

## Morphological parafoveal preview benefit effects in reading: Evidence from Hebrew

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Hebrew words are composed of two interwoven morphemes: a three-consonantal root and a word-pattern (a nominal or a verbal pattern). Previous research has revealed that a parafoveal preview of a word derived from the same root morpheme as the foveal target word facilitated first-pass reading (as indexed by first fixation duration and gaze duration). In the current study we extended our research on parafoveal preview effects to other derivational morphemes in Hebrew and also examined whether context has an influence on these early morphological effects. We found that a parafoveal preview which had a common verbal pattern with a target word facilitated processing, but a preview with a common nominal pattern did not. These results are similar to previous results obtained using the masked priming paradigm with single words, and suggest that masked priming and parafoveal preview tap similar cognitive processes in word recognition. Furthermore, a preview of a verbal form (that was syntactically incongruent with the prior sentence context) inhibited the identification of a nominal form. However, biasing semantic context did not affect the first-pass reading time for target words which were previewed by a word derived from the same root. These results suggest that morphological information extracted from the parafovea in the initial phases of word recognition in Hebrew may be affected by syntactic contextual processes.

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The identification of morphologically complex words has usually been investigated in the context of studies of single-word identification. A typical experiment involves making responses to target words (either a naming or lexical decision response), and morphological processing is probed by presenting primes that are either morphologically related or unrelated to the target word. Morphological involvement in the encoding of the target is inferred if there is greater priming from a morphologically related prime than from an unrelated control prime when the primes are equated on a number of attributes (such as orthographic and/or phonological similarity to the target). This paradigm has provided substantial evidence, that component morphemes are involved in the encoding of morphologically complex words (Taft & Forster, 1975 in English; Laudana, Cermele, & Caramazza, 1997 in Italian; Grainger, Cole, & Segui, 1991 in French; Drews & Zwitserlood, 1995 in German and Dutch; Frost, Forster, & Deutsch, 1997 in Hebrew; Boudelaa & Marslen-Wilson, in Arabic 2001).

The priming paradigm has been generally employed in tasks that involve the identification of isolated words. However, readers usually do not encounter isolated words. Words are usually identified when people read text, which involves the rapid, on-line integration of the words into syntactic structures and semantic representations of discourse (Rayner & Pollatsek, 1989). Indeed, a fundamental question in research on word recognition concerns the role of sentential context in the process of word recognition—whether higher level contextual information can interact with lexical processes of word identification, or whether sentential effects are restricted to post-lexical phases of lexical selection and sentence integration. This question is especially important in investigating the involvement of morphological factors in the process of word recognition because the semantic and grammatical characteristics of words are related to their morphological structure. As a result, the on-line processes of syntactic parsing and sentence integration may influence the morphological analysis of an upcoming word during reading. Accordingly, it seems important to determine the role of morphemes in the process of word identification in conditions that mimic natural reading as closely as possible, namely in identifying morphologically complex words within sentential context. Thus, an important challenge for research that deals with the process of morphological decomposition during word identification is to find an experimental setting that reflects early processes of lexical access but is also sensitive to other on-line contextual factors that may affect lexical access.

Much of the evidence for early morphological decomposition occurring during single-word identification is based on priming under masked presentations. These include findings in various Indo-European languages

(Dutch: Drews & Zwitserlood, 1995; English: Forster & Azuma, 2000, Rastle, Davis, Marslen-Wilson, & Tyler, 2000, but see Masson & Isaak, 1999; French: Grainger et al., 1991; German: Drews & Zwitserlood, 1995), as well as in Hebrew, in which all derivational morphemes have been studied (Frost et al., 1997; Frost, Deutsch, & Forster, 2000; Deutsch, Frost, & Forster, 1998). The masked-priming paradigm is particularly useful for exploring early processes of word recognition because the brief presentation of the prime combined with forward and backward masking prevents the full conscious identification of the prime. Consequently, the priming effect obtained in this procedure is not influenced by the participants' appreciation of the prime-target morphological relation, as is the case with some long-term morphological priming effects. However, for technical reasons, this procedure has not been applied to investigating word recognition within sentential context.

