suffix when a stem is identified; thus, the suffix has in effect been stripped.

Although Taft (1985) described these processes, he did not make predictions about how processing differences between prefixes and suffixes should affect reaction times. Other researchers have, however, addressed this question. Bergman, Hudson, and Eling (1988) replicated Taft and Forster's (1975) prefix stripping results, but failed to find any effects for suffixes. Their results may indicate either that suffixed words are not prelexically decomposed, or that suffixes do not affect recognition time due to the left-to-right recognition process described above. The latter possibility is a conclusion that Taft (1985) would also predict.

Andrews (1986) performed a similar experiment and also failed to find effects for suffixes. In a second experiment, however, she presented the stimuli in a context that included a large number of compound words. She found that the compound word context induced decompositional effects. This result supports the idea that prelexical decomposition may be induced, although it may not normally occur.
Semantic Compositionality. A complex word is semantically compositional if the meaning of the whole word can be constructed from the meanings of its parts. That is, the word’s meaning is composed of the meanings of its morphemes. For example, "government" is "that which governs" and so is compositional in meaning, but "department" is not "that which departs" and so is non-compositional in meaning. Some evidence points in the direction of individual representation of only semantically non-compositional derivations. Aronoff (1976) and Butterworth (1983) suggested that a word might have a whole-word representation only if it is semantically non-compositional. Tyler and Marslen-Wilson (1991) reported just such an effect. In a cross-modal priming task, they demonstrated that semantically compositional prefixed and suffixed words (like "government") primed their stems, indicating that they were either decomposed during recognition, or related to the stem. Non-compositional derivations (like "department"), however, did not prime their stems, indicating that the lexical entry is independent of the entry for the stem. In other words, non-compositional derivations are treated in the same way as monomorphemic words during recognition, activating explicit, whole-word representations.

Sandra (1990) drew a similar conclusion using compound words rather than derivations. Sandra used a visual lexical decision task and primed individual morphemes of compound words to see if access to the constituent morphemes occurred automatically. For example, the word "buttercup" was primed with "bread". Presumably, if automatic access to the constituent morphemes occurs, then it should be reflected in faster response times when one element is primed, such as
"butter" of "buttercup." Results showed that priming of either the first or last constituent of non-compositional compounds had no effect. For example, neither "butter" nor "cup" primed "buttercup." But for compositional compounds, priming either constituent facilitated response times. For example, both "tea" and "spoon" primed "teaspoon." This indicated that access to the individual morphemes occurred during recognition of compositional compounds.

Summary

One possibility for a mixed model is that two routes are available for word recognition. Words activate both whole-word representations and the morphemes that comprise the words. Another possibility is that word characteristics may determine how a word is represented. Furthermore, these two possibilities may not be independent. Whole-word access may be used for some words, but decomposition may be used for other words. Which process is used may depend on the characteristics of the particular words.

Current Standing and Design Issues

Unanswered Questions

Table 1 contains a brief summary of the major theoretical issues concerning morphology, and the researchers who have contributed evidence relevant to the issues. A large body of evidence seems to indicate that the mental lexicon contains individual, whole-word listings for some but not all morphologically complex words. Also, in some situations prelexical morphological decomposition occurs during recognition. It is still unclear, however, whether decomposition occurs only as a fall-
back procedure in unfamiliar situations, or whether it occurs as a regular process of reading. A related question is whether or not there is a "preferred" process in normal reading situations. The answer to that question may not be the same for all words. For example, it appears that semantically non-compositional words are represented and processed as monomorphemic words. Also, it appears that unfamiliar complex words are more likely to be decomposed in representation and processing than familiar complex words. Finally, the last two points raise an additional question. What happens to an unfamiliar, semantically noncompositional word during the recognition process? Is it prelexically decomposed even though its lexical representation must be whole-word?

In sum, current evidence indicates that both whole-word and decompositional processes are available. Which process is used may depend on word characteristics. Additionally, aspects of experimental tasks may induce morphological decomposition where it may not normally occur. This is a problem that must be addressed when designing morphological experiments.

**Design Issues**

It is obviously desirable to devise a task that does not induce morphological analysis as a special strategy. Also, because familiar words are of primary interest and because it is generally uncontested that people perform morphological analysis on
previously unencountered words, the task should provide data on familiar words. Furthermore, it is possible that the presence of a large number of nonwords in a task may induce decomposition, so it is preferable to avoid using a lexical decision task.

The nature of English morphology introduces even more problems. Standard priming paradigms are difficult to employ, due to inherent confounds with morphology. Specifically, aspects of the language such as orthography, semantics, phonology and syllable structure are confounded with morphology. For example, "fear" and "fearless" have orthographic, semantic, and phonological overlap. Because the confounds cause problems for priming with the stem of a morphologically complex word as well as its affixes, it is difficult to create prime-target pairs with non-confounded morphemic overlap. Fowler, Napps and Feldman (1985) showed that it might be possible to separate out the confounds, but that it requires large interval repetition priming.

To summarize, problems that bear on design are that 1) decomposition strategies may result from the experimental setting, 2) single word priming is vulnerable to semantic, phonological and orthographic confounds, and 3) more data on familiar words rather than nonwords are needed. With these constraints taken into consideration, the following task was designed to provide a new perspective on several current controversial issues concerning morphology. The experiments reported below used a morpheme recognition task. The task is a variation of the partial-report procedure developed by Sperling (1960). Partial-report is a procedure during which a visual display is presented briefly to a subject and the subject reports
some subsequently cue-specified part of the display. Alternatively, subjects may be shown a target after the display and be asked to confirm or deny the presence of the target in the preceding display. Reicher (1969) used such a recognition task to demonstrate the well-known word-superiority effect. The word-superiority effect is a phenomenon in which a letter is more recognizable when it is flashed on a screen as part of a word than when it is flashed alone or as part of a non-word. The effect is generally taken to mean that people process letters more efficiently within words. The point that is most relevant here, though, is that the context in which a letter is presented affects the recognizability of the letter. The same may be true for individual morphemes of a word.

The task used here is based on the hypothesis that people may process affixes more quickly and more accurately when the affixes are part of truly affixed rather than pseudoaffixed words. To test the hypothesis, a partial-report procedure with a recognition task was used. The displays were affixed and pseudoaffixed words, and the targets on critical trials were the affixes or pseudoaffixes. The subject's task was to either confirm or deny the presence of the target in the preceding word by pressing either a "YES" or "NO" button. The rationale behind this procedure is that if prelexical decomposition occurs during recognition, the affix or pseudoaffix will be more salient than if decomposition does not occur. The underlying assumption is that the individual morphemes should be more recognizable, and therefore more quickly verified if the word is decomposed during recognition that if the word is not decomposed.
This task has several advantages over other tasks such as lexical decision and priming. First, nonwords are not necessary, which reduces the likelihood that decomposition will be induced by the task. Second, this task does not involve priming, so the priming-related confounds are irrelevant. Third, generalizability to familiar words is not a problem because familiar words are used. However, a concern with this method is that subjects could adopt a decomposition strategy in order to cope with the task of recognizing affixes. To address this problem, filler trials are included that are designed to make such a strategy less useful, perhaps even detrimental. Filler trials consist of a mix of both affixed and unaffixed words. Targets following these words correspond to letter strings from the middle of the words. The presence of these trials is intended to discourage subjects from deliberately looking only for affixes. In addition, filler trials with affixed words and mismatched targets (requiring a "NO" response) are included. The inclusion of each of these types of filler trials should discourage affix-stripping strategies.

