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Parafoveal versus foveal processing of morphologically complex (prefixed) words.

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PARAFOVEAL VERSUS FOVEAL PROCESSING OF MORPHOLOGICALLY
COMPLEX (PREFIXED) WORDS

A Dissertation Presented

by

GRETCHEN KAMBE

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

DOCTOR OF PHILOSOPHY

September 2001

Department of Psychology

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ABSTRACT

PARAFOVEAL VERSUS FOVEAL PROCESSING OF MORPHOLOGICALLY COMPLEX (PREFIXED) WORDS

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Three experiments investigated whether morphological constituents influence word processing during reading. Individuals read sentences containing free stem, bound stem, and pseudo- prefixed words. In Experiments 1 and 2, a parafoveal display change manipulation indicated that the morphological constituents of a prefixed word are not available for preprocessing in the parafovea as reading times on the target word did not differ for prefixed versus pseudo-prefixed words. Interestingly, parafoveal preview of word initial and word final letters resulted in an equivalent amount orthographic facilitation for all word types. In Experiment 3, a fast priming manipulation indicated that morphological priming effects for prefixed words are obscured during sentence processing. However, the form of the prime did facilitate subsequent word processing for all three word types. The results suggest that English prefixed words are accessed via their whole word form, as there was no evidence of morphological decomposition for prefixed words during sentence processing.

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CHAPTER I

INTRODUCTION

Studies examining morphologically complex words outside of sentence contexts have found evidence to indicate that morphological processing is involved in the early stages of word identification, suggesting that morphology plays an important role in word processing. However, the majority of the research on morphological processing has focused on studies of isolated words. Very little research has been conducted on morphologically complex words during reading (Bertram, Hyona, & Laine, 2000; Hyona & Pollatsek, 1998; Inhoff, 1989; Inhoff, Briihl, & Schwartz, 1996; Lima, 1987; Niswander, Pollatsek, & Rayner, 2000; Pollatsek, Hyona, & Bertram, 2000). Thus, it is important to determine whether morphology plays an equally significant role in word processing during reading. In this dissertation, three experiments are reported that investigate the early stages of morphological processing during reading. These studies examine whether morphological information is available 1) in the parafovea such that a parafoveal preview of a morphological constituent benefits subsequent word processing, and 2) in the fovea such that a brief foveal prime of a morphological constituent facilitates subsequent word processing. The advantage of examining morphological processing in the parafovea in conjunction with foveal priming is that the results of the two types of studies will provide insight into parafoveal versus foveal processing.

Characteristics of Eye Movements During Reading

During reading, the visual system acquires information about the characteristics of the letters and words making up a text. Recently, a great deal of research has been devoted to understanding how eye movements are related to moment-to-moment

cognitive processes during reading. For example, we know that the eyes do not move smoothly over a page. Rather, reading is characterized by a series of fixations (when the eyes remain relatively stable) and saccades (when the eyes move) geared at focusing the image of a letter/word onto the retina. However, new information is only acquired during fixations and not during saccades due to “saccadic suppression”. While individuals vary greatly, the average saccade size for skilled readers is about 7-9 letter spaces and the average fixation duration is 200-250 ms (Rayner, 1978, 1998).

The primary reason for the frequency of eye movements during reading is acuity limitations in the visual system. The retina of the eye may be roughly separated into three regions: the fovea, the parafovea, and the periphery. While the retina is capable of covering 240 degrees of visual angle (Llewellyn-Thomas, 1968), high acuity vision is limited to the *fovea* (comprising about 2 degrees of visual angle), which is located in the center of vision where neural receptors are most dense. Directly adjacent to the fovea is the *parafovea* (which subtends an additional 10 degrees of visual angle), where photoreceptors are less densely packed and visual acuity is less precise. Beyond the parafovea is the *periphery* where there are fewer photoreceptors and visual clarity diminishes rapidly. Because visual acuity diminishes rapidly as a stimulus is presented outside of the fovea (Bouma, 1973), it is necessary to make eye movements in order to bring words into focus on the fovea to process them more efficiently.

Visual Processing in the Parafovea

Although the oculomotor system is especially attuned to bringing information into the fovea for processing, parafoveal vision plays an important role in reading (Rayner, Well, Pollatsek, & Bertera, 1982). One indication that words are processed in the

parafovea (at least to some degree) is that short function words such as conjunctions and articles (O'Regan, 1979; Blanchard, Pollatsek, & Rayner, 1989; Brysbaert & Vitu, 1998; Gautier, O'Regan, & Gargasson, 2000) and words that are highly predictable or constrained by the preceding sentence context are more likely to be skipped (Balota, Pollatsek, & Rayner, 1985; Binder, Pollatsek, & Rayner, 1999; Ehrlich & Rayner, 1981; Inhoff, 1984; Rayner & Duffy, 1986; Rayner & Well, 1996; Schustack, Ehrlich, & Rayner, 1987). Such an effect indicates that readers obtain at least some information from the word to the right of fixation (i.e., the parafoveal word).

Information in the parafovea affects more than the probability of a word being skipped. Parafoveal information also affects how far readers move their eyes and where the eyes land in a word. Thus, the length of a saccade is influenced by both the length of the currently fixated word and the length of the word to the right of fixation (Rayner, 1979; O'Regan, 1979, 1980). Another factor that influences where the eyes land when moving into the parafoveal word is the location of the eye before moving (the launch site). For example, if the launch site is further away from the target word location, the eyes tend to land closer to the beginning of the newly fixated (target) word than when the launch site is closer to the beginning of that word (McConkie, Kerr, Reddix, & Zola, 1988; Rayner, Sereno, & Raney, 1996). Thus, it appears that word length information is reliably obtained from the parafovea and is subsequently used in computing the location of the next fixation (O'Regan, 1980; Morris, Rayner, & Pollatsek, 1990; Pollatsek & Rayner, 1982; Rayner, 1979; Rayner & Morris, 1992; Rayner et al., 1996). Underwood, Clews, and Everatt (1990), however, reported an experiment that found evidence to indicate that higher order (semantic) information also influenced readers' initial landing

positions. They embedded two types of target words in sentences: words that were highly identifiable from their beginning letters (quarantine) or words that were highly identifiable from their ending letters (underneath). They found that readers' saccades onto parafoveal words were longer when the informative information was located at the end of the word than the beginning of the word. They used this as evidence in support of the idea that some aspect of meaning was available for processing in the parafovea. However, Rayner and Morris (1992), in more finely controlled experiments, were unable to replicate this result.

Additional research on the extent to which parafoveal information affects visual word processing has been concerned with the influence of such information on fixation durations during reading. The methodology typically used to study parafoveal information processing is an eye contingent display change technique (see Figure 1 for an example of a display change within a sentence context). This technique has been used to study word and sentence processing. Typically, a word or sentence is presented on a computer monitor. When the eyes cross a pre-specified invisible boundary, part or all of the information on the screen may change. The display change occurs during a saccade when vision is suppressed so the reader is typically unaware that it has occurred. As a result, if the information presented in the parafovea affects processing when the target location is subsequently fixated (as compared to when no parafoveal information is available), then it is attributed to parafoveal preview. For example, when information to the right of a fixation is degraded during reading, readers markedly decrease their reading rate (McConkie & Rayner, 1975; Rayner & Bertera, 1979; Rayner, Inhoff, Morrison, Slowiaczek, & Bertera, 1981; Rayner & Pollatsek, 1981; Rayner et al., 1982). Further,

there is a great deal of evidence demonstrating that when readers are allowed to preview a word in the parafovea (i.e. to the right of the currently fixated word), processing time on that word when it is subsequently fixated is facilitated in comparison to when no preview of that word is available (Balota et al., 1985; Blanchard, Pollatsek, & Rayner, 1989; Henderson & Ferreira, 1990; Inhoff, 1989a, 1989b, 1990; Inhoff, Pollatsek, Posner, & Rayner, 1989; Inhoff & Rayner, 1986; Lima, 1987; Lima & Inhoff, 1985; Morris et al., 1990; Pollatsek, Rayner, & Balota, 1986; Rayner, 1975; Rayner et al., 1982; Rayner, Balota, & Pollatsek, 1986; Rayner & Morris, 1992). Thus, readers are not necessarily constrained by the boundaries of the fixated word in that at least some partial letter/word information may be extracted from the parafoveal region during reading. The advantage gained by the availability of useful information in the parafovea over the absence of useful information in the parafovea is called the *parafoveal preview benefit* (Rayner & Pollatsek, 1989).

* |

My younger brother has brilliantly composed a new tune for the school play.

| *

My younger brother has brilliantly composed a new song for the school play.

Preview conditions:

Identical = *song*

Semantically related = *tune*

Orthographically related = *sorp*

Control word = *door*

Target word: *song*

Figure 1: Example sentence for a parafoveal preview display change experiment. (Taken from Rayner, et al., 1986)

* The asterisk denotes the position of the eye and the “|” denotes the location of the boundary

Parafoveal preview benefit is greatest when the entire word is available in the parafovea suggesting that the preview benefit is lexical (as opposed to entirely orthographic). In a series of experiments, Inhoff and colleagues (1989a, 1989b, 1990; Briihl & Inhoff, 1995; Lima & Inhoff, 1985; Inhoff & Tousman, 1990) found that all of the letters of a parafoveally available word contribute to its subsequent identification; however, this effect is not additive. Readers benefit from the availability of partial word information in the parafovea, but the preview benefit gained from word initial letters and word final letters did not equal the benefit obtained from the availability of the entire word. While ending letters contribute to parafoveal preprocessing, Briihl and Inhoff (1995; Inhoff, 1990) argue that beginning letters appear to be of larger importance to the word identification process. They further suggest that word initial letters provide linguistic constraints on the identification of non-initial letters. Thus, information

available to the reader in the parafovea influences subsequent word processing by activating lexical representations.

In addition to lexical information, the parafoveal word's phonological (sound) codes influence subsequent word processing. Pollatsek, Lesch, Morris, and Rayner (1992) found a preview effect from a homophone of a subsequently fixated target word in comparison to when the parafoveal word was orthographically similar to the target word. Contextual constraint has also been shown to mediate parafoveal processing. Balota et al., (1985) found that the parafoveal preview benefit was greater when the parafoveal word was predictable from previous context, indicating that parafoveal word processing is more efficient when facilitated by sentence context. Readers have also been shown to obtain more information from a high frequency word in the parafovea than a low frequency word (Inhoff & Rayner, 1986). On the other hand, Henderson and Ferreira (1990) found an inverse relationship between the difficulty of the word in the fovea and the efficiency of parafoveal processing: when the currently fixated word was low frequency (i.e. was difficult to process) parafoveal preview benefits disappeared.

However, not all aspects of word processing appear to be available in the parafovea for preprocessing. For example, semantic information does not appear to be extracted from the parafovea. Several studies (Altarriba, Kambe, Pollatsek, & Rayner, 2001; Rayner & Morris, 1992; Rayner et al., 1986) have failed to find any evidence to indicate that semantic information in the parafovea facilitates subsequent word processing. Rayner et al. (1986) asked individuals to read sentences like that shown in Figure 1 (and repeated here): "My younger brother has brilliantly composed a new song for the school play". When the sentence was initially presented on the monitor for

individuals to read, one of four preview conditions was initially displayed on the screen (see Figure 1). As the readers' eyes moved from the pre-target word (i.e. "new") to the target region, the preview word ("tune") was replaced with the target word ("song"). This change occurred as the reader's eyes crossed an invisible boundary (consisting of the last letter of the pre-target word) during the saccade from the pre-target to the target word location. Because the change occurred during a saccade, readers were unaware of the display change (see Inhoff, Starr, Liu, & Wang, 1998; Binder et al., 1999). In the sample sentence, the four initially presented previews were: the target word (song), a semantically related control word (tune), a totally unrelated word (door), or an orthographically related non-word (sorp). Rayner et al. only found a parafoveal preview benefit in the orthographically similar condition. There was no difference in parafoveal preview benefit between the semantically related and unrelated conditions. Thus, the results reported in Rayner et al. (1986) fail to support the contention that semantic information is extracted from the parafovea

A more recent study (Altarriba et al., 2001) also failed to find any indication of semantic preprocessing, and it provided a stronger manipulation of semantic relatedness between the preview and target word. In Altarriba et al.'s (2001) Experiment 2, Spanish-English bilinguals who were fluent readers of both languages were asked to read a series of sentences in each language. As in the Rayner et al. (1986) study, a display change occurred as the reader's eyes moved across an invisible boundary immediately preceding the target word. An example English sentence is: "The kitten was given a bowl of cream along with two soft toys". For this sentence the target word was "cream", and the preview conditions were: identical to the target word (cream), a direct translation of the target

word (creme), and an unrelated control word (torre). In addition to the three preview conditions, there were three translation conditions: 1) cognates (cream-creme), where the target and preview were orthographically similar and had the same semantic meaning; 2) non-cognates (dance-baile), where the preview and target were not orthographically similar but they had the same semantic meaning; and 3) pseudo-cognates (grass-grasa), where the preview and target were orthographically similar but semantically unrelated. The translation conditions were an improvement over previous studies looking at semantic preprocessing because the semantic content of the preview and target word was virtually identical. Additionally, semantic and orthographic overlap could be manipulated independently to examine the individual contributions of each.

Despite the increase in semantic overlap between the preview and target word, Altarriba et al. (2001) found no evidence of semantic preprocessing. No parafoveal preview benefit was found in the non-cognate translation condition. A parafoveal preview benefit was found for the cognate and pseudo-cognate conditions. In both cases, the effect was driven by orthographic overlap between the preview and the target word, as there was no difference in the magnitude of the parafoveal preview benefit between the cognate and pseudo-cognate conditions. Thus, similar to Rayner et al. (1986), Altarriba et al. (2001) found no evidence to indicate that semantic information is consistently extracted from the parafovea for processing.