Recently, converging evidence for morphological decomposition was obtained in Hebrew by measuring preview benefit effects induced by presenting morphological information in the parafovea. This effect was demonstrated both in single-word identification tasks (Deutsch, Frost, Pollatsek, & Rayner, 2000) and when people (silently) read sentences (Deutsch, Frost, Pelleg, Pollatsek, & Rayner, 2003). In particular, it was found that the parafoveal presentation of a letter string derived from the same root morpheme as the foveal target word shortened the processing time of the word when it was later fixated. As this method reveals early processes of word recognition on the one hand, and can be applied for identifying words in sentential context on the other hand, we made use of this methodology in the present research. We will briefly discuss the results of research using the masked priming and the parafoveal preview paradigm in the domain of morphology and will focus on findings obtained in Hebrew. First, however, we provide some general information regarding Hebrew morphology.

### BASIC FEATURES OF HEBREW DERIVATIONAL MORPHOLOGY

In Hebrew, as in other Semitic languages, all verbs and the vast majority of nouns and adjectives consist of two basic derivational morphemes: (a) the root, and (b) either a nominal or verbal pattern. The root usually consists of three consonants, while the word-pattern consists of either vowels or a mixture of vowels and consonants. Whereas the root usually carries the core semantic meaning of the word, the word-pattern defines its word-class and other grammatical characteristics, such as gender, the verb's mode (active or passive) and the verb's transitivity. Thus, the specific meaning of a word is determined by both the root and the word-pattern. It should be

noted, however, that even though the word-pattern shapes the meaning of the root for any specific word, the exact meaning of a word cannot be unequivocally predicted by considering its constituent morphemes (the root and the word-pattern) independently. This semantic fuzziness is much greater for the more than 100 word-patterns in the nominal system than for the verbal system, which contains only seven word patterns in Modern Hebrew (see Deutsch et al., 1998, for a more detailed description).

A fundamental feature of derivational morphology of Semitic languages is the non-concatenated manner in which the two derivational morphemes are interwoven to form words. For example, the root *xbr* (meaning 'to assemble') may intertwine with the nominal pattern *ma - - e - et* (a feminine nominal form) to form the word /*maxberet*/ ('notebook') or with the word-pattern *ta - - i -* (a nominal masculine form) to form the word /*taxbir*/ ('syntax'). The same principle also applies to conjugations in the verbal system: the root *xbr* may intertwine with the verbal pattern *i - - e -* (an active verbal form) to form the word /*xibber*/,<sup>1</sup> a causative transitive verb ('he combined'), or with the verbal-pattern *- u - - a -* (a passive form) to form the word /*xubbar*/ ('was combined').

This nonlinear structure often obscures the phonological and orthographic transparency of the two constituent morphemes as two independent units. Furthermore, the position of the root and the word-pattern letters within the orthographic sequence of a word is not fixed, and depends on the structure of the word-pattern. For instance, in the above examples, whereas the root consonants, *xbr*, constitute the second, third, and fourth letters within the five-letter word *mxbrt*, /*maxberet*/, they constitute the second, third, and fifth letters in the five-letter word *txbyr* pronounced as /*taxbir*/. (In unpointed Hebrew script, which is the common way of writing, the vowel marks are often omitted from print, except for some vowels which are sometimes denoted by 'vowel letters', such as the letter 'y' for the vowel /i/ in the word *taxbyr*. The same 'vowel letters', however, may represent consonants in other contexts.) Thus, unlike concatenated linear morphological systems, Hebrew morphemes are not spatially contiguous.

### MORPHOLOGICAL DECOMPOSITION IN HEBREW WITH THE MASKED PRIMING PARADIGM

Previous experiments in Hebrew that used the masked priming procedure have consistently obtained two principal findings. First, there is a robust priming effect induced by the root morpheme. One way this was

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<sup>1</sup> The double b represents germination of the second consonant of the root.

demonstrated was using the isolated root as the prime. These root primes facilitated lexical decision and naming of nouns and verbs derived from them, both in the nominal and verbal systems (Deutsch et al., 1998; Frost et al., 1997). Another way this was demonstrated was by using primes derived from the same root as the target. In this paradigm, a similar pattern of facilitation was observed even though the root was not presented explicitly as a unit in the prime. Furthermore, this facilitation was found to be independent of semantic transparency (Deutsch et al., 1998; Frost et al., 1997). Second, there was a robust priming effect induced by verbal patterns (Deutsch et al., 1998), whereas no priming was obtained for nominal patterns (Frost et al., 1997). Thus, even though word patterns are basically the same types of morphological unit in the nominal and verbal systems, the two types of patterns seem to have a different role in lexical organisation and in lexical access.