II. "Morpheme Recognition" Experiments

This research focused on two questions. The first question was whether representation and recognition are predominantly whole-word or decomposed. All three experiments addressed this question. The second question was whether or not word characteristics like semantic compositionality and word frequency influence representation and recognition of complex words. This question was addressed by Experiment 3.
General Procedure

Displays were presented on a microcomputer, using Micro Experimental Laboratory software (Schneider, 1988). Subjects performed a morpheme recognition task. On each trial, the following events occurred (see Figure 1).

A fixation cross appeared in the center of the screen. The fixation cross disappeared and a word appeared. The word was then masked with hashmarks after a specified duration. The mask disappeared and the screen remained blank for 57 ms to avoid forward masking the target. Finally, an affix (the target) appeared on the screen. The subjects' task was to determine whether or not the target was part of the word that had been presented before the mask. They responded by pressing one of two buttons, marked "YES" and "NO." Word durations were chosen in order to assess processing at two different stages -- early in the process of lexical access, and when lexical access is complete. The mask was used to interrupt subsequent processing at the moment the word disappears. Words were presented in lower case letters, and targets were presented in capital letters in order to avoid orthographic overlap.

Experiment 1: Strict Prelexical Decomposition?

The primary question was whether or not affix stripping is an indiscriminate, prelexical process applied to both truly affixed words and pseudoaffixed words. Taft and Forster's (1975) theory states that prelexical morphological decomposition should
be attempted on both word types. Thus, affix-stripping predicts no differences in reaction time for recognizing an affix or pseudoaffix. Other theories, such as the AAM model, argue that no morphological decomposition occurs for pseudoaffixed words, thus predicting faster responses for affixes than for pseudoaffixes.

The second question was whether or not the stripping process is equivalent for prefixes and suffixes. So, both types of affixes were examined. Evidence from Bergman, Hudson, and Eling (1988) and Andrews (1986) suggests that affix/pseudoaffix effects may occur for prefixes but not for suffixes, as discussed earlier. Finally, the third question was when during the task should processing or representation differences (if any) become evident? To answer this question, two stimulus onset asynchronies (SOAs) from word to target affix were used: 230 ms and 460 ms. These SOAs were chosen because the time needed for lexical access of a word is estimated to be between 200 and 300 ms. Lexical access should be in its early stages at 230 ms, but should already be complete at 460 ms. If morphological information is available prelexically, differences should be found at both 230 ms and 460 ms (at least for prefixes). If prelexical decomposition occurs indiscriminately, but morphological information becomes available postlexically, then differences should be found only at 460 ms.

Predictions were based on three assumptions: that only truly affixed words are decomposed during recognition; that individual morphemes should be more recognizable when a word is decomposed during recognition; and that prefixes affect recognition, but suffixes do not. Thus, subjects should respond more quickly to
prefixes than to pseudoprefixes, but equally quickly to suffixes and pseudosuffixes, at both SOAs.

Method

Subjects

Forty Lehigh University undergraduates randomly chosen from the Introductory Psychology/Social Relations subject pool participated in order to fulfill a course requirement. Six of the subjects were eliminated from the analyses because their error rates exceeded a predetermined cutoff of 20% of the total number of critical trials. All subjects were native speakers of English.

Design and Materials

A 2 X 2 X 2 within-subjects design was used. The first factor was word type (affixed, e.g. "uncap," vs. pseudoaffixed, e.g. "uncle"). The second factor was affix type (prefix vs. suffix). The third factor was Stimulus Onset Asynchrony (230 ms vs. 460 ms). SOA was blocked and counterbalanced across subjects to avoid order effects. Each subject received a different randomized order of items. The following criteria were used for selection of pseudoaffixed items:

1) The etymology in the dictionary does not list the word as affix + stem, or stem + affix;
2) The stem (portion that remains, after removing the affix-like letters), or any other affixed form of the stem, is not used in the definition of the word;
3) The stem cannot stand alone, with the exception of stems clearly not relevant to the whole word, e.g. "son," from "bison";
4) The affix string cannot be replaced with any other affix to make another form of the word.

The criteria for selection of truly affixed words were as follows:

1) The etymology lists the word as affix + stem or stem + affix;

and either

2) a. The stem must be able to stand alone, and is semantically related to the word, or
   b. The affix can be replaced with another affix to make a semantically related word.

Critical stimuli are presented in Appendix 1. Affixes and pseudoaffixes always corresponded to the first or last syllable of the critical words. Generalizability to familiar words was important, so it was desirable to use only high frequency words. Note, though, that the use of high frequency words makes detection of differences less likely. Sternberger and MacWhinney (1986) showed that only stem frequency predicts response latencies to suffixed words, and only whole-word frequency predicts response latencies to prefixed words. In this experiment, however, only whole-word frequencies were used because pseudoaffixed words have no real stems. Finding high frequency affixed words was difficult, so average whole-word frequency of critical items in this experiment was only around 30 occurrences per million words. However, this frequency should be high enough so that the words are at least familiar to subjects. Average word frequency and word length were approximately balanced between conditions.
Each subject received a total of 240 trials. The correct answer to exactly half was "YES." The "YES" trials consisted of 80 critical trials and 40 filler trials. Of the 80 critical trials, there were 20 prefixed words, 20 suffixed words, 20 pseudoprefixed words, and 20 pseudosuffixed words. The 40 filler trials consisted of 20 words in which the various prefixes from critical trials were embedded in the middle of the words, and 20 in which the various suffixes were embedded. The embedded targets did not necessarily correspond to a syllable. Embedded target trials were included to discourage affix-stripping strategies. So, one-third of the targets in "YES" trials match the beginning of the word, one-third match the end of the word, and one-third match a letter string embedded in the middle of the word. The "NO" trials consisted of 20 prefixed words, 20 suffixed words, and 80 non-affixed words. The prefixed and suffixed "NO" trials were included in order to discourage subjects from simply responding affirmatively whenever they saw a prefixed or suffixed word. From each subgroup of items, half of the items were randomly assigned to each SOA block, for each subject.

Procedure

Each subject was tested individually. Subjects were seated directly in front of the computer, approximately one to two feet from the monitor screen. Subjects were instructed to focus on the fixation cross when it appeared on the screen, and to watch carefully because the subsequent displays would be extremely brief. They were asked to respond as quickly as possible when the target appeared on the screen. The experimenter reviewed the instructions using a diagram of the displays for each trial.
The instructions also informed the subjects that there would be two blocks of trials, and were told which display duration (short or long) was to be presented first.