While most research has indicated that semantic information is not extracted from the parafovea, few studies have been performed to determine whether morphological information is processed parafoveally. Morphemes are the smallest unit of meaning in the language, and they contain semantic, syntactic, and phonetic information. The semantic

information contained within a morpheme is fairly consistent. Because morphemes contain some aspects of meaning, they are often considered to behave similarly to semantic information. However, there is a growing body of evidence indicating that morphemes are a unique level of linguistic representation and that morphemes are treated differently than whole words (Rastle, Davis, Marslen-Wilson, & Tyler, 2000) and that they play a role in word processing (Andrews, 1986; Coolen, Jaarsveld & Schreuder, 1993; Hyönä & Pollatsek, 1998; Frost, Deutsch, Gilboa, Tannenbaum, & Marslen-Wilson, 2000; Frost, Forster, & Deutsch, 1997; Laudanna, Badecker, & Caramazza, 1989; Lima & Pollatsek, 1983; Monsell 1985; Pollatsek, Hyona, & Bertram, 2000; Prinzmetal, 1990; Sandra, 1990; Shillcock, 1990; Taft & Forster, 1976; Taft, 1985; Van Jaarsveld & Rattink, 1988; Zwitserlood, 1994). As a result, it is important to investigate morphological preprocessing separately from semantic preprocessing, as it is possible that morphological information may be extracted from the parafovea during reading even though semantic information is not.

Two studies have addressed this issue to date (Lima, 1987; Inhoff, 1989a). Inhoff (1989a) performed a parafoveal preview experiment to determine whether morphological information was accessible in the parafovea. In his study, compound words such as “cowboy” were compared to pseudo-compound words such as “carpet”. The prediction was that if morphological information can be obtained parafoveally, compound words would benefit from a parafoveal preview of the initial letter string (e.g. “cow”), whereas pseudo-compound words would not. There were four preview conditions in this experiment: 1) no preview, 2) the first three letters of the target word, 3) the first four letters of the target word, and 4) the entire target word. The three and four letter previews

either corresponded to linguistically defined sub-word units or violated them. Inhoff (1989a) found no differences in parafoveal preview benefits with respect to the morphological status of the previewed letters: preview benefit was similar when the preview letters formed morphological units as compared to when they did not. Inhoff's (1989a) data provided evidence in support of a model of parafoveal word recognition driven by letter identification, but not morphological identification.

Additional research investigating the effect of morphology on parafoveal processing was reported by Lima (1987). In a display change experiment, she compared prefixed words (e.g. "revive") to pseudo-prefixed words (e.g. "rescue") placed within identical sentence contexts. Pseudo-prefixed words have the same initial letter sequence as a prefixed word, but the initial letter sequence is not actually a separate morphological unit. In her study, Lima (1987) found no evidence to indicate that a parafoveal preview of a morphological unit (prefixes) facilitates processing on a target word when it was subsequently fixated. However, there were several factors that may have influenced Lima's results. First, she failed to distinguish between the various classes of prefixed words. There is an important distinction to be made between prefixed words with a free stem versus a bound stem. Free stem prefixed words consist of a prefix and stem, where the stem is a recognizable word on its own (re-view). These are generally classified as orthographically transparent; a classification that typically results in a processing advantage over bound stem prefixed words. In contrast, bound stem prefixed words do not have an orthographically transparent word as their stem (re-duce) and have generally been found to take longer to identify during word processing tasks than free stem prefixed words (Zwitzerlood, 1994). A second problem in Lima's experiment was that the

pronunciation of the initial letter sequences of the preview and target word (i.e. unable, unique) was not controlled. Different pronunciations of the same letter sequence could be inhibitory, thus eradicating any facilitation resulting from morphological preprocessing. A third problem with her study involves syllabification. Morphemes are important indicators of syllable boundaries. While the initial letter sequences of the pseudo-prefixed words were identical to prefixed words, they did not always mark the end of the syllable (i.e. revive, rescue). A better comparison between prefixed and pseudo-prefixed words would maintain syllable boundaries and pronunciation across all conditions while including a manipulation of prefix type. Thus, it appears that the question of whether morphological information is extracted from the parafovea and denotes a unique level of linguistic representation needs to be examined further. The first experiment of this dissertation examined whether morphological information can be extracted from the parafovea such that it is able to benefit subsequent word processing during reading. This was run as a parafoveal preview experiment, where the amount of parafoveal information available to the reader was manipulated (see below for details).

Visual Processing of Morphology in the Fovea

Support for the idea that morphemes are a unique level of linguistic representation has come from a series of masked priming studies (Forster & Azuma, 2000; Giraudo & Grainger, 2000; Rastle et al., 2000) and morphological priming studies (Raveh & Rueckl, 2000; Stanners, Neiser, & Painton, 1979; Stanners, Neiser, Hernon, & Hall, 1979) on words in isolation. Studies on morphological priming suggest that morphologically complex words are represented both by their constituent morphemes as well as the whole word form. These studies, however, are relatively sensitive to semantic factors which

influence word processing. Masked priming studies are relatively insensitive to semantic factors (Forster & Azuma, 2000), and consist of a brief foveal prime preceded by a forward mask (generally consisting of hash marks) which is immediately followed by the target word (acting as a backward mask). All three of these studies found positive evidence in support of morphological priming. Additionally, morphological priming was found in the absence of semantic and/or orthographic priming with the masked priming paradigm. These results leave us with two questions: 1) can morphological priming be found within a sentence context, and 2) what is the time course of morphological priming during reading? It is possible that morphological information is accessed within the first moments of visual word processing, without employing conscious or episodic components of the cognitive system. If so, we should find morphological priming during text processing.

Some previous research examining early stages of foveal processing in reading has used the fast-priming technique developed by Sereno and Rayner (1992). An illustration of the procedure is presented in Figure 2. A string of random letters (e.g. gzsd) initially occupies a target location as individuals read a sentence (a). The purpose of the random letter string is to prevent meaningful parafoveal processing of the target region until the word is fixated. Thus, in this type of experiment, no parafoveal preview of the target word is available. When the eyes cross an invisible boundary, the random letters are replaced by a prime (e.g. love), which remains onscreen for a specified duration after the onset of the fixation (b). The prime is then replaced with the target word (hate), which remains on the screen until the individual has finished reading the sentence (c) and (d).

The fixation time on the target word is then examined as a function of the relation between the target word and the prime.

-
- *-----*-----*--
- a) Tight quarters produce|d gzsd and discord.
- *
- b) Tight quarters produce|d love and discord.
- *
- c) Tight quarters produce|d hate and discord.
- *
- d) Tight quarters produce|d hate and discord.

Prime words:

Identical = *hate*

Semantically related = *love*

Semantically unrelated = *rule*

Target word: *hate*

Figure 2: Example sentence for a fast priming experiment. (Taken from Sereno & Rayner, 1992).

* The asterisk denotes the position of the eye and the “|” denotes the location of the boundary.

Previous research on priming during reading using the fast-priming technique (Lee, Binder, Kim, Pollatsek, & Rayner, 1999; Lee, Rayner, Pollatsek, 1999; Rayner, Sereno, Lesch, & Pollatsek, 1995; Sereno, 1995; Sereno & Rayner, 1992) has focused on the time course of phonological, orthographic, and semantic priming. Rayner et al. (1995) found a phonological effect with a 36 ms prime duration, and Lee et al. (1999) found a phonological priming effect with 32 and 35 ms prime durations. Lee et al. (1999), Sereno (1995), and Sereno and Rayner (1992) found semantic priming effects with 32, 35, and

30 ms prime durations respectively. Orthographic priming has been found at all prime durations tested (24-42 ms). Lee et al. (1999) compared the time course of phonological, orthographic, and semantic priming. They found: 1) phonological priming at all durations between 29 and 35 ms, 2) semantic priming with a 32 ms prime duration, and 3) orthographic priming with all prime durations tested (29-42 ms). There is no prior research examining the time course of morphological priming during reading.

In the process of examining the time course of morphological preprocessing, one important consideration is the nature of morphological decomposition during the process of visual word recognition. The experiments reported in this dissertation addressed this issue with respect to prefixed words. In a series of stem priming experiments, Forster and Azuma (2000) found no differences in the amount of facilitation found for bound versus free stem prefixed words in English such that both types of prefixed words demonstrated clear priming effects independent of semantic overlap and orthography. These results are consistent with Frost, Forster, and Deutsch (1997) who found strong morphological priming effects in Hebrew with masked primes that were independent of semantic similarity and orthographic overlap. These results conflict, however, with the findings of Marslen-Wilson, Tyler, Waksler, and Older (1994) who failed to find bound stem priming with a cross-modal paradigm. Marslen-Wilson et al., (1994) argued that semantic transparency and stem productivity are critical factors in determining whether morphological priming will occur. While Forster and Azuma (2000) did not find semantic transparency necessary for morphological priming in their experiments, the productivity of the stem did influence their results with less productive stems providing less priming.

In all cases where stem priming was found, the stem was presented below the consciousness threshold. Forster and Azuma (2000; see also Forster & Veres, 1998) therefore argued that when the stem is consciously available, priming for the bound stem is most likely being inhibited by the absence of a congruent semantic relationship between the prime and the target. The prime durations during fast priming experiments are brief enough to affect processing at the subconscious level. Thus, it is possible that morphological priming during sentence processing will facilitate reading times on prefixed words. It is also possible that both free and bound stem prefixed words will benefit equally from prefix-only and stem-only priming (although see predictions below for alternative hypotheses). These issues will be examined during the final experiment of this dissertation.

Parafoveal and Foveal Processing: The Present Research

During visual word processing, phonological, orthographic, morphological, and semantic levels of representation are involved in identifying words. Previous research has already determined that phonological and orthographic information are available for processing in the parafovea. Further, different levels of text complexity have been found to interact with the availability of information in the parafovea in determining how much processing can be accomplished before a word is actually fixated.

Previous research has provided some insight to the conditions under which the availability of parafoveal information fluctuates (Henderson & Ferreira, 1990; Inhoff & Rayner, 1986; Kennison & Clifton, 1995; O'Regan, 1980; Morris et al., 1990; Pollatsek & Rayner, 1982; Rayner, 1979; Rayner & Morris, 1992; Rayner et al., 1996). What has not been laid to rest, however, is whether morphological information is accessible for

processing in the parafovea. This issue will be addressed first in the present research. Presumably, if morphological information is available in the parafovea, it is involved in the early stages of word processing. Studies examining morphologically complex words outside of sentence contexts have found evidence to indicate that morphological processing is involved in the early stages of foveal word processing. Thus, a second issue to be addressed in the present research involves the time course of morphological processing during reading (discussed below).

An advantage of examining morphological preprocessing in the parafovea in conjunction with foveal priming is that the results of the two types of studies will provide insight into parafoveal versus foveal visual processing. If morphological information is not available for processing in the parafovea but does result in foveal priming, then we can draw some definitive conclusions about parafoveal versus foveal visual processing. It is entirely possible that the parafoveal preview benefit is entirely driven by low-level visual cues. Previous research (McConkie & Zola, 1979; Rayner, McConkie & Zola, 1980; see also Rayner & Morris, 1992) has concluded that the primary source of the preview benefit appears to be some type of an abstract code, because the letters of a word can change case without affecting reading behavior. This research assumes that morphological (and semantic) information is not available for parafoveal preprocessing. Evidence for morphological preprocessing in the absence of evidence for semantic preprocessing would suggest that morphological structure, while including semantic information, is a unique process or level of linguistic representation. Thus the issue of morphological preprocessing was re-examined. It was predicted that morphological information would be available in the parafovea to facilitate subsequent word processing.

Additionally, it was predicted that preview benefit would interact with prefix type such that free stem prefixed words show more parafoveal preview benefit than bound stem prefixed words.

The second aim of this research is to examine the time course of morphological priming during reading with the fast priming paradigm (described above). Of primary interest was determining whether prefixed words are decomposed in the initial stages of word processing such that morphological units prime morphologically complex (prefixed) words. The second goal of this study was to determine whether the time course of morphological and semantic priming overlaps. Studies that have successfully disassociated semantic and morphological factors accomplished this by manipulating the stimuli being tested in words in isolation. While semantic priming has been found during reading (with the fast priming paradigm), it only occurs within a narrow time frame (~30-35 ms). If morphological priming is dependent upon the semantic aspect of the morpheme, then there should be no distinction between the time course for semantic and morphological priming. However, evidence that morphological priming extends beyond the time frame in which semantic priming is found, would suggest that morphological priming is distinct from semantic priming. Further, morphological priming was not predicted to be limited to a specific morpheme. The prefix was expected to facilitate subsequent word processing as much as the stem of the prefixed words (although the predictions vary with prefix type: bound stem vs. free stem). Evidence of morphological priming (from the prefix or stem of the word) during sentence comprehension would provide evidence in support of theories of morphological decomposition.

CHAPTER II

EXPERIMENT 1: PARAFOVEAL PREVIEW

The goal of Experiment 1 was to further clarify what types of information are available for processing in the parafovea. Previous research has indicated that semantic information is not available for processing in the parafovea. Phonological, orthographic, letter shape, and word length information are readily available in the parafovea to facilitate word processing; however, very little research has been conducted to examine the extent to which morphological information is available in the parafovea. Lima's (1987) research indicated that morphological information available in the parafovea does not facilitate subsequent word processing. This may have been the result of problems within Lima's (1987) stimuli. She compared prefixed words to pseudo-prefixed words, but failed to distinguish between different types of prefixed words. There are two main classes of prefixed words: bound stem (e.g., reduce) and free stem (e.g. review). The stem of a bound stem prefixed word cannot stand on its own as a word in the English language (e.g., reduce - duce). The stem of a free stem prefixed word is able to stand on its own as a word in the English language (e.g., review - view). The intent of the current research was two-fold: 1) to re-examine whether morphological information is available for processing in the parafovea, and 2) to determine whether bound stem and free stem prefixed words are processed differently.

Method Section

Participants

Thirty-six individuals from the University of Massachusetts community were asked to participate in this experiment. All of the participants were native English

speakers and were naive to the purpose of the study. All participants had normal or corrected to normal vision.

Apparatus

Eye movements were recorded by a Fourward Technologies Dual Purkinje Eyetracker (Generation V). The eyetracker has a resolution of less than 10' of arc. The participant's view of the screen was binocular, but only the right eye was monitored for eye location. The signal from the eyetracker was sampled every millisecond by a 486 computer. The average vertical and horizontal positions of the eye were compared with those of the previous position to determine whether the eye was fixated or moving. The single line sentences were presented on a NEC MultiSync 4FG color monitor. During the experiment, all participants were seated 62 cm from the monitor with three characters subtending 1 degree of visual angle. The letters were presented in light cyan (on a black background) by mixing green and blue input signals on the display monitor with a P-22 phosphor, which allows blanking of the display to produce a drop to 10% of maximum brightness in .06 ms. The luminance of the screen was adjusted to a level of brightness that is most comfortable for the participant and then held constant throughout the study. The experimental room was dark except for a small indirect light, which enabled the experimenter to keep notes during the experiment.