In an attempt to explain these differences, we (Deutsch et al., 1998; Deutsch & Frost, 2003; Frost et al., 2000) have suggested that they stem from differences in the specific linguistic characteristics of the nominal and the verbal patterns. Whereas there are only seven different verbal patterns in Hebrew, there are more than 100 different nominal patterns into which any root can be embedded to form a noun or an adjective. Furthermore, each conjugated verbal form must be derived using one of the verbal patterns, whereas there are numerous examples of foreign nouns in Hebrew which are used in the language almost in their original form. Consequently, for most cases, any verbal pattern appears much more frequently than any nominal pattern. Another difference between the nominal and the verbal patterns concerns the linguistic information they convey. First, a verbal pattern conveys grammatical information beyond identifying the word as a verb (such as active/passive mode) which is important for syntactic analysis. In addition, the variation in the meaning conveyed by any specific nominal pattern is usually much higher than any specific verbal pattern. In sum, verbal patterns have both the advantage of being more frequent in the language and conveying more semantic and grammatical information than nominal patterns. Our findings thus suggest that the role of a given morpheme in mediating lexical access may reflect a fine tuning among the morpheme's distributional properties, semantic transparency, syntactic role, and structural properties.

### PARAFOVEAL PREVIEW BENEFIT EFFECTS

A good procedure for monitoring the early processes of lexical access that is similar to masked priming, is measuring how the information extracted from a word before the eyes land on it affects the identification of that word. We will refer to this information as parafoveal because this

information is typically about 5–10 characters from fixation and thus is near, but not in, the foveal region. A large body of research on eye movements in reading (see Rayner, 1998, for a review) has revealed that although the perceptual span from which readers extract information is small, it is not restricted to the fixated word, and readers can extract information from the next word or two. The common finding is that reading is significantly slowed if the parafoveal information about the word to the right of the fixated word is withheld. In addition, the perceptual span is asymmetric, being extended further to the right of the fixation point when reading from left to right and to the left when reading from right to left (Pollatsek, Bolozy, Well, & Rayner, 1981). This asymmetry is probably due to an attentional shift from the currently fixated word to the following words in the text, before the initiation of the actual eye movement (Morrison, 1984; Reichle, Pollatsek, Fisher, & Rayner, 1998). Subsequent experiments have attempted to discover, in more detail, what kind of information is extracted from a word before it is fixated, and how this information is combined with the information extracted when the word is fixated.

A detailed assessment of the benefit from a parafoveal preview can be provided using the boundary technique (Rayner, 1975). This technique involves rapidly changing a single word during the saccade in which the eyes move to fixate the word. (The display change is triggered when the eyes cross an invisible boundary just prior to the target word.) An important feature of the boundary technique is that readers are virtually unaware of the display change, and are also unable to identify the stimulus in the parafovea. Nevertheless, the parafoveal information is apparently integrated with the subsequent activation of the foveal word, as parafoveal information was found to facilitate the identification of the foveal target word (Rayner, McConkie, & Zola, 1980). Using the boundary technique, it has been shown that both orthographic (Inhoff, 1989b; Rayner, Well, Pollatsek, & Bertera, 1982) and phonological information (Henderson, Dixon, Peterson, Twilley, & Ferreira, 1995; Pollatsek, Lesch, Morris, & Rayner, 1992) are extracted from the parafovea, while the exact visual shape of the letters is irrelevant (i.e., whether the case of the letter in the parafovea matches the case of the letter when fixated; Rayner et al., 1980). The explanation for parafoveal benefit resembles the one for masked priming effects: information extracted from the parafovea causes partial activation of the lexicon, and this activation is integrated with the later activation due to accessing information from the foveal word (Rayner, 1998; and see Forster & Davis 1984, for masked priming).

When preview benefit is assessed during sentence reading, the fixation time on the target word is the primary dependent measure. Thus, participants are not required to perform any external task aside from

naturally reading the text. This procedure has three fundamental advantages in studying word identification in reading. First, it is based on a natural phenomenon that takes place in reading (extracting information from the parafovea), and therefore does not require the introduction of additional experimental procedures that affect the visual system, such as masking. Second, the dependent variable, fixation duration, registers an inherent element of the reading process, rather than being based on the reaction time to specific artificial tasks external to the process of reading. Furthermore, because a word is often fixated more than once, this procedure makes it possible to monitor the time course of lexical processing. Finally, since the target word is embedded in a sentential context, it is possible to manipulate contextual factors and assess their effects on the early on-line processes of word identification.