Subjects were allowed up to 2000 ms to respond, and responded by pressing the "YES" or "NO" key. Each subject used his or her dominant hand's index finger for the "YES" key, and the other hand's index finger for the "NO" key. A 500 ms tone sounded after incorrect responses and time-outs. Feedback on response time was displayed on the screen after every 24 trials. The feedback display reported overall average reaction time and average reaction time for the 24 trials preceding the feedback message. The display always encouraged subjects to respond quickly. Subjects continued by pressing the "YES" button when they were ready.

At the end of the first block of trials, subjects were allowed to rest, and were told that the display duration would be different for the second block. Ten practice trials were provided before the first block, and five were provided before the second block. Practice trials used the same SOA as the block of trials that they preceded.

The trial displays were based on the assumptions that word recognition occurs automatically, begins immediately upon presentation, and proceeds rapidly. On each trial, the fixation cross appeared for 500 ms, followed by a word. The word duration was approximately 70 ms in one block, and 300 ms in the other. The mask duration was constant, 100 ms. Following the mask, the screen was blanked for approximately 57 ms, to avoid forward-masking the target string, which appeared immediately after the blank interval. These durations resulted in SOAs of about 230 ms and 460 ms. SOAs varied slightly from these estimates due to the refresh cycles of the monitor.
Results and Discussion

For this and all subsequent experiments, error trials were excluded from the reaction time data, and for all main analyses, minimum quasi-F's (min F') were calculated on both reaction times and error rates, using subjects (E₁) and items (E₂) as random effects (Clark, 1973). In the main analyses, min F' is reported first, followed by E₁ and E₂. For reaction times, biweight estimation (Mosteller and Tukey, 1977) was used to calculate a central estimate for every condition for each subject (see Appendix 3). These values were then averaged across subjects to calculate the means for each condition. For item analyses, biweight estimates of reaction times were calculated for the items in each condition, across subjects.

Because SOA was counterbalanced over blocks in this experiment, a preliminary analysis included order of SOAs as a factor. The analysis showed an interaction of order with SOA, E₁(1, 32) = 26.97, p < .0001. The analysis involved a between-groups order factor and the same three within-subjects effects as in the main analyses below. Table 2 rearranges the data by block showing means of biweight estimates of response times for the first block and second block to highlight the fact that the interaction is a simple practice effect: Subjects responded faster in the second block than in the first block, regardless of SOA.

Insert Table 2 about here

Because order did not interact with any other factors, order was not included
as a factor in the main analyses. Means of biweight estimates of reaction times, standard errors of the means, and percentage of errors for each condition of Experiment 1 are presented in Table 3. A three factor ANOVA on reaction times indicated that subjects did not respond significantly more quickly to prefixes than to suffixes, \( \text{min } F'(1,105) = 2.72, p < .05 \), but the effect was significant both by subjects and by items, \( F(1,33) = 6.88, p < .05 \), \( F(1,76) = 4.50, p < .05 \). No other effects or interactions were significant. An analysis of error rates showed no significant effects.

The effect of affix type is not surprising because of the relative locations of the prefixes and suffixes in the words. However, the main interest of the experiment was the comparison of truly affixed words with pseudoaffixed words. There was no significant effect of this variable. The fact that there were no differences between truly affixed words and pseudoaffixed words suggests one of three conclusions. First, prelexical affix stripping may have been indiscriminate, as Taft and Forster (1975) argued. Second, prelexical decomposition may not have occurred for either type of word. Third, this task may not be able to detect differences in processing. The first possibility seems unlikely because it seems that if both types of words are decomposed prelexically, the misleading decomposition of a pseudoaffixed word ought to be resolved at the longer SOA. Resolution would involve whole-word activation.
rather than constituent morpheme activation, so response latencies for true affixes should have been shorter than response latencies for pseudoaffixes at the long SOA. However, there was no difference. The second and third possibilities, thus, are each more likely than the first. However, deciding between the second and third is impossible at this point.

Further exploration of the results of the experiment provided insight into whether or not the task is able to detect differences. One indicator of a potential problem with the task was that error rates were high. Although there were no effects in the main analysis, several more analyses were conducted on error rates for the purposes of further exploring the results. Because there was no word type effect, a post-hoc analysis of error rates collapsed over word type was performed. For this analysis, filler trials in which the target was embedded in the word were compared to critical prefix and critical suffix trials. Means of error rates and standard errors of the means for this test are presented in Table 4.

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Insert Table 4 about here

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The analysis indicated that targets from the middle of the word were most difficult to recognize, followed by prefixes and suffixes, $F_1(2, 66) = 73.93, p < .0001$. This effect presumably reflects discernibleness of the target within the word. Targets taken from the middle of the word are possibly most difficult to recognize because they are surrounded by other letters, and also because they did not necessarily correspond to a
syllable or morpheme, as did prefix and suffix targets.

An additional post-hoc analysis indicated that subjects made fewer errors on embedded prefix targets ($M = 21.3\%$) than on embedded suffix targets ($M = 35.4\%$), $F(1, 33) = 23.36, p < .0001$. This effect was unexpected, and could reflect a deliberate subject strategy of scanning for prefixes. If subjects were doing this, word type differences would be difficult to detect because subjects would be paying attention only to fragments of the words instead of to the words as whole-units.

The results of Experiment 1 indicated that a subject strategy may have reduced the likelihood of finding word-type effects. This possibility was indicated in particular by higher error rates for embedded suffixes than for embedded prefixes. A probable cause of the high error rates was that the instructions emphasized speed of responses, not accuracy. The emphasis on speed may have encouraged subjects to use a strategy resulting in high error rates. In order to adequately judge the task's ability to detect word-type differences, the possibility of a subject strategy needed to be eliminated. Experiment 2 was an attempt to eliminate the possibility of a subject strategy by emphasizing accuracy over reaction time.

**Experiment 2: Emphasis on Accuracy**

In Experiment 1, the difference between errors on critical prefix/suffix trials and filler embedded trials was expected. However, it is possible that subjects were simply concentrating on the beginnings and ends of the words so they could respond quickly in most cases. Furthermore, subjects verified embedded prefix targets more accurately than embedded suffix targets, which may indicate a "prefix-scanning"
strategy employed to cope with the task, allowing faster responses at the expense of accuracy. Such a strategy would probably diminish any word type effects, because subjects would be paying less attention to the actual word and more attention to the affixes. High overall error rates and the significantly higher rate for embedded targets may mean that the instructions placed too much emphasis on reaction time and not enough emphasis on accuracy. Experiment 2 was a replication of Experiment 1, with changes in subject instructions and feedback displays to address the concern about accuracy.