Procedure

When a participant arrived for the experiment, he/she was given a general description of the experimental situation and procedure. Participants were told that they would be expected to read a series of sentences on a computer screen while their eye movements were being monitored. They were told to read the sentences for

comprehension. Each participant read 12 practice trials, 108 experimental and 54 filler trials. Approximately 30% of the sentences were followed by a question requiring a yes/no response made by clicking a button on a keypad. After each participant understood the procedure and signed an informed consent, a bite bar was prepared in order to minimize head movements.

Once the participant was seated in front of the monitor, an initial calibration procedure that took approximately five minutes was completed. The calibration of the eye tracking system was checked regularly to ensure that accurate records were being obtained. Calibration was checked using a display that appeared between each sentence. The display consisted of a single row of five boxes arranged in a line across the screen. Between each trial, the subject was asked to fixate on the box in the center of the screen, then box-by-box to the left side of the screen. The far-left box marked the location of the first letter of the sentence. As soon as the experimenter determined that the participant was fixating on the far-left box, the entire sentence was presented on the screen. The participant was told ahead of time to click a button to erase the sentence from the screen once they had completed reading it. When a sentence had been removed from the screen and the trial ended, the row of boxes again appeared on the screen. Once the calibration had been checked, the participants were told to fixate on the far-left box to indicate that they were ready for the next sentence. This procedure was repeated throughout the entire practice and experimental sessions.

For each sentence, an invisible boundary was located immediately after the last letter of the word prior to the target word (see Figure 3 - below). When the sentence was initially presented on the computer monitor, a preview word or letter string occupied the

target word location. When the participants' eyes moved across the boundary location during a saccade, the preview word or letter string was replaced by the target word (see Rayner, 1975, for a comprehensive description of this technique). Because the display change took place during a saccade (when vision is suppressed), subjects were not aware of the display change. To ensure that this was true, participants were asked to report what they noticed about the display changes at the end of the experiment. None of the participants reported seeing a display change during the experiment.

Materials

Target words consisted of prefixed words and pseudo-prefixed words (words that share the same initial letter sequence with a prefixed word, but are not actually prefixed words). For the sake of simplicity, both an actual prefix and the pseudo-prefix initial letter sequence will be referred to as the "prefix" as the intent is to focus on the identical initial letter strings. Each target word was embedded in one of 108 experimental sentences, with 36 sentences assigned to each of three conditions: 1) pseudo-prefixed (e.g. region), 2) bound stem prefixed (e.g. reduce), and 3) free stem prefixed (e.g. review) words.

Each target word was chosen and categorized by two individuals with 98% inter-rater reliability (all words failing to be categorized in the same manner were replaced). Words were categorized as prefixed or pseudo-prefixed according to *Webster's English Dictionary* and *Atyo's Dictionary of Etymology*. Words were categorized as free stem versus bound stem prefixed words according to whether or not the stem of the prefixed word could stand on its own as a word in the English language. The target words in each of the three conditions were also matched according to overall word length, overall word

frequency, part of speech, pronunciation, similarity, and number of word-initial letters (see Appendix A for target word information). In the free stem prefixed word condition, the stem word was orthographically transparent in that no letters were altered or deleted; however, the FP words were not necessarily semantically transparent. The meaning of the word making up the stem of the prefixed word was always consistent with the overall meaning of the prefixed word containing the stem, but stem and root combinations sometimes resulted in a unique meaning. For example, while *refill* means to “fill again”, *return* means to “go back” and not to “turn again”. In the bound stem prefix condition, common stems were used, all of which are familiar (and known to be word stems) to the local subject population (as determined by a rating study). Bound stem prefixed words are considered to be semantically opaque. Measures of semantic transparency do not apply for the pseudo-prefix condition (as they are considered to be monomorphemic words), but every effort was made to ensure all words were common and familiar to the reader. Thus, semantic transparency was not manipulated in the present study, although all stems were consistent in meaning to the whole word meaning.

Familiarity was measured in a rating study completed by 24 UMass students. The rating study contained 268 free prefixed, bound prefixed, and pseudo-prefixed words. Individuals were asked to perform two tasks during this study. First, they were asked to categorize the three word types according to how they should be defined (the definitions were provided). Next to each definition was an example word matching that definition. In the prefix examples the root of the word was underlined to further highlight the differences between the two prefix types. Each definition was given a number and the participant was told to write the appropriate number next to the word. All participants

demonstrated (verbally) that they understood all three definitions before proceeding with the rating task. They were then asked to rate how familiar each word was to them.

Familiarity ratings were made on a scale of 1 to 10, with 10 indicating that the word was very familiar and 1 indicating that the word was unfamiliar to the participant. All words included in the experiment had a familiarity rating of 8 or above (with an overall mean of 9.64).

The results of the word classification task were somewhat surprising. Individuals were only able to successfully classify 88% of the free stem prefixed words correctly. Miscategorized free stem prefixed words were categorized as being both bound stem prefixed words (8%) and pseudo-prefixed words (4%). They were unsuccessful in discriminating between the bound stem prefixed words and the pseudo-prefixed words. Over 67% of bound stem prefixed words were classified as pseudo prefixed. In fact, the majority of the words in the experiment (regardless of word type) were classified as being pseudo-prefixed (~78% overall). This trend is surprising considering the fact that more than two-thirds of the words in the list were prefixed words (either free or bound stem).

Because the definition-based classification task may have been too complex, another rating study was conducted. A separate group of 24 UMass undergraduates were asked to look at a list containing the stem of the words from the original rating task. They were asked to simply indicate whether or not each letter string was a real word or not. The intent was to determine whether or not the stem of the free stem prefixed words were recognizable to the participants. In this rating task, all of the “actual word” stems were correctly identified. However, participants identified another 2% of the non-word stems as being actual words. As a result, all of the words that failed to be classified as free stem

in the first rating study and all of the non word stems that were rated as words in the second rating study were excluded from the final word list.

Each target word was placed in a neutral sentence context preceded by at least two words. The word immediately prior to the target word was always at least five letters long to increase the probability of fixating the target word. For each target word type, there were four preview conditions: 1) identical (e.g. review) - the parafoveal preview is the same as the target word; 2) prefix only (e.g. rexwsz) - the parafoveal preview consisted of the prefix from the target word followed by a random string of letters; 3) stem only (e.g. cmview) – the parafoveal preview consisted of the stem of the word preceded by a random string of letters; and 4) control (e.g. cmxwsz) – the parafoveal preview consisted of a random string of letters (see Figure 3). All random letter sequences excluded vowels and were chosen so that the overall letter shape was consistent with the original target word letters (i.e. ascenders were replaced with ascenders, descenders with descenders, and non descenders with non descenders (Bouma, 1973)). The random letter string was a no preview control condition. The identical condition served as a baseline condition as the information was the same in the parafoveal as it was in the fovea. This “no-change” condition¹ allowed for an examination of differences in word processing for the three target word conditions (without the interruption of a partial preview).

¹ A display change actually occurred in the identical condition. However, because the preview was identical to the target word, the change is not detectable (even when searching for it).

* |

Mary wants to quickly rehsxc her credit card debt this year.

| *

Mary wants to quickly reduce her credit card debt this year.

Preview Conditions

Identical = *reduce*

Prefix-only = *rehsxc*

Stem-only = *zvduce*

Control = *zvhsxc*

Target word: *reduce*

Figure 3: Example sentence for Experiment 1: Parafoveal preview

* The asterisk denotes the position of the eye and the “|” denotes the location of the boundary

Results

The following oculomotor measures were computed: (1) first fixation duration, consisting of the duration of the first fixation on target words during the sentence’s initial (first pass) reading, irrespective of the number of fixations on these words, and (2) gaze duration, consisting of the cumulated viewing time on a target word during its first pass reading (i.e., excluding the time spent re-reading the target after the reading of other words). In addition to these two reading time measures, saccade length onto target words, and the landing position within target words were calculated.

Data was excluded from the following analysis for any of the following reasons:

- 1) a track loss occurred;
- 2) the eyes triggered the boundary change but remained on the word prior to the target word (usually the last letter of this word);
- 3) the first fixation of the target word was less than 100 ms, or a first pass fixation was greater than 800 ms; and

4) the first pass fixation was the last fixation recorded for the sentence. The mean percentage of usable data was 88% and the mean percentage of correct responses for yes/no questions was 96%, indicating little problems understanding the sentences.

All eligible trials were subjected to 3 (Target Word Type: Free prefixed, bound prefixed, pseudo-prefixed) x 4 (Preview Type: Identical, prefix-only, stem-only, control) ANOVAs with error variance computed within subjects (F_1) and between items (F_2). As in previous experiments, planned contrasts were performed to compare preview effect sizes for each of the three target word types.

Effect of Word Type

Neither first fixation nor gaze duration times varied across the different types of prefixed and pseudo-prefixed words (all F 's < 1), and the interaction between word type and preview type was not significant (F 's < 1). The results from the reading time measures are presented in Table 1. This result fails to replicate the Lima's (1987) finding that pseudo-prefixed words are read slower than prefixed words. It's possible that this discrepancy is a result of list differences in how the words were categorized for list participation. However, the results of the current experiment fail to provide evidence in support of morphological decomposition such as prefix stripping during reading. If prefix stripping had occurred, word reading times would be longer for the pseudo-prefixed words. Reading times were the same for prefixed and pseudo-prefixed words.

Table 1. Mean Gaze Duration (in ms) with First Fixation Duration (in parenthesis) on the Target Word in Experiment 1

	Pseudo-Prefix	Bound Stem Prefix	Free Stem Prefix
Identical	290 (255)	295 (264)	286 (268)
Prefix-only	307 (280)	308 (279)	312 (279)
Stem-only	302 (274)	310 (279)	308 (274)
Control	313 (283)	310 (283)	320 (289)

Effect of Preview Type

First Fixation Duration. The mean first fixation durations on the target word for the identical, prefix-only, stem-only, and control preview conditions were 262, 279, 276, 285 ms, respectively (see Figure 4). Thus there was a reliable benefit resulting from parafoveal preview [$F_1(3,105)=11.94, p<.001$; $F_2(3,315)=12.43, p<.001$]. First fixation durations were shortest in the identical condition and longest in the control condition. The 3 ms difference between the prefix-only and the stem-only condition was not significant ($F's<1$). As a result, all planned pair-wise comparisons were made against the combined partial preview conditions. When the entire target word was available in the parafovea (the identical condition), subsequent fixations on the target word were significantly shorter than both the control condition [$F_1(1,35)=25.60, p<.001$; $F_2(1,105)=18.66, p<.001$] and the partial preview conditions [$F_1(1,35)=24.02, p<.001$; $F_2(1,105)=23.46, p<.001$]. First fixation durations in the partial preview conditions were significantly faster than the control condition by subjects [$F_1(1,35)=6.58, p<.05$], and marginally faster by items [$F_2(1,105)=3.75, p=.056$]. Thus, preview benefit was strongest when the entire target word was available in the parafovea. However, having partial word information in the parafovea also benefited subsequent word processing. Interestingly, the amount of preview benefit available was not modulated by 1) the number of letters available in the

preview (prefixes are much shorter than the stems), or 2) by the location of the available information. Parafoveal preview benefit was found for information presented at both the beginning and the end of the word.

Figure 4: Mean First Fixation Duration (in ms) on the target word, (collapsed across word type) in Experiment 1

Gaze Duration. The mean gaze durations on the target word for the identical, prefix-only, stem-only, and control preview conditions were 290, 309, 307, 317 ms, respectively (see Figure 5). There was a reliable benefit resulting from parafoveal preview [$F(3,105)=11.53, p<.001$; $F(3,315)=8.37, p<.001$]. Similar to first fixation durations, gaze durations on the target word were shortest in the identical preview condition and longest in the control preview condition. The 2 ms difference between the prefix-only and stem-only preview condition was not significant ($F's < 1$). As a result, the planned pair-wise comparisons were made against the combined partial preview conditions. Gaze durations on the identical preview condition were significantly shorter than both the control condition [$F(1,35)=18.95, p<.001$; $F(3,105)=22.51, p<.001$] and the partial preview conditions [$F(1,35)=17.34, p<.001$; $F(1,105)=16.20, p<.001$]. The target word was read faster after the partial preview conditions than the control

condition by subjects [$F(1,35)=7.21, p<.05$] and marginally faster by items [$F(1,105)=3.68, p=.058$]. Again, participants demonstrated the most preview benefit when the entire word was in the parafovea. However, gaze durations revealed the same facilitation as first fixation durations on subsequent word processing when only part of the target word was available in the parafovea. Importantly, it did not seem to matter which part of the word is available for preview; preview benefit was apparent when either the beginning or the end of the word is available in the parafovea.

Figure 5: Mean Gaze Duration (in ms) on the target word, (collapsed across word type) in Experiment 1

The degree of facilitation found when only the stem of the target word was available in the parafovea for preprocessing was somewhat surprising. Some preview benefit was expected for the end of the word, but not the same degree of facilitation as was found when the initial part of the target word was available in the parafovea. As a result, a post-hoc analysis was run to determine if the location of the eye prior to fixating the word modulated the strength of the preview benefit found for the partial preview conditions. For example, would the degree of facilitation for the end of the word decrease if the eye was further away from the target word on the prior fixation? To address this

question the data were divided into two groups. The near group included all trials in which the readers' eyes were within 4 character spaces of the target word before making a forward saccade onto the target word. The far group consisted of all trials in which the eyes were within 5-10 characters of the target word. Trials in which the eyes were further than 10 character spaces or the reader regressed to an earlier portion of the text before entering the target word were excluded from this analysis (which comprised of 2% of the data). The near group contained 48% of the overall data and the far group contained 50% of the overall data. The data for the near and far conditions are available in Table 3.