Interestingly, only a few studies have manipulated morphological factors in the parafovea while measuring preview effects. These consist of a few studies in English (Inhoff, 1989a; Kambe, 2004; Lima, 1987) and Hebrew (Deutsch et al., 2000, 2003). The studies in English used previews that shared a morpheme with the target word and found no greater benefit from these previews than from control previews that shared as many letters with the target (in the same positions) as the morphemic previews. However, in contrast to the findings in English, consistent morphemic effects have been obtained in Hebrew. Deutsch et al. (2003) demonstrated that a preview of a word derived from the same root morpheme as the foveal target word shortened processing of the target word, compared with a preview that was as orthographically similar to the target as the morphemic preview. (The measure employed in this study was *gaze duration*, the sum of the durations of all fixations made on a target word from the first time the reader's eyes land on the word until the eyes move to preceding or following parts of the sentence.) These results replicated previous results observed for single-word identification in the masked priming paradigm in Hebrew (Frost et al., 1997), with one interesting exception. Whereas an identical prime always provided the most priming in single-word identification reaction time paradigms using masked priming, a preview containing the same root morpheme provided as much preview benefit as an identical prime in the reading studies.

## THE PRESENT RESEARCH

The Deutsch et al. (2000, 2003) studies that used parafoveal preview to assess morphological processing in Hebrew examined only the root morpheme. The present study extends our investigation by examining morphological preview benefit for all other derivational morphemes, thereby providing a more complete picture of early morphological

processes in reading Hebrew. The first part of our study assessed the effects of parafoveal previews of the verbal pattern (Experiment 1) and the nominal pattern (Experiment 2). Consistent with our previous research on the root morpheme (Deutsch et al., 2003), we kept the semantic context of the sentences neutral in these two experiments, manipulating only the morphological relatedness of the preview. The second aim of our study was to examine whether morphological processing during word recognition, which presumably involves the semantic and the syntactic role of the word, is affected by contextual information in reading. This is related to the more general issue of the role of contextual processes in word recognition. That is, if contextual processes actually affect lexical access (rather than influencing post-lexical processes), they are likely to interact with any morphological parafoveal preview effects that are observed. Thus, in the second part of the present study, we investigated the interaction between early morphological effects and contextual processes in the semantic (Experiment 3) and syntactic (Experiment 4) domains. The use of parafoveal preview benefit to assess possible interactions between contextual effects and the early processes of lexical access is possible since the gaze duration (i.e., first-pass time) on the target word can reflect not only aspects of the word in isolation (such as its frequency), but also the influence of prior context, such as its predictability from the prior text (Rayner & Pollatsek, 1989). Given that the root mainly carries semantic information, while the verbal pattern contains the grammatical information relevant to syntactic processes, we manipulated contextual effects in the semantic domain with respect to the root morpheme, and contextual syntactic effects with respect to the verbal-pattern morpheme.

## EXPERIMENT 1

The aim of Experiment 1 was to examine whether a parafoveal preview of a verbal pattern can facilitate the encoding of a verb conjugated with this pattern. In line with the facilitation effects obtained for the root in masked priming and parafoveal preview experiments (Frost et al., 1997; Deutsch et al., 2003), we expected a morphological preview benefit effect to be induced by a verbal-pattern preview similar to the verbal-pattern effect observed in masked priming (Deutsch et al., 1998). As with the masked priming study, we employed three experimental conditions: (1) an identical condition—the parafoveal preview was identical to the foveal target word; (2) a morphologically related condition—the parafoveal preview and the foveal target words were two verbs conjugated with the same verbal pattern, but with a different root; (3) an orthographic control condition—the parafoveal preview and the foveal target words were two verbs with the same number of shared letters as in the morphologically related condition,

but with different verbal patterns and with different roots. In all conditions, previews and targets had the same number of letters. Facilitation in both the related and the identical conditions was assessed relative to the orthographic control condition.

As indicated above, in this experiment we attempted to keep the semantic context of the sentences neutral, manipulating only the morphological relatedness of the preview and target. Thus, the foveal targets were coherent with the semantic context of the sentence, but neither had a close semantic relation to any of the preceding words, nor formed a highly predictable continuation of the preceding part of the sentence.