Method

Subjects

Thirty-two Lehigh University undergraduates randomly chosen from the Introductory Psychology/Social Relations subject pool participated in order to fulfill a course requirement. Data from only one subject were eliminated from the analyses because of error rates that exceeded a predetermined cutoff of 20% of the total number of critical trials. All subjects were native speakers of English.

Design and Materials

Design and materials were the same as those used in Experiment 1.

Procedure

In this experiment, the instructions to subjects stressed accuracy instead of speed. Subjects were told to respond as accurately as possible, but also to respond quickly. Also, the instructions emphasized the possibility that the fragment could be present in any part of the word -- beginning, middle, or end -- to discourage
strategies. Finally, the feedback message was modified so that it reported accuracy rate as well as average response times. Otherwise, the procedure was the same as in Experiment 1.

Results and Discussion

Means of biweight estimates of reaction times for each condition are presented in Table 5. Analyses for Experiment 2 were similar to those for Experiment 1. A preliminary analysis indicated that there was a significant interaction of order and SOA, $F_1(1, 29) = 15.52, p < .001$. As explained earlier, this is simply a practice effect. Order did not interact with any other factors, so the main analyses did not include this factor.

A three factor ANOVA on reaction times indicated that subjects responded more quickly to prefixes than to suffixes, $min F'(1, 65) = 4.24, p < .05, F_1(1, 30) = 6.59, p < .05, F_2(1, 76) = 11.89, p < .001$. There was also evidence of an SOA X affix type interaction, indicating that subjects responded more quickly to prefixes than to suffixes at the short SOA, but equally quickly at the long SOA. For this interaction, $min F'(1, 62) = 3.24$, was not significant, but both $F_1(1, 30) = 4.92, p < .05$, and $F_2(1, 76) = 9.55, p < .01$ were significant. No other effects or interactions were significant. So, like Experiment 1, Experiment 2 provided no evidence that affixed and pseudoaffixed words are processed differently.

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The affix effect was smaller at the long SOA than at the short SOA in the separate analyses with subjects and items as random effects. This supports the possibility that the affix effect found in Experiment 1 and in this experiment is due to the affix's left-to-right position within the word rather than to some characteristic processing or representational differences between prefixes and suffixes. The shorter SOA may not provide enough time to process the suffix completely because it is at the end of the word, but the long SOA may provide enough time. That explanation does not rule out processing differences, but suggests that differences in response times to prefixes and suffixes in this task were due to the affixes' positions. However, in the absence of effects of word type, neither the affix main effect nor the affix type X SOA interaction are of great theoretical interest.

An analysis of error rates showed that subjects tended to make more errors at the short SOA than at the long SOA, min $F'(1, 81) = 3.22, p > .05, F_1(1, 30) = 6.04, p < .05, F_2(1, 76) = 6.90, p < .05$. This trend was not surprising because the longer SOA allowed subjects more time to read the word.

As in Experiment 1, a post-hoc analysis of error rates collapsed over word type was performed. For this analysis, filler trials in which the target was embedded were again included. Means and standard errors of the means for this test are presented in Table 6. The analysis again indicated that targets from the middle of the word were most difficult to recognize, followed by prefixes and suffixes, $F_1(2, 60) = 80.87, p < .0001$. 

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Again, an additional post-hoc analysis indicated that subjects made fewer errors on embedded prefix targets (M = 19.4%) than on embedded suffix targets (M = 28.5%), $F_1(1, 30) = 11.90, p < .01$. A concern in both Experiment 1 and this experiment was that subjects adopted a "prefix-scanning" strategy. It is possible, however, that prefix letter combinations are simply more familiar and therefore more easily recognizable than derivational suffixes. Alternatively, some other characteristic of prefixes and suffixes may be responsible, such as the fact that most prefixes used here began with consonants, while most suffixes began with vowels. Because of the emphasis on accuracy in the instructions, the possibility that subjects were "prefix-scanning" is less likely than in Experiment 1.

The absence of a word type effect is still unexplained. Three possible explanations were outlined for Experiment 1. The first was that prelexical decomposition occurred for both types of words. This possibility was discarded in Experiment 1 because the word type effect was absent even at the long SOA. The second possibility was that prelexical decomposition may not have occurred for either type. That is still possible and needs to be considered further. The third possibility was that the task is unable to detect differences in processing. That is also still possible. Although Experiment 2 reduced the possibility that a subject strategy was present, it did not explain the absence of the word type effect.
**Experiment 3: Semantic Compositionality and Frequency**

Experiments 1 and 2 left unanswered the question of prelexical morphological decomposition because there were no word type effects. One of the two remaining explanations for the absence of the word type effect was that decomposition did not occur for either word type. This explanation is quite possible because Experiments 1 and 2 used only high frequency words, and it is possible that only unfamiliar words are morphologically decomposed during recognition. Experiment 3 therefore manipulated word frequency to test the hypothesis that only low frequency words are decomposed during recognition.

Experiments 1 and 2 compared truly affixed words with pseudoaffixed words. In Experiment 3, however, the word type manipulation compared semantically compositional and semantically non-compositional words. The word type manipulation was changed because other researchers have demonstrated that semantically non-compositional words are not decomposed in representation or recognition, but that semantically compositional words are (Tyler & Marslen-Wilson, 1991; Sandra, 1990). So, semantic compositionality effects may be more detectable than affix/pseudoaffix effects. Additionally, as in Experiments 1 and 2, the type of affix (prefix vs. suffix) was manipulated.

High frequency words were not expected to produce a compositionality effect, for two reasons. First, there is evidence that high frequency complex words (even semantically compositional words) are represented in whole-word form (Stemberger & MacWhinney, 1986). In that case, there should be no differences between the
compositional and non-compositional words high frequency words. The second reason was that the manipulation of word type had no effect in Experiments 1 and 2, both of which used only high frequency words.

The low frequency words, on the other hand, were expected to produce a compositionality effect, based on the assumption that low frequency non-compositional words would not be decomposed, but that low frequency compositional words would be decomposed. In other words, even if a non-compositional word is low frequency, it must be in whole-word form in the lexicon in order to be recognized and interpreted at all, because its meaning cannot be constructed from its morphemes. A compositional word may, however, be represented in decomposed form because its meaning can be constructed from its morphemes.

To summarize, a frequency X compositionality interaction was predicted, with only low frequency words predicted to show compositionality effects. Also, based on Experiments 1 and 2, an affix main effect was also predicted, with responses to prefixes predicted to be faster than responses to suffixes.

**Method**

**Subjects**

Forty-six Lehigh University undergraduates randomly chosen from the Introductory Psychology/Social Relations subject pool participated in order to fulfill a course requirement. Data from six subjects were discarded because the subjects exceeded the predetermined error cut-off rate of 20% of critical trials.
Design and Materials

Experiment 3 was a 2 X 2 X 2 within-subjects design. The factors were semantic compositionality, frequency, and affix type. A semantically non-compositional word is, in a sense, a pseudoaffixed word with the peculiarity that its "pseudostem" is a free-standing word. It is pseudoaffixed in the sense that its etymology may not be listed as stem + affix or affix + stem, because the stem word is semantically unrelated to the whole. For example, the etymology for "sublime" does not list "lime" as a source of the word. Non-compositional words were selected according to the following criteria:

1) The stem must exist as a free form;
2) The stem or the definition of the stem is not used in the whole-word definition;
3) There is no intuitive semantic relation between the stem and the whole-word.