Gaze durations on the target word were examined conditionalizing on the location of the prior fixation in a 2 (distance: near versus far) x 3 (word type: pseudo-prefixed, bound stem prefixed, and free stem prefixed) x 4 (preview type: identical, prefix-only, stem-only, and control) ANOVA. The mean gaze durations in the near condition for the identical, prefix-only, stem-only, and control conditions were 280, 308, 303, 316 ms, respectively (see Figure 6). In the near condition, the main effect of preview was significant [$F(1,105)=7.75, p<.001$; $F(1,282)=12.77, p<.001$]. There was no main effect for word type and the interaction between word type and preview type was not significant (all F 's <1). The 5 ms difference between the prefix-only and the stem-only preview conditions was not significant. As a result, all pair-wise comparisons were made against the combined partial previews. The identical preview resulted in faster gaze durations on the target word than both the control condition [$F(1,35)=20.76, p<.001$; $F(1,94)=34.78, p<.001$] and the partial preview conditions [$F(1,35)=10.84, p<.005$; $F(1,94)=15.31, p<.001$]. Gaze durations for the partial preview conditions were faster than the control preview condition. This effect was not significant by subjects [$F(1$

(1,35)=2.62, $p = .115$], but it was significant by items [$F_2(1,94)=7.54$, $p < .01$]. Thus, readers benefited from the availability of parafoveal information at both the beginning and the end of the word.

Figure 6: Mean Gaze Duration (in ms) on the target word, for the Near condition in Experiment 1

The mean gaze duration in the far condition for the identical, prefix-only, stem-only, and control conditions were 300, 304, 311, 323 ms, respectively (see Figure 7). The main effect of preview was significant by subjects, but not items [$F_1(1,105)=2.82$, $p < .05$; $F_2(1,300)=1.71$, $p = .165$]. There was no main effect of word type and no interaction between word type and preview type (all F 's < 1). Planned pair-wise comparisons were carried out on all preview types. Gaze durations were significantly faster for the identical compared to the control preview condition [$F_1(1,35)=7.64$, $p < .01$; $F_2(1,300)=4.77$, $p < .05$]. The 4 ms difference between the identical and the prefix-only condition was not significant ($F < 1$). The 7 ms difference between the prefix-only and stem-only condition did not reach significance nor did the 11 ms difference between the identical and stem-only condition (F 's < 1). However, the 19 ms difference between the prefix-only and control condition was significant by subjects [$F_1(1,35)=4.14$, $p < .05$], but not items

($F < 1$). While the difference between the prefix-only and control condition did not reach significance by items, it reveals a trend in the data in which readers are more benefited by information at the beginning of a word when their prior fixation is distant from the target word location, suggesting that when the eye is distant to the target word location, the word initial letters are providing more parafoveal preview benefit than word final letters. However, there was no interaction between distance and word type or distance and preview type (all F 's < 1).

Figure 7: Mean Gaze Duration (in ms) on the target word, for the Far condition in Experiment 1

Oculomotor Measures

Lima (1987) found that departing saccades were longer for prefixed than for pseudo-prefixed words. In the current study, a similar effect for the saccade entering the target region was found, but only for the free stem prefixed words. These results are presented in Table 2. The average mean entering saccade lengths for free stem prefixed words, bound stem prefixed words and pseudo-prefixed words were 8.4, 8.0, and 8.0 characters respectively. This .4 character difference for the entering saccade length was significant by subjects, and marginally significant by items [$F_1(2,70) = 13.85$, $p < .001$; F_2

(2,105)=2.53, $p = .084$]. There was no effect of preview type and no interaction between word type and preview type (all F 's <1). The launch site of the eyes before moving in to the target region did not differ for the three word types (all F 's <1). However, the landing position of the eyes on the target word did differ for the three word types. Average mean landing positions for free stem prefixed words, bound stem prefixed words, and pseudo-prefixed words were 2.9, 3.1, and 3.3 characters respectively. These differences in landing position for the three word types were significant [F_1 (2,70)=10.44, $p < .001$; F_2 (2,105)=4.29, $p = .05$]. While there were differences in the location of the landing position for the three word types, the launch site for the entering saccades did not differ according to word type. As a result, it can be argued that the longer entering saccade length for the free stem prefixed word is not a result of differences in the launch site. While the differences here are reliable, they are quite small. The eyes moved further into a free stem prefixed word by .33 characters. Because this effect did not interact with preview type (F 's <1), it does not appear to be motivated by wanting to fixate a more "informative" point within the word.

Table 2. Mean Saccade Length (SL), Launch Site (LS), and Landing Position (LP, in character spaces) for the Target Word in Experiment 1

	Pseudo-Prefix			Bound Stem Prefix			Free Stem Prefix		
	SL	LS	LP	SL	LS	LP	SL	LS	LP
Identical	8.2	5.1	3.1	8.0	5.1	3.1	8.3	5.3	3.3
Prefix-only	7.8	5.2	2.8	7.9	5.2	3.0	8.4	5.4	3.2
Stem-only	7.9	5.2	2.9	8.0	4.8	3.2	8.4	5.4	3.3
Control	7.9	5.3	2.9	8.1	4.9	3.1	8.4	5.0	3.3

Discussion

The preview benefit found did not appear to be driven by morphological or lexical factors; it appeared to be pre-lexical or orthographic in nature. Interestingly, the parafoveal preview benefit was equally strong for the beginning and the ending letters of the target word, suggesting that the beginning and ending letters of a parafoveally available word work together to produce the increased parafoveal preview benefit found when the entire word is available parafoveally (Inhoff, 1989b). It is possible, however, that the equivalent preview benefit observed for the partial preview conditions results from a trade-off between the number of letters available for preprocessing in the parafovea and the distance between the preview letters and the eye before fixation (word initial versus word final). For example, prefix-only preview condition consisted of fewer letters, but it was closer to the eye before it was subsequently fixated. Additionally, the stem-only condition was further from the eye before being fixated, but more letters were available for preview in the parafovea. While it is possible that this difference led to the equivalent preview benefit for the partial preview conditions, it cannot be confirmed without further investigation outside of the scope of the current research. However, in Experiment 3 (below) the partial preview conditions are presented foveally. Thus, a significant difference in preview benefit for the two partial prime conditions would provide support for a trade-off hypothesis (see below).

While the interaction between distance and preview was not significant, there was some indication that the effect of preview type was modulated by the proximity of the reader's eyes to the location of the parafoveal preview of the target word. For example, when the fixation prior to entering the target word was within four character spaces of the

target word location, preview benefit was obtained for the identical, prefix-only, and stem-only preview conditions. When the eye was further than four character spaces from the target word location, preview benefit was greatest for the identical condition. Further, the preview benefit was greatest for the identical preview condition regardless of the distance of the eyes to the target word location suggesting that there is something special about having the entire word available in the parafovea. Having access to the entire word in the identical condition was more beneficial than having a preview consisting identical letters at the beginning of the word and visually similar letters at the end of the word (where the overall word form is quite similar). Thus it appears that while the preview benefit is pre-lexical, it is not just the form of the letters in the word that matter. Instead, the results of the current study provide evidence in support of the idea that parafoveal processing is driven by abstract letter codes, and that this appears to be somewhat letter specific.

It is also important to note that prefixed and pseudo-prefixed words were equally benefited by having the prefix and stem letters in the parafovea. There was no difference in reading times for the three word types. This is somewhat surprising in light of Lima's (1987) results. She found longer first fixations and gaze durations for pseudo-prefixed words than prefixed words. It is possible that Lima's effect was an artifact of the syllable boundary and pronunciation differences between the prefix and pseudo-prefixed words. Other research, however, suggests that prefixed and pseudo-prefixed words are processed differently. In a word pronunciation task, Zwitserlood (1994) demonstrated that orthographic transparency influences word processing, such that bound stem prefixed

words take longer to identify than free stem prefixed words. While the preview benefit found was orthographic, it did not interact with word type.

The failure to find an interaction between word type and preview type is a bit puzzling. I predicted that if a preview of the stem benefited subsequent word processing when words are presented in isolation, then free stem prefixed words would exhibit additional preview benefit because the morphological constituents were orthographically transparent and consistent in meaning. This hypothesis is plausible considering the reliable preview benefit found for the stem-only condition across all word types. However, it is possible that the consonant letter strings used in the current study (presented parafoveally) interfered with subsequent word processing. For example, *reduce* had the consonant letter string *-hsxc* in place of the stem *-duce*, and *return* had the consonant letter string *-fczx* in place of *-turn*. In both cases the resulting word initial trigram (visible in the parafovea) was common within the English language (e.g. *rehearse* and *refund*). Previous research has verified the availability of both phonological and orthographic information from word initial letters in the parafovea. Thus, the word initial letter string in the prefix-only condition may have originally been interpreted as *reh-* or *ref-* instead of *re-*, thus impeding word processing when the target word was subsequently fixated thereby preventing any resulting benefit for prefixed words over pseudo-prefixed words. The interference caused by the consonant letter string in the stem-only preview condition could have disrupted processing in the same manner. As a result, a second experiment was conducted to determine whether the consonant letter string in the parafovea was interfering with subsequent word processing thus masking any benefit resulting from parafoveal preview of morphological constituents.

CHAPTER III

EXPERIMENT 2: REPLICATION OF EXPERIMENT 1

In the previous experiment, the consonant letter string used to replace the target word letters in the partial preview conditions may have been interpreted as part of the preview word. The present experiment examined whether the consonant letter string presented in the parafovea disrupted subsequent word processing. In a large number of the stimuli, the initial trigram formed by the combination of the prefix and the consonant letter string was 1) common and 2) the initial letter sequence for a viable word in the English language. Removing the similarly shaped letters from the parafovea and restricting the parafoveal preview to the exact prefix or stem of the target word might provide a better test of the influence on morphology in parafoveal preprocessing. In order to restrict the parafoveal preview to the appropriate letters in the partial preview conditions, capital X's were used. Capital X's are visually distinct (XXview) and don't combine with any of the target word letters to form a word (reXXXX), thus making it possible to ascertain whether prefixed words are benefited by the availability of morphological information in the parafovea.

Method Section

Participants

Twenty-four individuals from the University of Massachusetts community were asked to participate in this experiment. All of the participants were native English speakers and were naive to the purpose of the study. All participants had normal or corrected to normal vision. None of the participants were in the prior experiment.

Apparatus

This was the same as in Experiment 1.

Procedure

The procedure for this experiment is the same as in Experiment 1.

Materials

The target words and sentence contexts were identical to Experiment 1. The information presented in the parafovea was modified to prevent confusion. Instead of replacing the target word letters with visually similar consonant strings (which may be interpreted as non target words), capital X's were used. Thus, the four preview conditions were: 1) identical (e.g. review) - the parafoveal preview is the same as the target word; 2) prefix only (e.g. reXXXX) - the parafoveal preview consisted of the prefix from the target word followed by a series of capital X's; 3) stem only (e.g. XXview) – the parafoveal preview consisted of the stem of the word preceded by capital X's; and 4) control (e.g. XXXXXX) – the parafoveal preview consisted of all capital X's (see Figure 8).

* |
Mary wants to quickly reXXXX her credit card debt this year.

| *
Mary wants to quickly reduce her credit card debt this year.

Preview Conditions

Identical = *reduce*

Prefix-only = *reXXXX*

Stem-only = *XXduce*

Control = *XXXXXX*

Target word: *reduce*

Figure 8: Example sentence for Experiment 2: Parafoveal preview

* The asterisk denotes the position of the eye and the “|” denotes the location of the boundary.

Results

The following oculomotor measures were computed: (1) first fixation duration, consisting of the duration of the first fixation on target words during the sentence’s initial (first pass) reading, irrespective of the number of fixations on these words, and (2) gaze duration, consisting of the cumulated viewing time on a target word during its first pass reading (i.e., excluding the time spent re-reading the target after the reading of other words). In addition to these two reading time measures, saccade length onto target words, and the landing position within target words were calculated.

Data were excluded from the following analysis for any of the following reasons:

1) a track loss occurred; 2) the eyes triggered the boundary change but remained on the word prior to the target word (usually the last letter of this word); 3) the first fixation of the target word was less than 100 ms, or a first pass fixation was greater than 800 ms; and

4) the first pass fixation was the last fixation recorded for the sentence. The mean percentage of usable data was 89% and the mean percentage of correct responses for yes/no questions was 97%, indicating little problem understanding the sentences. Readers reported some awareness of the X's in the parafovea during this experiment; however, the number of trials where the X's were reported underestimated the total number of trials in which they actually occurred.

All eligible trials were subjected to 3 (Target Word Type: Free prefixed, bound prefixed, pseudo-prefixed) x 4 (Preview Type: Identical, prefix-only, stem-only, control) ANOVAs with error variance computed within subjects (F_1) and between items (F_2). As in the previous experiment, planned contrasts were performed to compare preview effect sizes for each of the three target word types.

Effect of Word Type

Neither first fixation nor gaze duration measures varied across the different types of prefixed and pseudo-prefixed words (all F 's < 1). Additionally, there was no interaction between word type and preview type (all F 's < 1); indicating that morphological preprocessing does not occur in the parafovea and that the characteristics of the partial preview condition in the prior experiment did not mask processing differences among the three word types (see Table 3).

Table 3. Mean Gaze Duration (in ms) with First Fixation Duration (in parenthesis) on the Target Word in Experiment 2

	Pseudo-Prefix	Bound Stem Prefix	Free Stem Prefix
Identical	308 (264)	299 (266)	296 (268)
Prefix-only	330 (297)	334 (302)	330 (306)
Stem-only	334 (290)	332 (298)	334 (287)
Control	354 (310)	349 (307)	358 (313)

Effect of Preview Type

First Fixation Duration. The mean first fixation durations on the target word for the identical, prefix-only, stem-only, and control preview conditions were 266, 302, 289, 310 ms, respectively (see Figure 9). First fixation durations were benefited by accurate information available in the parafovea [$F_1(3,69)=17.43, p<.001$; $F_2(3,315)=25.64, p<.001$]. First fixation durations were shortest in the identical condition and longest in the control condition. The 13 ms difference between the prefix-only and the stem-only condition was marginally significant [$F_1(1,23)=3.42, p=.077$; $F_2(1,105)=3.40, p=.068$]. As a result, all planned pair-wise comparisons were made against the individual preview conditions. When the entire target word was available in the parafovea (the identical condition), subsequent fixations on the target word were significantly shorter than the control condition [$F_1(1,23)=27.48, p<.001$; $F_2(1,105)=64.99, p<.001$]; the prefix-only condition [$F_1(1,23)=27.37, p<.001$; $F_2(1,105)=49.41, p<.001$]; and the stem-only condition [$F_1(1,23)=17.07, p<.001$; $F_2(1,105)=32.89, p<.001$]. First fixation durations in the stem-only condition were significantly shorter than the control condition [$F_1(1,23)=10.83, p<.005$; $F_2(1,105)=8.85, p<.005$]; however, the difference between the prefix-only and control condition did not reach significance [$F_1(1,23)=1.96, p=.174$; $F_2(1,105)=1.86, p=.175$]. Again, the most benefit was gained by having the entire target word in the parafovea. However, having partial word information in the parafovea also benefited participants. Interestingly, the number of letters available in the preview seemed to affect the amount of preview benefit available, but this effect was only evident within first fixation duration.