The primary dependent variables employed for assessing the effects of a morphologically related preview in all the reported experiments were the following two first-pass reading-time measures: (1) the *first fixation duration* on the target word (this includes first fixations that are the only fixation on the target word and those that are followed by a refixation on the target word), and (2) the *gaze duration* on the target word (i.e., the sum of the durations of all fixations made on a target word from the first time the reader's eyes land on the word, until the eyes move to the preceding or following parts of the sentence). Both measures are means conditional on the word being fixated; that is, a trial in which the target word was skipped was excluded from the analysis rather than counted as zero fixation time. We anticipated that if morphological information from a verb's verbal pattern is extracted from the parafovea and influences early phases of lexical access during reading, its effects would be seen in at least one of these two measures. Two other commonly used measures to assess processing of a word are *total time* (i.e., the total fixation time on the target including regressive fixations), and *second-pass time*, (i.e., the fixation time on the word after it is left for the first time).<sup>2</sup> Although these measures were also calculated, we focus on the first pass measures, since the latter measures are associated with later processes of sentence integration.

## Method

*Participants.* The participants were 36 undergraduate students at the Hebrew University. All were native speakers of Hebrew who participated in the experiment for course credit or payment. All had normal vision or wore corrective lenses.

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<sup>2</sup> The statistical analysis will be carried out only on the second pass measure, as it is a cleaner measure than total time which includes also first-pass duration.

*Stimuli and design.* There were 48 target words, all verbal forms (4–5 letters long) that were inflected on the past, singular, masculine base form. All targets were conjugated with one of three different verbal patterns. (Note that there are only seven different verbal patterns in Hebrew.) Each target word was paired with three different previews to form the identical, related, and control conditions (see Figure 1 for an example of the materials). Each target word and its two non-identical preview words were equated for length. Both the morphologically related previews and the control previews shared, on average, 2.3 letters with the target, and the shared letters in the non-identical previews and the target always appeared in the same order. However, the original position of the common letters was not necessarily preserved, except for the first or first two letters. Since most verbal patterns in Hebrew include a prefix of one or two letters, all morphological previews shared the first or the first two letters with the target. Because past research has found that the initial letters of a word have special importance in inducing parafoveal preview benefit (see Rayner, 1998), we ensured that the number and the position of the common initial letters within each triple were equated.

All the target words were embedded in sentences of 7–10 words, each of which had a simple structure of subject, predicate, and object. The sentences also included attributive phrases attached to the noun phrases of the subject and the object. Each target word was the predicate of the sentence and was the fourth or fifth word in the sentence. The target word was never the last word on a line. Another 12 filler sentences were included, in which the display change took place in a different syntactic

### Target Sentence

לאכזבת הילד המפונק התירס התבשל (hitbaʕel/) יתר על המידה

(To the disappointment of the spoiled child the corn was cooked too long)

### Preview Sentences:

#### Identical Preview Condition:

(hitbaʕel/) התבשל

#### Morphological Preview Condition:

( was impressed /hitraʕem/) התרשם

#### Orthographic Control Condition:

(started /hitxil/) התחיל

**Figure 1.** Example of the stimuli used in Experiment 1. Target and preview words are underlined.

component of the sentence (the nominal object rather than the verbal predicate). We added these filler sentences to try to prevent participants from developing special strategic process for processing the verb if they happened to see a flicker caused by the display change.

The predictability of the target word was assessed with a rating procedure. Twenty participants were asked to assess the predictability of the predicate phrase for each of the sentences given the beginning of the sentence, on a 1 (low)–7 (high) scale. In the rating procedure, another eight filler sentences (in which the verb was in the same position in the sentence but was not predictable) were added to the experimental sentences to increase the range of predictability in the list of sentences to be scored. Only sentences that scored between 3 and 6 were included in the experiment. (Sentences that had a score of 7 were not included because a highly predictable completion increases the probability of skipping the predictable word; Rayner & Well, 1996.)

The sentences were divided into three lists. Each list contained 60 sentences: 16 sentences in each of the three experimental conditions and the 12 filler sentences. The stimuli were rotated within the three conditions in each list by a Latin square design. Twelve participants were tested on each list, allowing each participant to provide data in each condition, yet avoiding stimulus repetition effects. The stimuli were ordered randomly for each subject.