Semantically compositional words were chosen according to these criteria:

1) The stem exists as a free form;
2) The etymology lists the word as stem + affix or affix + stem;
3) The stem or the definition of the stem is used in the whole-word definition.

Critical items for Experiment 3 are presented in Appendix 2. As in Experiments 1 and 2, affixes always corresponded to the first or last syllable of the critical words. Because both stem frequency and whole-word frequency were available for all words in Experiment 3, an average of both was used for the frequency manipulation. This average, in effect, is a compromise on the issue of whether stem or whole-word frequency is the important factor in processing.
Each subject received 240 trials, one-half of which contained the target (thus requiring a "YES" response). The "YES" trials consisted of 10 words in each of the eight conditions, plus 40 embedded filler trials. The embedded filler trials and the 120 "NO" trials were designed as in Experiments 1 and 2. Each subject received a different randomized order of items.

**Procedure**

The procedure was similar to that of Experiment 2, with one exception: all items were presented in one block using one SOA of 230 milliseconds because SOA did not interact with word type in Experiments 1 and 2. Accuracy was emphasized in the instructions. Otherwise, the procedure was as in Experiment 2.

**Results and Discussion**

Means of biweight estimates of reaction times, standard errors of the means, and accuracy rates are presented in Table 7.

A three factor ANOVA was calculated on reaction times. Subjects tended to respond more quickly to targets following high frequency words than to targets following low frequency words, but this effect was significant only in the analysis by subjects, $\text{min } F'(1, 104) = 2.79, p > .05, F_1(1, 39) = 12.33, p < .01, F_2(1, 72) = 3.61, p > .05$. Responses to prefixes were significantly faster than responses to suffixes, $\text{min } F'(1, 74) = 6.06, p < .05, F_1(1, 39) = 8.83, p < .01, F_2(1, 72) =$
There was no main effect of compositionality, but there was evidence of a compositionality X affix type interaction (see Figure 2). This test was not significant with the \( \text{min } F' \) test, \( \text{min } F'(1, 104) = 3.19, p > .05 \), but both the subject and item analyses showed significance, \( E_1(1, 39) = 6.75, p < .05 \), \( E_2(1, 72) = 6.06, p < .05 \). Subjects verified prefixes faster following non-compositional words than following compositional words, but for suffixes the opposite was true. No other effects were significant. An analysis of error rates showed no significant effects.

Affixes were expected to be more easily recognizable and more quickly verified in semantically compositional complex words than in non-compositional words. This was because the evidence in the literature suggests that compositional words are more likely to be prelexically decomposed. Therefore, the constituent morphemes of a compositional word ought to be more easily recognized and thus more quickly verified. Faster responses would indicate a decompositional process, and slower responses would indicate whole-word recognition.

However, the data for prefixes conflict with these predictions. That is, prefixes appeared to be less recognizable in compositional words. Data for suffixes, though, align well with the predictions. Subjects responded somewhat more quickly to suffixes following semantically compositional words -- words more likely to be
decomposed. The interaction supports the ideas that compositionality affects morphological processing, and that prefixes and suffixes are processed differently. But why are prefixes and suffixes processed differently with respect to compositionality?

First, I suggest that Taft and Forster’s (1975) affix-stripping model and Taft’s (1979) theory of word recognition are fundamentally flawed. Taft claims that the process of word recognition involves indiscriminate prefix stripping and concatenating letters from left to right until the string matches a lexical entry. On this account, compositionality should have no effect on the verification of affixes. The data from Experiment 3, then, contradict Taft and Forster (1975). A dual route model such as AAM may be able to accommodate the data if the model specifies that non-compositional words do not activate constituent morphemes in the same way that compositional words do. However, this would require some revision because non-compositional words contain a real stem, and no information would be available prelexically that could prevent activation of the constituent morphemes.

It may, however, be possible to explain the data by assuming direct lexical access and representational differences between semantically compositional and semantically non-compositional words. Although more research is needed to support any conclusions, the following theory is one possible way of explaining the pattern of data.

In direct access theories, like McClelland and Rumelhart’s (1981) interactive activation model, the letters of a semantically non-compositional word would activate
a whole-word lexical entry. Because the word's meaning cannot be constructed from its morphemes, its lexical entry must be in whole-word form. Compositional words, on the other hand, could activate a stem and an affix in a direct access model with a morphological level of representation. The compositionality X affix interaction can be explained as a consequence of the relative importance of word-initial and word-final letters. In general, word-initial letters are more important in word identification than word-final letters. This is supported by faster responses to prefixes than to suffixes in all three experiments. The generalization holds true for non-compositional words because non-compositional words are treated as monomorphemic. On the other hand, the difference in importance between word-initial and word-final letters is diminished when the letters constitute the affixes of compositional words. The reason for the diminution is that compositional words are morphologically decomposed during recognition, so the stems become the most salient parts of the words. This explanation requires the additional assumption that the affixes are important for recognition of compositional words, and that the importance of the affixes relates to the importance of word-initial and word-final letters in the following ways: 1) prefixes are LESS important than are word-initial letters of monomorphemic words, but 2) suffixes are MORE important than are word-final letters of monomorphemic words. In other words, both prefixes and suffixes are intermediate in importance between word-initial and word-final letters of unaffixed words. The result in terms of recognition in this task is a convergence of response times to prefixes and suffixes of compositional words. Note in Figure 2 that the prefix-suffix difference is much more
pronounced for non-compositional words than for compositional words. This result follows directly from the discussion above. The effect of the relative importance of word-initial and word-final letters is diminished for semantically compositional words because word-initial letters become less important and word-final letters become more important, due to their status as affixes. For semantically non-compositional words, this is not the case. Non-compositional words are treated as monomorphemic words, so the relative importance of the letter positions is reflected in large prefix-suffix reaction time differences.

Overall, the trend towards a compositionality X affix interaction suggests that non-compositional words are treated as monomorphemic, but compositional words may be decomposed during recognition. The relative importance of word-initial and word-final letters appears to be responsible for reaction time differences between prefixes and suffixes. However, that effect is diminished when a word is decomposed during recognition.