Figure 9: Mean First Fixation Duration (in ms) on the target word, (collapsed across word type) in Experiment 2

Gaze Duration. The mean gaze durations on the target word for the identical, prefix-only, stem-only, and control preview conditions were 301, 331, 333, 354 ms, respectively (see Figure 10). The differences in preview benefit were reliable [$F_1(3,69)=12.54, p<.001$; $F_2(3,315)=17.09, p<.001$]. Gaze durations on the target word were shortest after the identical preview condition and longest after the control preview condition. Unlike first fixation duration, there was no difference in reading times between the partial preview conditions; the 1 ms difference between the prefix-only and stem-only preview condition was not significant ($F's<1$). As a result, the planned pair-wise comparisons were made against the combined partial preview conditions. Gaze durations on the identical preview condition were significantly shorter than both the control condition [$F_1(1,23)=29.06, p<.001$; $F_2(3,105)=51.91, p<.001$] and the partial preview conditions [$F_1(1,23)=15.08, p<.001$; $F_2(1,105)=28.99, p<.001$]. The partial preview conditions were significantly faster than the control condition [$F_1(1,23)=6.24, p<.05$; $F_2(1,105)=9.88, p=.005$]. Again, participants demonstrated the most preview benefit when the entire word was in the parafovea. However, gaze durations were equally facilitated for

the prefix-only and the stem-only preview conditions. The difference in amount of information available in the parafovea may have affected initial processing measures (first fixation duration), but not overall word processing (gaze duration). Additionally, it did not seem to matter which part of the word is available for preview; parafoveal preview benefit was equivalent for the beginning and the end of the word.

Figure 10: Mean Gaze Duration (in ms) on the target word, (collapsed across word type) in Experiment 2

In Experiment 1, readers' demonstrated more preview benefit for the identical and partial preview conditions when their eyes were close (between 1-4 characters) to the target word location. No significant preview benefit was found for the partial preview conditions when the eyes were far (5-10 characters) from the target word. However, there was a trend in the data indicating that some preview benefit was available for the word initial letters in the prefix-only condition, while there was little indication that any preview benefit was being acquired from the word final letters. In order to determine whether the characteristics of the consonant letter strings used to mask the appropriate letters muted the amount of preview benefit found for the word initial letters in the far condition, the data from the current experiment was again divided into two groups. The

near group again included all trials in which the readers' eyes were within 4 character spaces of the target word before making a forward saccade onto the target word. The far group again consisted of all trials in which the eyes were within 5-10 characters of the target word. Trials in which the eyes were further than 10 character spaces or the reader regressed to an earlier portion of the text before entering the target word were excluded from this analysis (which comprised of 21 % of the data). The near group contained 40% and the far group contained 39% of the overall data.

Gaze durations on the target word were examined conditionalizing on the location of the prior fixation in a 2 (distance: near versus far) x 3 (word type: pseudo-prefixed, bound stem prefixed, and free stem prefixed) x 4 (preview type: identical, prefix-only, stem-only, and control) ANOVA. The mean gaze durations in the near condition for the identical, prefix-only, stem-only, and control conditions were 280, 328, 333, 354 ms, respectively (see Figure 11). In the near condition, the main effect of preview was significant [$F(3,69)=18.04$, $p<.001$; $F(3,261)=15.12$, $p<.001$]. There was no main effect of word type and no interaction between preview and words type All F 's <1). The 5 ms difference between the prefix-only and the stem-only preview conditions was not significant (F 's <1). As a result, all pair-wise comparisons were made against the combined partial previews. The identical preview resulted in faster gaze durations on the target word than both the control condition [$F(1,23)=41.55$, $p=.001$; $F(1,87)=52.62$, $p<.001$] and the partial; preview conditions [$F(1,23)=30.01$, $p<.005$; $F(1,87)=37.06$, $p<.001$]. Reading times for the partial preview condition were marginally faster than the control preview condition [$F(1,23)=6.74$, $p<.05$; $F(1,87)=3.08$, $p=.08$]. Thus readers

were benefited by the availability of parafoveal information at the beginning and the end of the word.

Figure 11: Mean Gaze Duration (in ms) on the target word, for the Near condition in Experiment 2

The mean gaze duration in the far condition for the identical, prefix-only, stem-only, and control conditions were 316, 327, 324, 361 ms, respectively (see Figure 12). The main effect of preview was significant by subjects but not items [$F_1(3,48)=3.85$, $p<.05$; $F_2(3,198)=2.09$, $p=.1$]. There was no main effect of word type and no interaction between word type and preview type (all F 's <1). The 3 ms difference between the prefix-only and stem-only preview conditions did not reach significance (F 's <1). As a result, the partial preview conditions were collapsed for all planned pair-wise comparisons. Gaze durations were significantly faster for the identical compared to the control preview condition for subjects and marginally faster by items [$F_1(1,16)=8.07$, $p=.05$; $F_2(1,66)=6.98$, $p=.01$]. Gaze durations did not significantly differ for the partial preview conditions as compared to the identical condition by subjects (F 's <1), although this difference approached significance by items [$F_2(1,66)=3.15$, $p=.08$]. However, the partial preview conditions did differ reliably from the control condition [$F_1(1,16)=6.57$,

$p < .05$ $F_2(1,66)=4.53$, $p = .05$], indicating that preview benefit was found for both the prefix-only condition and the stem-only condition when the eyes were distant from the target word. When the eyes are further from the target word, the magnitude of the preview benefit did not appear to differ between the identical, prefix-only, and stem-only preview conditions. There was no interaction between distance and word type or distance and preview type (F 's < 1), suggesting that subsequent word processing was facilitated when both word initial and word final letters benefited subsequent word processing, even when the eyes were relatively far away. The visual characteristics of the parafoveal preview affect the amount of preview benefit acquired by the reader. Thus when the masking letters are visually distinct from the target word letters, parafoveal preview benefit is available for the entire word even when the eyes are distant from the target word location.

Figure 12: Mean Gaze Duration (in ms) on the target word, for the Far condition in Experiment 2

Oculomotor Measures

In Experiment 1 word type differences were found for saccade length and landing position measures, but not for reading time measures. Oculomotor measures were examined in the present experiment in order to determine whether morphological constituents influence eye movement behavior. The data are presented in Table 4. In the present experiment, parafoveal masks that did not interfere with word segmentation were used, enabling a better examination of oculomotor behavior with respect to preview type.

Table 4. Mean Saccade Length (SL), Launch Site (LS), and Landing Position (LP, in character spaces) on the Target Word in Experiment 2

	Pseudo-Prefix			Bound Stem Prefix			Free Stem Prefix		
	SL	LS	LP	SL	LS	LP	SL	LS	LP
Identical	7.7	4.6	3.0	7.8	4.8	3.2	8.2	5.4	3.3
Prefix-only	7.4	4.8	2.9	7.6	4.3	3.4	7.9	5.4	3.2
Stem-only	8.0	4.5	2.8	7.9	4.6	2.9	8.2	4.8	3.0
Control	7.4	4.4	3.1	7.7	4.7	3.2	8.0	4.6	3.4

Saccade Length. Average mean entering saccade lengths for free stem prefixed words, bound stem prefixed words and pseudo-prefixed words were 8.1, 7.8, and 7.6 characters respectively. There was a main effect of word type on the length of the saccade entering the target word [$F_1(2,46)=9.21, p<.001$; $F_2(2,105)=3.47, p=.05$]. Saccade lengths were longest when moving into the free stem prefixed words and shortest when moving into pseudo-prefixed words. There was also a main effect of preview type [$F_1(2,69)=4.60, p<.01$; $F_2(2,315)=3.66, p<.05$]. Average mean entering saccade lengths for the identical, prefix-only, stem-only, and control preview conditions were 7.9, 7.6, 8.0, and 7.7 characters respectively, suggesting that saccades lengths were longer moving into the identical and stem-only preview condition than the prefix-only and control conditions.

There was no interaction between word type and preview type ($F's < 1$). These data are similar to Experiment 1 as indicated by longer saccades when looking at prefixed as opposed to non-prefixed words. However, in Experiment 1, only free stem prefixed words showed this effect. Additionally, there was a main effect of preview in the current experiment that was not observed in the prior experiment. This effect is quite small and most likely reflects noise in the data.

Launch Site. Average mean launch sites for free stem prefixed words, bound stem prefixed words, and pseudo-prefixed words were 5.1, 4.6, and 4.6 characters respectively. The .5 character difference between free stem prefixed words and the other two word types was significant by subjects [$F(1, 246) = 7.00, p < .01$] and marginally significant by items [$F(2, 105) = 2.49, p = .088$]. There was no effect of preview type and no interaction between word type and preview type (all $F's < 1$). Unlike Experiment 1, there was a slight difference in the location of the eyes before moving to the target word. The launch site was further away from the target word for the free stem prefixed words than the other two word types.

Landing Position. Landing position of the eyes on the target word differed for the three word types by subjects [$F(1, 246) = 3.89, p < .05$], not items [$F(2, 105) = 1.67, p < .2$]. Average mean landing positions for free stem prefixed words, bound stem prefixed words, and pseudo-prefixed words were 3.2, 3.2, and 3.0 characters respectively. Landing positions were further into the target word for both prefix word types than the pseudo-prefixed words. Average mean landing positions for the identical, prefix-only, stem-only, and control preview conditions were 3.2, 3.2, 2.9, and 3.2 characters respectively. The .30 character difference between the stem-only and other preview conditions resulted in a

reliable effect of preview type [$F_1(2,46)=3.53$, $p < .05$; $F_2(2,315)=3.87$, $p < .05$]. Landing positions were closer to the beginning of the word when the preview was of the stem-only condition. There was no interaction between word type and preview type for landing position ($F's < 1$). In Experiment 1, readers' eyes landed further into free stem prefixed target words than the other two word types. In the current experiment, the landing position was further into both free and bound stem prefixed words than pseudo-prefixed words. Additionally, there was a main effect of preview for landing position in the present experiment that was not observed in Experiment 1. This effect is inconsistent with the saccade length effect found above indicating that it may just reflect noise in the data.

Discussion

Reading times did not differ according to word type. There was no main effect of word type for first fixation duration or gaze duration on the target word. In Experiment 1, it was proposed that the potentially confusing letters used as the consonant letter strings might have interfered with parafoveal preview benefit for prefixed words. In the current experiment, visually distinct capital X letter strings were used to mask portions of the target word in the parafovea. This manipulation was intended to avoid providing misleading information in the parafovea about word components allowing for a better test of whether morphological information is 1) available and 2) utilized in the parafovea during sentence processing. The results of the two parafoveal preview experiments are consistent. In both cases there was no indication in reading time measures that prefixed and pseudo-prefixed words are processed differently. Thus morphological information does not appear to be available for preprocessing in the parafovea. Further, effects of

morphological decomposition were obscured during sentence processing. Reading time differences found between prefixed and pseudo-prefixed words in isolation were not replicated during sentence processing.

The parafoveal preview benefit found was entirely orthographic. All three word types benefited from having identical letters available for processing in the parafovea. The identical preview condition resulted in the most parafoveal preview benefit as demonstrated by significantly faster reading times. Reading times were faster on the target word for the partial preview conditions than for the control condition. Additionally, readers were equally benefited by having letters from the beginning and the end of the word available in the parafovea. Thus it appears that parafoveal preview benefit can be found for the word final as well as the word initial letters of a word. The 27 ms difference between the identical and partial preview conditions further indicate that having the exact letter string in the parafoveal benefits subsequent word processing the most suggesting that the beginning and ending letters of a parafoveally available word work together to produce the increased parafoveal preview benefit found for the entire word. Again, it is possible that the equivalent preview benefit for the two partial preview conditions results from a trade-off between the number of letters available in the parafovea for preview and the proximity of the eye to the target letters (word initial versus word final). This hypothesis will be addressed in the General Discussion.

The distance of the eyes prior to fixating the target word did not modulate the parafoveal preview effect found in the current experiment. There was no interaction between distance and word type or distance and preview type. When the data was analyzed according to the distance between the eyes and the target word, parafoveal

preview benefit was found for the identical, prefix-only, and stem-only preview conditions for both the near and the far analysis. In both the near and the far analysis, the identical condition resulted in the most preview benefit. Additionally, the prefix-only and stem-only preview conditions demonstrated equivalent amounts of parafoveal preview for the near and far analysis, such that readers were benefited by having word final letters available in the parafovea as much as 10 character spaces away from the target word. In some respects, this is not surprising. The capital X's used to mask the target words in the parafovea were visually distinct from the other letters in the word (and sentence). Thus readers' may have found it easier to disregard the irrelevant letters and begin processing relevant parafoveal information even when was fairly distant. The characteristics of the preview affected subsequent word processing resulting in greater parafoveal preview benefit and larger differences between preview conditions.

Although reading times did not differ according to word type, there was a there was a reliable effect of word type within the oculomotor measures. Reader's eye movements differ for prefixed and pseudo-prefixed words. In the present experiment, this effect was signified by longer saccade lengths and landing positions that were further into prefixed as opposed to pseudo-prefixed words. In Experiment 1, a slightly different pattern of data was observed. Readers' eyes moved further into free stem prefixed words than bound stem prefixed words, which in turn were further than pseudo-prefixed words. Additionally, saccades were longer for free stem prefixed words than both bound stem and pseudo-prefixed words, suggesting that prefixed words affect oculomotor behavior differently. However, in the present experiment, saccades were longer into both types of prefixed words, suggesting that no such difference between types of prefixed words

exists. While the oculomotor effects are reliable, they are quite small. Because these differences are so small and vary slightly between the two preview experiments, it is unlikely that much should be made of these results without further investigation.