*Procedure and apparatus.* Eye movements were monitored by an SR RESEARCH Ltd. (Canada) EYLINK eyetracker. The eyetracker is an infra-red video-based tracking system with two cameras (one for each eye), with two infra-red LEDs for illuminating each eye mounted on a headband (which weighs 450 g). The cameras sample pupil location at a rate of 250 Hz. The sentences were presented on a video monitor (EIZO FlexScan F56 /T) that was interfaced with a 586 computer, which in turn was interfaced with another 586 computer which was interfaced to the eyetracking system. Although viewing was binocular, only data from the right eye were used for analysis. The spatial resolution of the eyetracking system is less than half a degree. Participants were seated 57 cm from the video monitor and 1.8 characters subtended one degree of visual angle.

Each trial started with a fixation point on the right-hand side of the monitor, the location of which coincided with the location of the first letter in the sentence. Once the participant focused on the fixation point, the calibration was verified and the preview screen, which consisted of the complete sentence with one of the three preview words in the target location, was displayed. An invisible boundary was located before the last letter of the word preceding the target word. Participants were instructed to read the sentences for comprehension. When the participant's eyes

crossed the invisible boundary, the preview screen was replaced by the target screen, which was identical to the preview screen for all words except the target word (Rayner, 1975). This display change was accomplished within 16 ms, and thus always took place during the saccade. The target screen was displayed until participants finished reading the sentence and moved their eyes towards a green square at the bottom left corner of the screen. Seeing the participant's eyes fixed on the green square signalled the experimenter to bring up the next trial. Twenty-five per cent of the sentences were followed by a yes/no question to ensure that the sentences were being read for meaning. The experiment began with 9 practice sentences, which were immediately followed by the 48 experimental sentences and 12 filler sentences.

## RESULTS

All trials in which the word preceding the target word was skipped were eliminated from the analysis, as there would have been little processing of the preview on those trials. Cut-off points of 140 ms and 800 ms were used to eliminate very short or very long single fixations. Twenty-eight per cent of the total observations were excluded on the basis of these criteria. (Most were excluded because of skipping the prior word.) Separate means were calculated for each participant and each item for each of the measures: first fixation duration, gaze duration, total time, and second-pass time. For each of the four measures, outliers more than 2.5 SD above the mean (for each participant in each condition) were replaced by the cut-off value and the mean was recalculated. The same procedures were used for Experiments 2-4.

We first examined the percentage of times the target word was skipped, which would be the earliest plausible effect of the preview manipulation. As indicated in Table 1, the target words were rarely skipped, and there was little effect of the preview on the skipping rate ( $F < 1$ ). There was virtually no difference between the morphemically related and control conditions, and for some reason, the skipping rate was actually a bit lower in the identical preview condition than in the other two conditions. In contrast, for the earliest fixation measure, the first fixation duration, there was a significant effect of preview condition,  $F_1(2, 70) = 18.11$ ,  $MSE = 120$ ,  $p < .001$ ,  $F_2(2, 94) = 10.55$ ,  $MSE = 228$ ,  $p < .001$  (see Table 1). Of greatest interest in the planned comparison analysis is that the 9 ms advantage of the morphologically related condition over the orthographic control condition was significant,  $F_1(1, 35) = 8.67$ ,  $MSE = 293$ ,  $p < .01$ ,  $F_2(1, 47) = 5.13$ ,  $MSE = 479$ ,  $p < .05$ . The 7 ms difference between the identical and morphologically related conditions was also significant,  $F_1(1, 35) = 13.53$ ,  $MSE = 136$ ,  $p < .001$ ;  $F_2(1, 47) = 7.12$ ,  $MSE = 332$ ,  $p < .01$ .

TABLE 1

Percentage of time the target word was skipped and mean (and SD) of first fixation duration, gaze duration, and second-pass time (in ms) on the target word for the three preview conditions in Experiment 1

<i>Dependent variable</i>	<i>Identical preview</i>	<i>Morphologically related preview</i>	<i>Orthographic control preview</i>
Percent of trials target word was skipped	3.1%	3.7%	3.5%
First fixation duration	225 (14.7)	232 (14.6)	241 (22.5)
<b>Preview effect</b>	<b>16</b>	<b>9</b>	–
Gaze duration	274 (22.0)	279 (23.5)	295 (25.3)
<b>Preview effect</b>	<b>21</b>	<b>16</b>	–
Second pass	54 (26.7)	49 (32.0)	48 (26.3)
<b>Preview effect</b>	<b>–6</b>	<b>–1</b>	–