General Discussion

Taken together, the three experiments provide evidence against indiscriminate, prelexical affix stripping, and against Taft’s (1979) BOSS model of word recognition. No word-type effects were found in Experiments 1 and 2, indicating that truly affixed and pseudoaffixed words were represented and recognized in the same manner. Because the words were high frequency, it is more likely that neither word type was decomposed, than that both types were decomposed. The lack of effects at the longer SOA supports this idea. If both word types were prelexically decomposed, the
indiscriminate decomposition of pseudoaffixed words should have been resolved at the longer SOA, resulting in whole-word activation and, hence, slower verification of affixes. Although no such effect was found, the conclusion that decomposition did not occur must be made with hesitation, because it is still possible that decomposition occurred for both types of words, or that the task was insensitive to the effect.

Experiment 3, on the other hand, showed evidence of decomposition for semantically compositional words, but not for non-compositional words. This further contradicts the idea of indiscriminate affix stripping. Affix stripping models cannot account for any word type differences because affix stripping is supposed to be indiscriminate. Furthermore, the trend was present for both high and low frequency words.

Caramazza, Miceli, Silveri and Laudanna’s (1985) AAM model, as it stands, is also unable to explain the compositionality effects. Because both compositional and non-compositional words contain free stems, activation of the individual morphemes of both types of word should occur. Differences in verification times of the affixes in Experiment 3 indicates that this was not the case.

Judging from the results of the three experiments presented here, Taft’s (1979) BOSS model, Taft and Forster’s (1975) morphological decomposition theory, and Caramazza, Miceli, Silveri and Laudanna’s (1985) AAM model are rejected in favor of a standpoint embodying direct lexical access and lexical entries that are either decomposed, whole-word, or both, as determined by various characteristics of the words. Among these characteristics are, type of complex word (i.e. inflected or
derived), word frequency, and semantic compositionality. A large body of evidence, both clinical and empirical, demonstrates that inflections and derivations are somehow processed differently and perhaps represented differently. Because whole-word frequency and stem frequency were not compared here, no judgements can be made on the separate influences of each on morphological processing and representation. Logical arguments suggest that semantically non-compositional words are represented and recognized in whole-word form, independently of their stems. The trend in the data from Experiment 3 supports that argument. Representation and recognition of semantically compositional words, on the other hand, may involve morphological decomposition. Decomposition of semantically compositional words may depend on frequency, as suggested by evidence in the literature, but that conclusion awaits empirical support.

Finally, prefixes and suffixes were originally supposed to be processed differently, and perhaps represented differently as well. However, the data from these experiments indicate that word-initial letters are simply more important than word-final letters, and are therefore verified more quickly. Furthermore, Experiment 2 showed that the affix effect weakened at the longer SOA, which tends to indicate that the effect is due to the positions of prefixes and suffixes rather than to differences in their representations. Additionally, the effect of their relative positions may be diminished if the word is decomposed during recognition. So, the differences in reaction times for prefixes and suffixes are probably a direct result of their positions within words. The evidence of a compositionality X affix interaction seems to
indicate that when a word is decomposed during recognition, the difference in
importance between word-initial and word-final letters is diminished. This may be a
result of an elevation of the stem's importance when a word is decomposed.

Conclusions

The main purpose of the experiments reported here was to determine whether
or not different types of words are processed differently. Specifically, Experiments 1
and 2 compared affix recognition for truly affixed versus pseudoaffixed words.
Prefixes were verified more quickly than suffixes in these experiments, presumably
because of the different positions of prefixes and suffixes within words.
Unfortunately, there was no word type effect in either of the first two experiments.
Possible reasons for the absence of a word type effect are that decomposition occurred
for both word types, that decomposition did not occur for either word type, or that
the task was not able to detect differences. For design reasons, only high frequency
words were used in these first tests of the morpheme recognition task. However, it is
possible that the absence of word type effects was a result of using only high
frequency words, because high frequency words may be less likely to be decomposed.

In Experiment 3, however, the word type manipulation produced an effect.
Experiment 3 compared affix recognition for semantically compositional versus
semantically non-compositional words, and showed an interaction of affix type and
semantic compositionality. The interaction suggests that morphological decomposition
occurred only for semantically compositional words. The compositionality X affix
effect in Experiment 3 demonstrated that the morpheme recognition task is, in some
cases, able to detect word type differences. Experiment 3 also manipulated word frequency. This manipulation produced no effect, but word frequency effects are so widely demonstrated in language research that it is reasonable to expect frequency to affect responses in the morpheme recognition task in future tests. It is possible that the frequency manipulation in Experiment 3 just was not strong enough to produce an effect.

So, although word frequency produced no effect in Experiment 3, it still may be a worthwhile factor to include in subsequent morpheme recognition experiments. Taken together, the three experiments and the literature on morphological processing show that word characteristics such as semantic compositionality, affix type, and word frequency influence processing of morphologically complex words. The morpheme recognition task may be useful in further elucidating exactly how these characteristics of complex words influence morphological processing and representation.
Footnotes

1. Caramazza and Hillis describe this task as single word production, but a more appropriate description is single word repetition, since the patients do not spontaneously produce the words.

2. All word frequency counts are from Kucera and Francis (1967).

3. Whole-word frequency tends to give a low estimate of frequency for affixed words. If stem frequencies were used, the estimates would be higher.
Table 1

Summary of current theoretical issues concerning morphology.

<table>
<thead>
<tr>
<th>Theoretical Issue</th>
<th>Source of Evidence</th>
<th>Researchers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Indiscriminate affix stripping</strong></td>
<td>lexical decision</td>
<td>Taft &amp; Forster, 1975</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Taft, 1979, 1985</td>
</tr>
<tr>
<td><strong>Full listing</strong></td>
<td>logical arguments</td>
<td>Butterworth, 1983</td>
</tr>
<tr>
<td><strong>Decomposition only as a strategy</strong></td>
<td>lexical decision</td>
<td>Rubin et al., 1979</td>
</tr>
<tr>
<td></td>
<td>lexical decision</td>
<td>Caramazza et al., 1988</td>
</tr>
<tr>
<td></td>
<td>phoneme monitoring</td>
<td>Schriefers et al., 1991</td>
</tr>
<tr>
<td><strong>Dual Routes</strong></td>
<td>lexical decision</td>
<td>Caramazza et al., 1985</td>
</tr>
<tr>
<td><strong>Word Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Inflections vs. Derivations</em></td>
<td>clinical evidence</td>
<td>Caramazza &amp; Hillis, 1989</td>
</tr>
<tr>
<td></td>
<td>speech errors</td>
<td>Fromkin, 1973; Garrett, 1980</td>
</tr>
<tr>
<td><em>Whole-word vs. stem frequency</em></td>
<td>speech errors</td>
<td>Stemberger &amp; MacWhinney, 1986</td>
</tr>
<tr>
<td></td>
<td>lexical decision</td>
<td>Cole et al., 1989</td>
</tr>
<tr>
<td><em>Prefixes vs. Suffixes</em></td>
<td>lexical decision</td>
<td>Bergman et al., 1988</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Andrews, 1986</td>
</tr>
<tr>
<td><em>Semantic Compositionality vs. Non-compositionality</em></td>
<td>cross-modal priming</td>
<td>Tyler &amp; Marslen-Wilson, 1991</td>
</tr>
<tr>
<td></td>
<td>lexical decision priming</td>
<td>Sandra, 1990</td>
</tr>
</tbody>
</table>
Table 2

Means of biweight estimates of reaction times for blocks 1 and 2, for each order of presentation in Experiment 1.