CHAPTER IV

EXPERIMENT 3: FOVEAL PRIMING

In Experiment 3, the intent was to extend the foveal fast-priming literature to include morphology. Previous research on foveal fast priming within a sentence context indicates that orthographic, phonological, and semantic information is available for processing. However, semantic information only becomes available within a short, isolated window of time (Lee et al., 1999). No previous research has been conducted to determine the time course of morphological priming during reading. The purpose of the present experiment was to extend the research on morphological pre-processing in the parafovea to include foveal priming during sentence processing at two prime durations. One (32 ms) has been previously identified as the time frame within which semantic priming is found, whereas the second (40 ms) is outside of the range in which semantic or phonological priming has been found; however, orthographic priming has been found at this prime duration. The intention was to determine: 1) whether evidence of morphological priming could be found during sentence processing and 2) whether the facilitation could be distinguished from orthographic and/or semantic priming. If morphological priming is dependent upon the meaning (or semantic) portion of the morpheme, then morphological priming should only occur at the 32 ms prime duration. While morphological priming was expected for prefixed words, orthographic priming was expected for all word types. Semantic priming was only expected for free stem prefixed words in the stem-only prime condition.

If morphological priming mimics semantic priming, then morphological facilitation should occur at the 32 ms prime duration. There should be no priming for

pseudo-prefixed words; however, both types of prefixed words should be facilitated by the prefix-only and the stem-only primes. This would indicate that morphological priming (which may be partially semantic in nature) occurs within the same time frame as semantic priming. Evidence for morphological priming at both prime durations (32 and 40 ms) would indicate that semantic and morphological priming are distinct. However, another possibility is that all word types will demonstrate the same degree of facilitation, indicating that no morphological priming occurred. In this case, the facilitation resulting from the prime types would be entirely orthographic.

In addition to looking at foveal processing, this experiment made it possible to further examine how morphologically complex (prefixed) words are processed. Support for theories of morphological decomposition would be obtained if both types of prefixed words (bound stem and free stem) benefit from the two partial prime types (as opposed to the pseudo-prefixed words). However, if the degree to which free stem and bound stem prefixed words benefit from the different prime types differs, then theories of morphological decomposition would have to be modified in order to account for the fact that different types of prefixed words are processed differently.

Thus, the third experiment of this dissertation directly examined morphological priming within a sentence context via the fast-priming paradigm. This experiment contained three target word types (pseudo-prefixed words, bound stem prefixed words, and free stem prefixed), four prime types (identical, prefix-only, stem-only, and a consonant letter string control), and two prime durations (32 and 40 ms). Such a manipulation made it possible to determine: 1) whether morphological priming was apparent during sentence processing, 2) whether the different morphological constituents

facilitate subsequent word processing equally, 3) whether the different type of prefixed words were equally benefited by morphological priming within a sentence context, and 4) whether the prime durations differentially affected the degree of priming available for the different word types.

Method Section

Participants

Forty-eight individuals from the University of Massachusetts community participated in this experiment. None had participated in the previous two experiments and 46 of the participants had never been in an eye tracking study before. Twenty-four participants were assigned to each of the between subject prime duration conditions (see below). All of the participants were native English speakers with normal or corrected to normal vision.

Apparatus

This was the same as in Experiment 1.

Procedure

The general procedure for this experiment was the same as in Experiment 1. However, due to the additional display change that occurred in this experiment, participants were warned that they may occasionally see a flash on the screen, but they were to ignore it and read normally. All participants were expected to read 12 practice trials and a total of 216 experimental trials (108 critical trials and 108 filler trials) of which approximately 30% were followed by a question requiring a yes/no response made by clicking a button on a keypad. Once the informed consent had been signed, a bite bar

was prepared for each participant, and the calibration routine and checks were performed (exactly as described in Experiment 1).

For each sentence, an invisible boundary located just after the last letter of the word prior to the target word was established (see Figure 2). When the sentence was initially presented on the computer monitor, a random string of letters occupied the target word location. Once the participants' eyes moved across the invisible boundary during a saccade, the random string of letters was replaced by a brief foveal prime (see Sereno & Rayner, 1992, for a comprehensive description of this technique) which was either: 1) identical to the target word (e.g. review); 2) the prefix of the target word plus a random letter string (e.g. rexwsz); 3) the stem of the target word with word-initial random letters (e.g. cmview); or 4) a random letter string (no prime) control condition (e.g. cmxwsz). Because the first display change took place during a saccade (when vision is suppressed), subjects were not aware of it. The foveal prime appeared in the target location for a pre-specified amount of time (32 or 40 ms, measured from the onset of the fixation, not the saccade) and was then replaced with the target word. The second display change from the prime to the target was made during the fixation and was often noticeable to the participant (though they could never actually determine what the prime was). Often the second display change was "noticed" as a flicker of light on the monitor. The target word remained in the target location until the sentence disappeared from the screen. Display changes are delayed until the electron beam finishes replotting the text (Lee et al., 1999). Because of this, the display changes are actually 6.25 ms longer than the nominal prime duration (which was the signal for the display change to occur). As a result, the actual prime interval could range from 32 to 39 ms for the nominal 32 ms prime duration

(because the signal to replace the prime with the target may occur at any point during the 6.25 ms needed to “paint” the screen.). At the end of the experiment, participants were asked to report what they noticed about the display changes. They reported noticing that something occurred when they fixated the target word (i.e. when the prime changed to the target word), but they were unable to identify the prime.

Materials

The same stimuli were used in Experiment 3 as in Experiment 1, but the four prime conditions (described in Experiment 1) were presented foveally using the fast-priming paradigm. In addition, a different string of random letters was placed in the target word location when the sentence was first presented on the computer monitor. The random letter string was replaced by one of the four priming conditions: 1) identical (e.g. review) - the foveal prime is the same as the target word; 2) prefix only (e.g. rexwsz) - the foveal prime consisted of the prefix from the target word followed by a random string of letters; 3) stem only (e.g. cmview) – the foveal prime consisted of the stem of the word preceded by a random string of letters; and 4) control (e.g. cmxwsz) – the foveal prime consisted of a random string of letters. The prime appeared briefly (for a pre-specified amount of time) before being replaced by the target word (see Figure 13). Prime duration was manipulated as a between subjects variable. Thus, individuals participating in the experiment read sentences with a 32 ms prime or a 40 ms prime, never both. A set of 108 filler sentences was also included in the experiment (see Figure 2). The filler sentences were taken directly from Sereno and Rayner (1992) and contained semantically related, unrelated, or identical prime words, which were presented in a within subjects manipulation at three prime durations (24, 32, and 40 ms). The filler sentences made it

possible to vary the duration of the prime in order to avoid any inadvertent strategies that may develop when a single prime duration is used. It also made it possible to verify whether or not participants were sensitive to the semantic relationship between the primes and target words within the experiment. Results for the semantic priming filler sentences will be discussed below.

* |

Mary wants to quickly ndvhfz her credit card debt this year.

| *

Mary wants to quickly rehsxc her credit card debt this year.

| *

Mary wants to quickly reduce her credit card debt this year.

Prime words:

Identical = *reduce*

Prefix-only = *rehsxc*

Stem-only = *zvduce*

Control = *zvhsxc*

Target word: *reduce*

Prime Durations: 24, 32, 42 ms

Figure 13: Example sentence for Experiment 3: Fast priming

* The asterisk denotes the position of the eye and the “|” denotes the location of the boundary.

Results

Data were excluded from the following analyses for any of the following reasons:

- 1) a track loss occurred; 2) the reader skipped the target word; 3) the eyes triggered the boundary change but remained on the word prior to the target word (usually the last letter of this word); 4) the onset of the prime did not coincide with the onset of the fixation; 5)

the first fixation of the target word was less than 100 ms, or a first pass fixation was greater than 900 ms (these values include the prime duration); and 6) the first pass fixation was the last fixation recorded for the sentence. The mean percentage of usable data across the 48 subjects was 79%, and the mean percentage of correct responses to the yes/no comprehension questions was 95%, indicating that participants did not have difficulty understanding the sentences.

First fixation, single fixation, and gaze durations were analyzed on the target word (see Table 5). *First fixation duration* is the duration of the initial fixation on a target word, independent of the number of fixations made, and *single fixation duration* is the duration of the first fixation on the target word, when it was the only fixation made, *gaze duration* is the sum of all consecutive fixations on a word prior to an eye movement (either forward or backward) to another word (in all three cases, only trials in which the word was not initially skipped are counted in the means). In the table, prime durations were subtracted from the means so that these measures assess the time that the target was fixated after the target word appeared.

Table 5. Mean First Fixation Duration (FF), Single Fixation Duration (SF), and Gaze Duration (GD, in ms) on the Target Word in Experiment 3

		Pseudo-Prefix			Bound Stem Prefix			Free Stem Prefix		
		FF	SF	GD	FF	SF	GD	FF	SF	GD
32 ms	Identical	290	301	333	300	323	336	288	303	334
	Prefix-only	328	373	378	336	366	396	340	364	414
	Stem-only	335	369	400	341	384	415	346	380	408
	Control	346	384	427	355	378	416	377	405	428
		Pseudo-Prefix			Bound Stem Prefix			Free Stem Prefix		
		FF	SF	GD	FF	SF	GD	FF	SF	GD
40 ms	Identical	281	289	310	281	290	320	274	285	307
	Prefix-only	328	363	392	330	345	398	339	372	391
	Stem-only	320	341	396	335	367	398	338	367	385
	Control	349	387	434	358	381	435	375	417	429

All eligible trials for were subjected to a 2 x (Prime Duration: 32 and 40 ms) x 3 (Target Word Type: Free prefixed, bound prefixed, pseudo-prefixed) x 4 (Preview Type: Identical, prefix-only, stem-only, control) ANOVAs with error variance computed within subjects (F_1) and between items (F_2). As in the previous experiments, planned contrasts were performed to compare preview effect sizes for each of the target word types at all prime durations. Participants saw all target types and all preview types, but the prime duration was held constant for each subject.

Morphological Priming

First fixation duration. There was a main effect of word type that was significant by subjects [F_1 (1,46)= 5.36, $p < .01$], but not items [F_2 (2,212)= 1.27, $p < .3$]. Reading times were faster for pseudo-prefixed (322 ms) words than for free (335 ms) and bound (330 ms) stem prefixed words. This first hint of a difference between prefixed and pseudo-prefixed words was only evident in the subject analysis for first fixation durations. No other analysis hinted at a similar effect suggesting that this may be a result

of a type 1 error. The main effect of prime duration was not significant by subjects ($F < 1$), but it was by items [$F_2(1,212) = 19.83, p < .001$]. Reading times on the target word were faster in the 40 ms prime duration (326 ms) than the 32 ms prime duration (332 ms) condition. Again, this effect was only significant by items in first fixation duration, nowhere else. Word type did not interact with prime type ($F's < 1$) or prime duration ($F's < 1$). Thus there appeared to be no advantage for having the stem (e.g. *-view*) of a free stem prefixed word as a prime over the stem (e.g. *-duce*) of another type of word.

The mean first fixation durations on the target word for the identical, prefix-only, stem-only, and control prime conditions were 285, 334, 336, 360 ms, respectively (see Figure 14). There was a main effect of prime type [$F_1(3,138) = 84.14, p < .001$; $F_2(3,636) = 57.72, p < .001$], indicating that the identical prime facilitated subsequent word processing the most, followed by the two partial prime conditions. The 2 ms difference between the prefix-only prime and the stem-only prime conditions was not significant ($F's < 1$), thus the paired comparisons were made against the combined partial prime conditions. The difference between the identical and control prime conditions was significant [$F_1(1,46) = 199.05, p < .001$; $F_2(1,212) = 164.15, p < .001$] as was the difference between the identical and partial prime conditions [$F_1(1,46) = 98.33, p < .001$; $F_2(1,212) = 110.09, p < .001$]. The partial prime conditions were read significantly faster than the control condition [$F_1(1,46) = 28.92, p < .001$; $F_2(1,212) = 21.58, p < .001$]. This pattern of data is entirely consistent with the pattern described above for the parafoveal preview experiments. Priming was greatest in the identical prime condition; however, the number of overlapping letters in the partial prime conditions did not appear to affect the amount of facilitation acquired from the prime.

Figure 14: Mean First Fixation Duration (in ms) on the target word, collapsed across word type and prime duration for Experiment 3

Single fixation duration. Unlike first fixation duration, there was no main effect of either word type ($F's < 2$) or prime duration ($F's < 1$) in single fixation duration. Further, word type did not interact with either prime type ($F's < 1$) or prime duration ($F's < 1$). No additional priming was found for stems of free stem prefixed words.

The mean single fixation duration on the target word for the identical, prefix-only, stem-only, and control prime conditions were 298, 364, 368, 392 ms, respectively (see Figure 15). There was a main effect of prime type [$F_1(3,138)=77.96, p < .001$; $F_2(3,636)=59.54, p < .001$], indicating that the identical prime facilitated subsequent word processing the most, followed by the two partial prime conditions. The 4 ms difference between the prefix-only prime and the stem-only prime conditions was not significant ($F's < 1$), thus the paired comparisons were made against the combined partial prime conditions. The difference between the identical and control prime conditions was significant [$F_1(1,46)=209.32, p < .001$; $F_2(1,212)=183.30, p < .001$] as was the difference between the identical and partial prime conditions [$F_1(1,46)=223.66, p < .001$; $F_2(1,212)=109.17, p < .001$]. The partial prime conditions were read significantly faster

than the control condition [$F_1(1,46)=14.70, p<.001$; $F_2(1,212)=24.60, p<.001$]. Again, readers were benefited most by the identical word prime; however, the two partial prime types equally facilitated subsequent word processing. The number of overlapping letters in the partial prime conditions did not appear to affect the amount of resulting facilitation, suggesting that the form of the prime causes the prime benefit for the partial preview conditions.

Figure 15: Mean Single Fixation Duration (in ms) on the target word, collapsed across word type and prime duration for Experiment 3

Gaze duration. Similar to single fixation duration, there was no main effect of either word type (F 's <2) or prime duration (F 's <1) in gaze duration. Further, word type did not interact with either prime type (F 's <2) or prime duration (F 's <2).