<table>
<thead>
<tr>
<th>Block Order</th>
<th>Block 1</th>
<th>Block 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>230-460 ms</td>
<td>570</td>
<td>484</td>
</tr>
<tr>
<td>460-230 ms</td>
<td>530</td>
<td>471</td>
</tr>
<tr>
<td>Overall</td>
<td>550</td>
<td>478</td>
</tr>
</tbody>
</table>
Table 3

Means of biweight estimates of reaction times, standard errors of the means, and error percentages by affix type, word type, and SOA, in Experiment 1.

<table>
<thead>
<tr>
<th>SOA</th>
<th>Prefix</th>
<th></th>
<th>Suffix</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pseudoprefix</td>
<td>True prefix</td>
<td>Pseudosuffix</td>
<td>True suffix</td>
</tr>
<tr>
<td>230 ms</td>
<td>RT errors</td>
<td>513 (±20)</td>
<td>522 (±19)</td>
<td>537 (±16)</td>
</tr>
<tr>
<td></td>
<td>errors</td>
<td>8.5%</td>
<td>9.4%</td>
<td>8.5%</td>
</tr>
<tr>
<td>460 ms</td>
<td>RT errors</td>
<td>494 (±15)</td>
<td>483 (±14)</td>
<td>508 (±19)</td>
</tr>
<tr>
<td></td>
<td>errors</td>
<td>5.6%</td>
<td>9.1%</td>
<td>6.2%</td>
</tr>
</tbody>
</table>
Table 4

Error percentages as a function of location of target in word, and SOA, in Experiment 1.

<table>
<thead>
<tr>
<th>SOA</th>
<th>critical prefix</th>
<th>filler embedded</th>
<th>critical suffix</th>
</tr>
</thead>
<tbody>
<tr>
<td>230 ms</td>
<td>9.0% (±1.3)</td>
<td>28.8% (±2.4)</td>
<td>7.9% (±1.5)</td>
</tr>
<tr>
<td>460 ms</td>
<td>7.4% (±1.4)</td>
<td>27.9% (±2.3)</td>
<td>5.1% (±1.0)</td>
</tr>
</tbody>
</table>
Table 5

Means of biweight estimates of reaction times, standard errors of the means, and error percentages by affix type, word type, and SOA, in Experiment 2.

<table>
<thead>
<tr>
<th>SOA</th>
<th>Prefix</th>
<th></th>
<th></th>
<th>Suffix</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pseudoprefix</td>
<td>True prefix</td>
<td>Pseudosuffix</td>
<td>True suffix</td>
</tr>
<tr>
<td>230 ms</td>
<td>484 (±20)</td>
<td>470 (±20)</td>
<td>522 (±21)</td>
<td>520 (±18)</td>
</tr>
<tr>
<td></td>
<td>7.1%</td>
<td>5.8%</td>
<td>5.8%</td>
<td>7.7%</td>
</tr>
<tr>
<td>460 ms</td>
<td>479 (±19)</td>
<td>505 (±21)</td>
<td>500 (±19)</td>
<td>495 (±19)</td>
</tr>
<tr>
<td></td>
<td>2.9%</td>
<td>5.2%</td>
<td>4.5%</td>
<td>3.9%</td>
</tr>
<tr>
<td>SOA</td>
<td>critical prefix</td>
<td>filler embedded</td>
<td>critical suffix</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>-----------------</td>
<td>-----------------</td>
<td>-----------------</td>
<td></td>
</tr>
<tr>
<td>230 ms</td>
<td>6.5% (±1.6)</td>
<td>24.0% (±2.1)</td>
<td>6.8% (±1.2)</td>
<td></td>
</tr>
<tr>
<td>460 ms</td>
<td>4.0% (±1.0)</td>
<td>23.9% (±2.2)</td>
<td>4.2% (±1.1)</td>
<td></td>
</tr>
</tbody>
</table>
Table 7

Means of biweight estimates of reaction times with standard errors of the means and error percentages, by compositionality, frequency, and affix type, for Experiment 3.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Prefix</th>
<th>Suffix</th>
</tr>
</thead>
<tbody>
<tr>
<td>High RT errors</td>
<td>487 (±14)</td>
<td>498 (±16)</td>
</tr>
<tr>
<td></td>
<td>6.5%</td>
<td>7.8%</td>
</tr>
<tr>
<td>Low RT errors</td>
<td>501 (±19)</td>
<td>534 (±18)</td>
</tr>
<tr>
<td></td>
<td>6.8%</td>
<td>6.0%</td>
</tr>
</tbody>
</table>
Figure 1

Example Displays

500 ms +

70 ms uncap

100 ms ######

57 ms UN

Example Display Durations

SOA Interval Interval
Figure 2

![Graph showing RT (reaction time) for non-compositional and compositional word types, with suffixes and prefixes plotted.]
References


Appendix 1

Critical items, average frequency of items(1), and average length of items(2), with standard deviations, by condition in Experiments 1 and 2.

<table>
<thead>
<tr>
<th>Pseudoprefix</th>
<th>Prefix</th>
<th>Pseudosuffix</th>
<th>Suffix</th>
</tr>
</thead>
<tbody>
<tr>
<td>abdomen</td>
<td>abnormal</td>
<td>furnace</td>
<td>grimace</td>
</tr>
<tr>
<td>abode</td>
<td>abuse</td>
<td>blemish</td>
<td>boyish</td>
</tr>
<tr>
<td>bison</td>
<td>bisect</td>
<td>furnish</td>
<td>freakish</td>
</tr>
<tr>
<td>cologne</td>
<td>cohost</td>
<td>garnish</td>
<td>greenish</td>
</tr>
<tr>
<td>convoy</td>
<td>confirm</td>
<td>voyage</td>
<td>voltage</td>
</tr>
<tr>
<td>concrete</td>
<td>contest</td>
<td>savage</td>
<td>dosage</td>
</tr>
<tr>
<td>demon</td>
<td>decline</td>
<td>cabbage</td>
<td>storage</td>
</tr>
<tr>
<td>devil</td>
<td>delay</td>
<td>cottage</td>
<td>footage</td>
</tr>
<tr>
<td>entry</td>
<td>enjoy</td>
<td>balance</td>
<td>guidance</td>
</tr>
<tr>
<td>entity</td>
<td>entitle</td>
<td>science</td>
<td>silence</td>
</tr>
<tr>
<td>expert</td>
<td>export</td>
<td>sentence</td>
<td>presence</td>
</tr>
<tr>
<td>exploit</td>
<td>explain</td>
<td>forest</td>
<td>highest</td>
</tr>
<tr>
<td>foreign</td>
<td>forward</td>
<td>modest</td>
<td>honest</td>
</tr>
<tr>
<td>formal</td>
<td>forgive</td>
<td>session</td>
<td>tension</td>
</tr>
<tr>
<td>forum</td>
<td>forearm</td>
<td>callous</td>
<td>joyous</td>
</tr>
<tr>
<td>index</td>
<td>input</td>
<td>jealous</td>
<td>zealous</td>
</tr>
<tr>
<td>mistress</td>
<td>mistrust</td>
<td>ladder</td>
<td>fewer</td>
</tr>
<tr>
<td>mister</td>
<td>mistake</td>
<td>hammer</td>
<td>owner</td>
</tr>
<tr>
<td>region</td>
<td>rerun</td>
<td>vulture</td>
<td>texture</td>
</tr>
<tr>
<td>uncle</td>
<td>uncap</td>
<td>torture</td>
<td>mixture</td>
</tr>
</tbody>
</table>

1) 31.2 (38.7) 1) 23.2 (27.5) 1) 29.1 (35.4) 1) 26.3 (24.3)
2) 6.0 (1.0) 2) 6.35 (1.0) 2) 6.75 (0.6) 2) 6.80 (0.89)

Below are embedded filler items with capital letters indicating the embedded target string. Note that actual word displays were all lower case letters, and actual target displays were all capital letters.

**Embedded prefix filler items**: cABin, tABle, seCONd, haBIt, balCONy, roBIn, alCOhol, falCOn, garDEn, moDEl, tUNnel, proMISe, agENt, gENeral, hEXagon, comFORt, siNGle, wINdow, barREn, caREer

**Embedded suffix filler items**: brACElet, fACEt, cANCEl, feaTUREs, spENCEr, diSHes, meAGEr, trAGEDy, ancESTor, bESTial, chESTnut, dESTiny, IONess, cOUSin, limOUSine, thOUSand, minERal, modERn, kERnel, artERY
Appendix 2

High frequency critical items, mean whole-word/stem frequencies (1), average of mean whole-word and mean stem frequencies (2), and mean word length (3), in Experiment 3.

<table>
<thead>
<tr>
<th>Non-compositional, prefixed</th>
<th>Compositional, prefixed</th>
<th>Non-compositional, suffixed</th>
<th>Compositional, suffixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>absent</td>
<td>abuse</td>
<td>flower</td>
<td>camper</td>
</tr>
<tr>
<td>delight</td>
<td>deform</td>
<td>figment</td>
<td>shipment</td>
</tr>
<tr>
<td>display</td>
<td>discard</td>
<td>heading</td>
<td>saying</td>
</tr>
<tr>
<td>disease</td>
<td>disclaim</td>
<td>homely</td>
<td>yearly</td>
</tr>
<tr>
<td>engross</td>
<td>enclose</td>
<td>hunger</td>
<td>farmer</td>
</tr>
<tr>
<td>entire</td>
<td>enlarge</td>
<td>necking</td>
<td>acting</td>
</tr>
<tr>
<td>present</td>
<td>preheat</td>
<td>pressure</td>
<td>moisture</td>
</tr>
<tr>
<td>remain</td>
<td>resize</td>
<td>shower</td>
<td>leader</td>
</tr>
<tr>
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<td>turning</td>
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<td>subway</td>
<td>tenure</td>
<td>failure</td>
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</table>

1) 78/163  
2) 121  
3) 6.6  

1) 7/214  
2) 112  
3) 6.5  

1) 30/198  
2) 114  
3) 6.6

1) 36/214  
2) 125  
3) 6.6
Low frequency critical items, mean whole-word/stem frequencies (1), average of mean whole-word and mean stem frequencies (2), and mean word length (3), in Experiment 3.

<table>
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<td>entomb</td>
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<td>foolish</td>
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<td>rehinge</td>
<td>sewage</td>
<td>linkage</td>
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<td>reink</td>
<td>wicker</td>
<td>gusher</td>
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<td>sublease</td>
<td>bushing</td>
<td>gnawing</td>
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<td>submerge</td>
<td>subplot</td>
<td>earnest</td>
<td>poshest</td>
</tr>
</tbody>
</table>

1) 7/19 1) 1/15 1) 7/7 1) 4/8
2) 13 2) 8 2) 7 2) 6
3) 6.6 3) 6.8 3) 6.8 3) 6.9

Below are embedded filler items with capital letters indicating the embedded target string. Note that actual word displays were all lower case letters, and actual target displays were all capital letters.

**Embedded prefix filler items:** cABin, tABLE, comPREhend, comPREss, interPREt, eDISon, raDISh, paraDISe, garDEn, moDEL, bABbit, agENt, gENERal, aDEpt, golDEn, agENt, beREave, barREn, caREer

**Embedded suffix filler items:** bUREau, dUREss, IINGual, bINGo, IINGerie, dISHes, meAGEr, trAGEdy, ancESTor, bESTial, chESTnut, dESTiny, anaLYze, newLYwed, moMENTum, deMENTia, minERal, modERn, kERnel, artERY
Biweight Estimation

Biweight estimation is a method of calculating a representative value for a data set. A median is calculated, and each value is then weighted by its distance from the median, with values further from the median being weighted less. A new median is calculated based on the weighted values, and the process continues iteratively until two estimates of medians converge.

These formulas are provided by Mosteller and Tukey (1977):

\[ y^* = \frac{\sum w_i y_i}{\sum w_i} \]

\[ w_i = \left( 1 - \left( \frac{y_i - y^*}{c^*} \right)^2 \right)^2 \]

but \( w_i = 0 \) when the subtrahend is > 1

In this application, \( c = 6 \) and \( S \) is the median of the absolute deviations from the current estimate.
Objective

Position as a professor in a university that encourages research, scholarship, teaching.

Professional Experience

August 1992 - present: Graduate Assistant, Teaching Assistant, Laboratory Supervisor, Software Consultant: Graduate assistant as computer consultant for Lehigh University Counseling Services; Teaching Assistant for Experimental Design and Statistics; Supervisor of undergraduate laboratory assistants in psycholinguistics laboratory and cognitive neuroscience laboratory; Micro Experimental Laboratory programming consultant for Lehigh University Psychology Department.

June 1991 - August 1992: Research Assistant: Programmed and conducted psycholinguistic research projects; prepared presentation of ongoing research for psycholinguistics conference.


September 1990 - August 1991: Research Assistant: Programmed and conducted psycholinguistic research projects; supervision of undergraduate laboratory assistants.

Education

September 1992 - present  Third year PhD student (Advisor: Dr. Padraig O'Seaghdha)

August 1990 - September 1992  Lehigh University, Bethlehem, PA 18015, M.S., Psychology

September 1986 - May 1990  Syracuse University, Syracuse, NY 13210, B.S., Psychology
Leadership

September 1991 - present: Psychology Department representative to the Graduate Student Council

Posters


END OF

TITLE