The mean gaze duration on the target word for the identical, prefix-only, stem-only, and control prime conditions were 324, 395, 400, 428 ms, respectively (see Figure 16). There was a main effect of prime type [$F_1(3,138)=99.54, p<.001$; $F_2(3,636)=94.14, p<.001$], indicating that the identical prime facilitated subsequent word processing the most, followed by the two partial prime conditions. The 5 ms difference between the prefix-only prime and the stem-only prime conditions was not significant (F 's <1), thus the paired comparisons were made against the combined partial prime

conditions. The difference between the identical and control prime conditions was significant [$F_1(1,46)=272.84, p<.001$; $F_2(1,212)=259.96, p<.001$] as was the difference between the identical and partial prime conditions [$F_1(1,46)=238.60, p<.001$; $F_2(1,212)=193.32, p<.001$]. The partial prime conditions were read significantly faster than the control condition [$F_1(1,46)=21.92, p<.001$; $F_2(1,212)=30.43, p<.001$]. Again, readers were benefited the most by the identical word prime, followed by the partial prime conditions. Similar to first fixation and single fixation duration, the two partial prime types resulted in the same amount of facilitation. The number of overlapping letters between the prime and target word did not influence the amount of facilitation obtained in the partial preview conditions; instead, it appears to be caused by the form of the prime.

Figure 16: Mean Gaze Duration (in ms) on the target word, collapsed across word type and prime duration for Experiment 3

The main effect of prime duration and word type observed for first fixation durations was not replicated within measures of single fixation duration or gaze duration. The average number of fixations did not differ for the three word types or the two prime durations (all F 's < 1). However, on the occasions when more than one fixation occurred on a word, the duration of the first and second fixation varied. Sometimes, the initial fixation was quite short, followed by a longer fixation; other times the opposite pattern

occurred. Thus arbitrary differences in fixation patterns may have caused the reading time differences found in first fixation duration for the different word types and prime durations.

Semantic Priming

The failure to find evidence of morphological or semantic priming for the free stem prefixed words in the stem-only condition or at the 32 ms prime duration was unexpected. In the current study, there were no differences in word type and no interaction between word type and preview type for the different prime durations. Similar to Experiments 1 and 2, there was no conclusive evidence that the individual morphemes or the semantic relation between the free stem prefixed word and its stem influenced processing during reading. Thus, we are left with the question of whether these participants were sensitive to the semantic relationship between the primes and target words.

Each participant read 216 items during the experiment. Half of those items consisted of morphological priming stimuli and half consisted of an exact replication of the Sereno and Rayner (1992) semantic priming stimuli. By including and replicating the semantic priming effects found previously (Sereno & Rayner, 1992; Sereno, 1995; Lee et al., 1999), it was possible to determine whether participants were sensitive to the semantic relationship between the prime and target word despite the fact that no morphological priming was found. Evidence for semantic priming in the absence of morphological priming should provide evidence in support of morphology as a unique level of linguistic representation. It would also indicate that morphological effects on word processing are obscured during sentence processing.

By analyzing the data from the semantic priming filler sentences, it is possible to ascertain whether participants were sensitive to the semantic relationship between the prime and target word. Morphological priming was expected for prefixed words in the 32 ms prime duration (as opposed to the 40 ms prime duration), but no effect of prime duration was found on reading times within the morphological priming stimuli. Because the 32 ms prime duration was the condition in which morphological priming was expected to occur, data from the semantic priming filler sentences from these subjects (the 32 ms between subjects prime duration condition) were analyzed. The filler sentences consisted of an exact replication of the Sereno and Rayner (1992) semantic fast priming Experiment 1. The same analysis and exclusion criterion were used for the present analysis as was used by Sereno & Rayner (1992). The resulting amount of usable data was 72% for the 24 participants included in the analysis. Gaze duration measures were subjected to a 3 (prime type: Identical, related, and unrelated) x 3 (prime duration: 24, 32, 40 ms) ANOVA. The data are presented in Table 6. The critical comparison to assess the effect of semantic priming was between the related and unrelated prime types across all prime durations. Despite the fact that the prime duration was a between subjects variable for the morphological priming stimuli, prime duration was manipulated within subjects for the semantic priming stimuli. Thus, all participants saw all target word types at all prime durations for this subset of the stimuli.

Table 6. Mean Gaze Durations (in ms) on the Target Word for the Semantic Priming Filler Sentences in Experiment 3

Prime Duration (ms)	Prime Type		
	Identical	Related	Unrelated
24 ms	331	370	368
32 ms	330	385	419
40 ms	324	414	416

The main effect of prime type was significant [$F(2,46) = 42.75, p < .001$], indicating that reading times were significantly faster for the identical prime than the related primes, which were read faster than the unrelated primes. The mean differences between the related and unrelated prime types for the 24, 32, and 40 ms prime durations were -2, 35, and 2 ms respectively (see Table 7). The 35 ms advantage on subsequent word processing after a related as opposed to an unrelated prime was significant [$F(1,23) = 12.47, p < .01$], providing clear evidence for semantic priming for the 32 ms primes. There was no significant difference in reading times on the target word for the related and unrelated prime words at the 24 or 40 ms prime durations ($F's < 1$). These results thus indicate that semantic priming did occur at the 32 ms prime duration but not at the 24 or 40 ms prime duration, replicating previous research on semantic priming, and indicating that participants were sensitive to the semantic relation between the prime and target word.

Table 7. Differences in Gaze Duration Means (in ms) for the Semantic Priming Filler Sentences in Experiment 3

Prime Duration (ms)	Differences		
	U-R	I-R	I-U
24 ms	-2	-39	-37
32 ms	35	-55	-90
40 ms	2	-90	-92

The main effect of prime duration was significant [$F(2,44) = 9.27, p < .001$] as was the interaction between prime type and prime duration [$F(2,88) = 5.85, p < .001$]. In effect, the related and unrelated prime types were fastest at the 24 ms prime duration. Since the prime word and target words were identical across prime duration conditions, this difference suggests that the 24 ms prime duration was too brief for the meaning of the prime to have an effect on reading times.

Discussion

The results of the morphological priming experiment fail to provide evidence for morphological decomposition. There was no indication that prefixed words are being decomposed in the early stages of word processing such that a foveal prime is able to facilitate reading times on a target word during sentence processing. It is possible that the morphological effects are obscured during sentence processing as prefixed and pseudo-prefixed words demonstrated the same degree of priming. The experimental items demonstrated no evidence to suggest that individual morphological constituents or semantic relatedness between the prime and target word facilitated subsequent word processing, suggesting that the priming effect found was entirely orthographic.

The identical and partial prime types equally facilitated prefixed and pseudo-prefixed words, with the strongest priming effect occurring for the identical prime words. Additionally, the two partial prime types (prefix-only and stem-only) provided clear evidence of facilitation over the orthographic control condition (consonant letter string comprised of letters similar in shape to the target word letters). The number of overlapping letters in the partial prime conditions did not influence the resulting amount of facilitation. Finally, prime type did not interact with word type indicating that prefixed words did not behave differently from 1) each other or 2) pseudo-prefixed words.

Previous studies in English have found evidence for morphological priming using prefixed words. These studies looked at prefixed words in isolation; none have looked at morphological priming (using prefixed words) within a sentence context. The priming studies testing words in isolation yield slightly different results depending on the methodology used. In a series of cross-modal repetition studies, Marslen-Wilson and colleagues found that free stem prefixed words (e.g. review) were primed by their stem (-view), whereas bound stem prefixed words (e.g. reduce) were not (Marslen-Wilson et al., 1994). From this they argued that morphological priming is restricted to semantically transparent cases of prefixed words. However, in a series of masked priming studies, Forster and Azuma (2000) found the same magnitude of priming for bound and free stem prefixed words. They concluded that semantic transparency was not necessary to demonstrate morphological priming.

Masked priming studies, while relatively insensitive to semantic effects, are successfully used to study morphological priming and decomposition when words are presented in isolation. The present fast priming experiment consists of a variation of

masked priming that is sensitive to semantic effects. However, it is clear from the current data that morphological priming effects are not apparent within a sentence context using this paradigm. Additionally, the semantic relationship between the free stem target word and its stem failed to benefit subsequent word processing. Thus, no evidence for morphological priming was found for prefixed over pseudo-prefixed words regardless of orthographic transparency or semantic consistency.

It is possible that semantic priming was not observed for the stem of free stem prefixed words because participants were not sufficiently sensitive to the semantic relationship between the stem and the whole word. However, semantic priming was observed within the filler stimuli, which directly tested for semantic priming. Thus, the readers were sensitive to the semantic relationship between the prime and target words.

The failure to find evidence of semantic priming for the prefixed word stimuli suggests that morphological and semantic priming are distinct. Within the morphological priming stimuli, the priming effect was most likely orthographic. There was no evidence that morphological constituents (within prefixed words) benefit subsequent word processing from a foveal prime during sentence comprehension. The prefixed words did not differ from pseudo-prefixed words. Further, there was no difference in the degree of priming acquired from the prefix-only and stem-only prime types indicating that the facilitation was not influenced by the amount of information available from the partial prime types. These results are consistent with the parafoveal preview benefit experiments (Experiments 1 & 2) with the identical condition demonstrating the highest degree of facilitation in the foveal priming (and parafoveal preview) experiment(s) followed by an equivalent amount of facilitation resulting from the two partial prime types, suggesting

that readers are sensitive to the degree to which the information overlaps between the prime and target word.

CHAPTER V

GENERAL DISCUSSION

In the introduction two major issues were presented with respect to morphologically complex (prefixed) words. The first issue was whether morphological decomposition is evident during sentence processing, and the second issue focused on the differences between parafoveal and foveal processing. In three experiments, no evidence was found to indicate that morphologically complex (prefixed) words were being decomposed during sentence processing. Reading times on prefixed words were not facilitated by a parafoveal preview or a brief foveal prime of the morphological constituents. The consistency of the data in all three experiments suggests that, at least for prefixed words, effects of morphological decomposition are 1) unavailable or 2) obscured during sentence processing (discussed below). As a result, no distinction can be made with respect to parafoveal and foveal processing of prefixed words from the current experiments.

While effects of morphological decomposition for prefixed words were not observed in the current studies, there were some interesting effects relating to the characteristics of the parafoveal preview. Experiments 1 and 2 demonstrated that when partial word information was available in the parafovea, reading times were facilitated. The largest parafoveal preview benefit was observed in the identical preview condition as indicated by faster reading times when the entire word was available. However, there was no difference in the amount of facilitation resulting from the prefix-only (consisting of 1-3 letters) or stem-only (consisting of 2-5 letters) preview conditions. The partial preview conditions demonstrated equivalent amounts of facilitation on subsequent word

processing, suggesting that readers are benefited by information at both the beginning and the end of a word. Consequently, the additional preview benefit observed in the identical condition does not appear to be directly related to the amount of information available for preprocessing, as more information was available at the end of the word than the beginning of the word in the partial preview conditions.

Inhoff (1989b) proposed that the additional facilitation found for the identical condition occurs because word initial letters act in concert with word final letters, mutually reinforcing each other resulting in the cumulative preview benefit observed in the identical condition. The results of the parafoveal preview experiments discussed above are consistent with this proposal. However, there was some indication that the characteristics of the parafoveal preview affected the preview benefit acquired by the reader, particularly when the eyes were further away from the target word. While the interaction was not significant, in Experiment 1, when the masking letters were visually similar to the target word letters, there was a trend in the data suggesting that the preview benefit observed differed according to the location of the eye to the target word. Preview benefit was equivalent for the beginning and ending letters of the word when the prior fixation was near the target word (1-4 characters), and parafoveal preview benefit was greater for word initial letters than word final letters when the prior fixation was distant from the target word (5-10 characters). On the other hand, in Experiment 2, when the masking letters were visually distinct from the target word letters, the beginning and ending letters (in the prefix-only and stem-only preview condition) equally facilitated subsequent word processing despite the location of the prior fixation (1-10 characters). However, less preview benefit was observed for the identical condition in the far versus

the near condition. In Experiment 2, the masking letters consisted of capital X's which are quite distinct. Apparently this distinction is available and able to be utilized in the parafovea.

The data in Experiments 1 and 2 are consistent with the Inhoff 's (1989a, 1989b, 1990; Briihl & Inhoff, 1995; Lima & Inhoff, 1985; Inhoff & Tousman, 1990) findings in three ways. First, parafoveal preview benefit was greatest when the entire word was available in the parafovea, suggesting that all of the letters of a to-be-identified word contribute to its identification. Second, the combined preview benefit found for the beginning and ending letter conditions did not equal the preview benefit found in the identical condition, suggesting that the parafoveal preview benefit obtained in the identical condition is lexical. Third, characteristics of the masking letters in the partial preview conditions interacted with the preview benefit observed. When the masking letters are visually distinct from the target word letters (capital X's), preview benefit is greater for beginning and ending letters. When the masking letters were visually similar, the location of the fixation prior to landing on the target word interacts with the amount of parafoveal preview benefit observed. When the prior fixation was near the target word location (1-4 character spaces) then preview benefit was equivalent for the prefix-only and stem-only partial preview conditions. When the prior fixation was far from the target word location (5-10 character spaces), beginning letters demonstrate more preview benefit than word final letters with the most preview benefit observed for the identical condition.

Inhoff (1990) consistently observed greater parafoveal preview benefit for word initial as opposed to word final letters even when reading from right-to-left. In his

experiments, the number of word initial and word final letters was equivalent (each consisting of 3 characters). The partial preview conditions in Experiments 1 and 2, differed with a higher average number of letters appearing in the stem-only condition as opposed to the prefix-only preview condition. It is possible that this difference in number of letters available for preprocessing in the parafovea was affected by their location (word initial versus word final) resulting in a trade-off in preview benefit. Fewer letters presented word initially resulted in the same preview benefit as more letters presented in a word final position. In Experiments 1 and 2, reading times did not differ between the partial preview conditions such that the availability of word initial and word final letters in the parafovea equally benefited subsequent word processing. However, this was also true of Experiment 3 in which the partial preview conditions were presented as brief foveal primes. While the trade-off hypothesis deserves further exploration, it would still have to account for the fact that foveal primes of partial previews consisting of differing numbers of letters failed to result in the difference in preview benefit such a hypothesis would predict. Thus, while Inhoff and colleagues (Briehl & Inhoff, 1995; Lima & Inhoff, 1985; Inhoff, 1989a, 1989b, 1990; Inhoff & Tousman, 1990) argue that word initial letters play a more significant role in word the identification process, Experiments 1 and 2 (above) suggest that the beginning and ending letter partial preview conditions equally benefit subsequent word processing.

In Experiment 3, the largest priming effect was observed in the identical condition. Reading times were also facilitated after a prefix-only or a stem-only prime. However, there was no difference in the amount of priming resulting from the partial preview conditions suggesting that the priming effect was not a function of the number of

overlapping letters. Further, prefixed words did not demonstrate an advantage over pseudo-prefixed words, indicating that the priming effect observed was orthographic, and not based on morphological factors. However, the issue of form priming should be addressed.

Previous research examining the effect of form priming has utilized the masked priming paradigm. Research using this technique (Colombo, 1986; Humphreys, Evett, Quinlan, & Besner, 1987; Forster, 1987; Forster & Veras, 1998; Veras, 1986) indicates that priming effects are obtained when the relationship between the prime and the target word is based on form rather than meaning. Studies successfully demonstrating form priming usually prime the target word with a prime word (or non word) that differs by one or two letters. When the prime word (or non word) contains more than two non-overlapping (but similarly shaped) letters then the prime fails to facilitate subsequent word processing.

In Experiment 3, overlapping and similarly shaped letter strings were used to prime the target word. The form of the prime was always relatively consistent with the form of the target word. While the control prime condition was comprised of orthographically similar letter strings, there was no orthographic overlap. Thus, it is not surprising that no form priming occurred in this condition. However, the partial preview conditions were comprised of a combination of overlapping and similarly shaped letters. Similar to Forster and Veras (1998), the partial prime conditions showed facilitation due to form priming, which was less than that obtained for the identical condition. However, the number of overlapping letters was not a factor in determining the amount of priming observed in the two partial preview conditions as form priming was found for both partial

preview conditions. At brief prime durations, form priming was evident even when as many as four non-overlapping, similarly shaped letters were used to prime the target word during sentence processing.

Morphological versus Semantic Priming Effects

Across all three experiments, there was no indication that morphologically complex (prefixed) words are being decomposed within a sentence context. Reading times did not differ for the prefixed and pseudo-prefixed words. Further, readers were not benefited by having morphological constituents available for preprocessing: 1) in the parafovea or 2) as a brief foveal prime. Previous research (Lima, 1987) examining whether morphological constituents in the parafovea would benefit subsequent word processing during reading indicated that this was unlikely. However, problems with the materials in that study indicated that another look at the issue was warranted. The data from Experiments 1 and 2 (parafoveal preview) are consistent with Lima's (1987) results, which fail to provide evidence that morphological processing begins in the parafovea. Despite the fact that morphological constituents available in the parafovea failed to facilitate subsequent word processing, morphological priming has been found previously (when studying words in isolation) when the prime was presented foveally. Thus, evidence of morphological priming was expected in the foveal fast priming experiment.

Morphological priming has been found for prefixed words when tested in isolation (Forster and Azuma, 2000; Frost, Forster, & Deutsch 1997; Marslen-Wilson et al., 1994; Rastle, et al., 2000). For example, Marslen-Wilson et al. (1994) found evidence of morphological priming for semantically and orthographically transparent prefixed words (words in which the relation between the meaning of the stem and whole word is

transparent: *refill*), but not for semantically and orthographically opaque prefixed words (words in which the semantic relation between the stem and whole is not transparent – orthographically and/or semantically: *return*, *reduce*). Marslen-Wilson argued that the semantic relationship between the stem and whole word form are critical for morphological priming to occur. According to this hypothesis, it is the semantic nature of the morphological constituent that is causing the priming effect. Forster and Azuma (2000; Frost, Forster, & Deutsch 1997), on the other hand, found the same magnitude of priming for bound and free stem (semantically transparent and opaque) prefixed words. In a series of masked priming studies, they concluded that semantic transparency was not necessary to demonstrate morphological priming. Thus, the semantic component of the morpheme is irrelevant to the priming effect obtained.

In Experiment 3 (fast priming), there was also no evidence for semantic or morphological priming. The priming effect found was entirely orthographic. However, evidence of semantic priming for a morphological constituent was expected (but did not occur) for the free stem prefixed words following a stem-only prime. There are three possible explanations for failing to obtain semantic priming effects from a word-like morphological prime for the free stem prefixed words: 1) participants were not sensitive to the semantic relationship between the prefix and the stem, 2) a lack of semantic transparency, or 3) semantic priming is distinct from morphological priming.

In Experiment 3, filler sentences were used as a verification task to ensure that participants were sensitive to the semantic relation between the prime and target word. The filler items were an exact replication of the semantic priming stimuli reported in Sereno and Rayner (1992). Data from these items indicated that participants were

sensitive to the semantic relationship between the prime and the target word, suggesting that the failure to find evidence of semantic or morphological priming with the prefixed words was not due to a lack of sensitivity.

The second reason semantic priming effects were not observed when a free stem prefixed word was primed by its stem may have been related to semantic transparency. Even though the free stem prefixed words contained roots that were semantically consistent with the whole word meaning, semantic transparency was not controlled in the present study. However, it seems unlikely that such a direct overlap in meaning is necessary when previous fast priming studies have found evidence of semantic priming when the prime words have been synonyms, antonyms, and word associates of the target word (Lee, et al., 1999; Sereno & Rayner, 1992; Sereno, 1995). However, in Marslen-Wilson et al. (1994), Forster and Azuma (2000), and Frost et al., (1997) studies, the stem was used to prime free stem prefixed words (e.g. *view* primed *review*). In the present study, the stem-only condition contained consonant letter strings in the prefix letter positions (e.g. *cmview* primed *review*). This difference in prime conditions is most likely responsible for the difference in findings. The additional letters might have interfered with lexical access of the stem masking the semantic relationship between the morphological prime and target word.

However, the critical issue is not whether semantic priming was found for a particular type of morpheme, but whether or not there is evidence of morphological priming during sentence processing. It is important to remember that the semantic priming effect resulting from the relationship between the free stem prefixed word and its stem is not a pure semantic effect, but a morphological effect. The stem of a prefixed

word is a morpheme, regardless of whether it stands alone as a word or maintains a transparent semantic relationship with the whole word form. While Marslen-Wilson et al. (1994) only obtained morphological priming effects for semantically transparent free stem prefixed words, Forster and Azuma (2000; Forster et al., 1997) did not find semantic transparency necessary to obtain morphological priming effects.

In Experiment 3, the fast priming manipulation provided no evidence of morphological priming. Further, semantic priming effects were not obtained for word-like morphological constituents. This finding is substantiated by the fact that the priming effect did not interact with prime duration. Semantic priming effects are generally found at the 32 ms prime duration, yet no additional facilitation was observed for this prime duration. The results of the morphological fast priming study indicates that morphological priming is not governed by the semantic component of the morpheme and that morphology is a unique level of linguistic representation.

English (Prefixed Word) Morphology

When morphologically complex (prefixed) words are presented in isolation, morphological constituents successfully prime whole word forms. To date, it appears to be the case that when prefixed words are placed within a sentence context, morphological effects disappear. Reading times do not differ between prefixed and pseudo-prefixed words matched on length and frequency following a preview or prime containing a morphological constituent. Thus, it appears that sentential context may obscure facilitation effects resulting from morphological constituents. However, this effect may be specific to English prefixed words. Niswander, Pollatsek, and Rayner (2000) placed derived and inflected suffixed words within a sentence context and manipulated whole

word and stem frequency. They found both whole word and stem frequency effects in first fixation duration, indicating that both the whole word form and the stem morpheme play a role in word processing.

Niswander, Pollatsek and Rayner (2001) have recently conducted a similar study where whole word and stem frequency were manipulated for semantically transparent free stem prefixed words. This is a specific and distinct subsection of the types of prefixed words that exist, but it is possible that initial processing measures will again reflect frequency effects in the stem morpheme for that type of word. However, in Experiments 1-3, whole word frequency was held constant for all word types and stem morpheme frequency was not manipulated. Further, when comparing types of prefixed words to each other and to pseudo-prefixed words, initial fixation durations did not differ despite the fact that the stem of a free stem prefixed word is more frequent and recognizable than the stems for the other word types. Free stem prefixed words were not more likely to be decomposed into their constituent morphemes. Thus, the data from Experiments 1-3 suggest that processing was based on the whole word form for all word types. A manipulation of stem frequency should be undertaken to ascertain whether evidence of morphological decomposition would be obtained with lower frequent stem morphemes in free stem prefixed words as compared to bound stem prefixed words.

The data reported in this dissertation indicate that the morphological constituents of the prefixed words did not benefit preprocessing after a parafoveal preview or a foveal prime. When semantic transparency and stem frequency are taken into account, effects of morphological decomposition may be apparent during sentence processing. However, for all other prefixed word types, evidence of morphological decomposition during sentence

processing appears to be 1) obscured by sentence context or 2) not occurring for all types of prefixed words. Future research is necessary to distinguish between these two hypotheses.

Generalizability of the Present Results

Research on prefixed words in isolation indicates that morphology can play a role in lexical access via morphological decomposition. Further, evidence of morphological decomposition during sentence processing has been found for suffixed and compound words in English. Clearly, not all morphologically complex words behave in the same manner. Both compound and suffixed words in the English language tend to be more productive. Prefixed words in the English language tend to be less productive and more idiosyncratic. For example, when new words or derivations of words develop in English, they tend to be predominantly through the addition of a suffix. Prefixes are added to the English lexicon at a slower rate than suffixed or compound words. For the current study, individuals were asked to rate whether a series of words were prefixed or pseudo-prefixed words. Over 2/3 of the total word list were miscategorized as being pseudo-prefixed, despite the fact that they could define the various prefixes and recognized the fact that the stems could be combined with other prefixes to form new words. This suggests that prefixes and their stems are generally not stored as separate lexical entries in the English lexicon. The association between the prefix and stem to derive the meaning of a prefixed word seems to have been replaced by a separate lexical entry for the whole word. This is in contrast to languages such as Finnish and Hebrew where morphological derivations are consistent, regular, and productive.

In Finnish, compound words are extremely common and productive. Similar to German, compounding is a constructive way to create new words (Hyona & Pollatsek, 1998) out of existing morphological constituents. The morphemes comprising Finnish compound words affect oculomotor behavior and word processing measures. Research on Finnish compounds words (Hyona & Pollatsek, 1998; Pollatsek, Hyona, & Bertram, 2000; Hyona & Pollatsek, 2000; Bertram, Hyona, & Laine, 2000) has revealed clear effects of morphological decomposition for words in isolation and within sentence contexts, suggesting that morphology plays an important role in the organization of the Finnish lexicon. In fact, syntactic cues have been shown to prime the inflected reading of nouns with ambiguous endings (Bertram et al., 2000). Thus, Finnish morphology appears to play a more significant role in word processing than English morphology.

In Hebrew, words are decomposed into their constituent parts during word processing, to the extent that one of the proposed routes to lexical access is via morphemes (Deutsch et al., 1998; Frost et al., 2000; etc.). If morphology is a potential route to lexical access, then the morphology must play a significant role in the organization of the Hebrew lexicon. Morphological effects in Hebrew are robust both in isolation and during sentence processing (Deutsch & Rayner, 1999; Deutsch, Frost, Pollatsek, & Rayner, 2001; Frost et al., 2000; Deutsch et al., 1998). In fact, recent research by Deutsch, et al. (2001) demonstrates parafoveal preview benefit for Hebrew words that share the derivational unit of the stem during sentence processing. Deutsch et al. (2001) conducted a parafoveal display change experiment in which the parafoveal previews consisted of words derived from the same stem as the foveal target word (instead of the stem letters alone). They found a significant morphological preview effect

for words that did not share initial letters in first fixation and gaze duration reading times, suggesting that morphological units mediate word identification in Hebrew.

English morphology is not as rich as Finnish or Hebrew morphology and plays a less significant role in word identification. The research reported in this dissertation provides additional evidence to indicate that morphological preprocessing is not evident during sentence processing for English prefixed words after: 1) a parafoveal preview, or 2) a foveal prime. Languages such as English make relatively limited use of morphology (see Plaut & Gonnerman, 2000, for a discussion) in contrast to Hebrew and Finnish, which are full of structurally (and morphologically) complex words. Languages rich in morphology tend to have stricter and more regular rules governing derivational processes. Languages such as English are more irregular and contain many exceptions to the rules of the grammar. As a result, theories of morphological decomposition must be able to account for the differences in morphological complexity both across and within languages for the various types of morphologically complex words.

APPENDIX

EXPERIMENTAL MATERIALS

Target word information

Pseudo-Prefixed	Word Length	Freq- uency		Bound Stem Prefixed	Word Length	Freq- uency		Free Stem Prefixed	Word Length	Freq- uency
access	6	0		Accuse	6	45		account	7	120
adopt	5	71		Admire	6	32		adjust	6	62
adorn	5	3		Admit	5	91		adverb	6	3
alarm	5	15		Adore	5	5		aloud	5	13
adult	5	1		Align	5	9		alone	5	8
aloof	5	2		Afraid	6	57		conform	7	18
conquer	7	10		Alert	5	25		dislike	7	22
condor	6	0		Confess	7	25		refill	5	0
decal	5	0		Dispute	7	37		alike	5	6
demon	5	17		Entice	6	1		retry	5	0
exude	5	2		Debate	6	36		unrest	6	5
demure	6	3		Immune	6	0		insane	6	13
defer	5	3		Imply	5	53		inbred	6	0
extinct	7	1		Dismal	6	8		detour	6	1
enter	5	213		Demand	6	92		exclaim	7	20
exempt	6	4		Explode	7	22		immoral	7	5
exert	5	29		Excess	6	19		enjoy	5	128
exist	5	202		Endow	5	10		inland	6	1
exploit	7	18		Expert	6	11		enrage	6	1
extra	5	48		Reply	5	35		react	5	32
inane	5	1		Excuse	6	23		import	6	0
missile	7	0		Infect	6	5		implant	7	1
protein	7	35		Innate	6	13		unreal	6	6
receipt	7	11		Incline	7	4		misuse	6	2
resist	6	36		Mishap	6	4		profile	7	18
recess	6	1		Request	7	54		review	6	52
regal	5	2		Repeat	6	95		remove	6	146
region	6	119		Refrain	7	7		resale	6	2
regret	6	0		Inept	5	2		unfit	5	1
remote	6	32		Result	6	329		return	6	232
relief	6	66		Export	6	19		reform	6	41
uncle	5	58		Recede	6	10		reborn	6	23
under	5	1		Until	5	125		inside	6	81
index	5	89		Reject	6	58		remind	6	57
engine	6	69		Infant	6	14		enrich	6	8
disco	5	0		Excel	5	2		repay	5	10
Total:	203	1162			212	1377			214	1138
Average:	5.64	32.28			5.89	38.25			5.94	31.61

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