A similar pattern of results was found for gaze duration. There was a significant effect of preview condition,  $F_1(2, 70) = 14.61$ ,  $MSE = 288$ ,  $p < .001$ ;  $F_2(2, 94) = 9.71$ ,  $MSE = 405$ ,  $p < .001$ . The 16 ms advantage of the morphologically related preview condition over the orthographic control was significant,  $F_1(1, 35) = 14.27$ ,  $MSE = 617$ ,  $p < .001$ ,  $F_2(1, 47) = 9.62$ ,  $MSE = 819$ ,  $p < .01$ . However, the 5 ms difference between the identical and the morphologically related preview conditions was not significant,  $F_1(1, 35) = 1.56$ ,  $MSE = 607$ ,  $p > .20$ ,  $F_2(1, 47) = 1.24$ ,  $MSE = 839$ ,  $p > .20$ .

In contrast to the robust preview effects on the first pass measures, there were no significant preview effects on second pass times ( $F_s < 1$ ). Indeed, as can be seen in Table 1, the largest difference in second pass measures is that the identical condition was actually 6 ms slower than the control condition (which is implausible as a real effect), and there was only a 1 ms difference between the morphologically related and the orthographic control conditions.

## Discussion

The results of Experiment 1 demonstrated a benefit induced by presenting a parafoveal preview word that had the same verbal pattern as the target. These results replicate the morphological priming effect observed in the masked priming paradigm (Deutsch et al., 1998), but in the context of sentence reading in conditions which simulate the natural conditions of reading quite closely. Furthermore, the 16 ms parafoveal preview effect in gaze duration obtained here was similar to both the 12 ms effect obtained in masked priming and the 12 ms parafoveal preview benefit effect induced by the root morpheme (Deutsch et al., 2003). As expected, the effect was

observed in first-pass measures only. This is the same pattern that we observed in an earlier study when the parafoveal preview shared the root with the target (Deutsch et al., 2003). As this effect was early—reflecting information extracted prior to the initial fixation on the word and measured within 200–300 ms of the initial fixation on the target word—the likely locus for our morphemic preview effect is in the process of word identification.

An interesting outcome is that the effect of the morphological condition was similar to that of the identical condition. The advantage of the identical over the morphological preview reached statistical significance in first fixation duration, but not in gaze duration. This outcome is different from the clear advantage of the identical over the morphologically related condition in masked priming, but resembles the pattern in our earlier experiment using the root as the preview, where there was no advantage of the identical over the morphological condition in either of the first-pass measures. We will postpone further discussion of these results to the general discussion.

## EXPERIMENT 2

In Experiment 2, we investigated whether a parafoveal preview of a nominal pattern can facilitate the reading of nouns derived from that pattern. Thus, in the morphologically related condition, the preview and the foveal word were two nouns with the same nominal pattern but with different root morphemes. Note that in the masked priming paradigm nominal patterns did not produce any priming (Frost et al., 1997).

### Method

*Participants.* The participants were 42 undergraduate students at the Hebrew University, all native speakers of Hebrew, who participated in the experiment for course credit or payment. All had normal vision or wore corrective lenses.

*Stimuli.* The 48 target words were 4–6 letters long. They were all nouns, whose word patterns represented a variety of common word patterns in Hebrew. As in Experiment 1, each target word was paired with three different previews to form the identical, related, and control conditions. All previews were equated in length with the targets (see Figure 2 for examples of the stimuli). The preview in the related condition shared the same nominal pattern as the target but had a different root, whereas the preview in the control condition had both a different nominal pattern and different root. Both the morphologically related previews and the control previews shared, on average, 2.1 letters with the target, and the

**Target Sentence:**

הפקיד המפוזר חיפש מחברת (/maxberet/) חשבון ריקה במגירה

(The absent-minded clerk looked for **a notebook** in the drawer)

**Preview Sentences:****Identical Preview Condition:**

(/maxberet/) מחברת

**Morphological Preview Condition:**

(a printer /madpeset/) מדפסת

**Orthographic Control Condition:**

(pruning shears /mazmera/) מזמרה

**Figure 2.** Example of the stimuli used in Experiment 2. Target and preview words are underlined.

shared letters in the non-identical previews and the target always appeared in the same order, and in most cases (45 out of 48) in the same position within the word.

All the target words were embedded in sentences of 7–10 words which had the same syntactic structure as the sentences used in Experiment 1. Each target word was an object completion of the sentential predicate and was the fourth or fifth word in the sentence. The target word was never the last word on a line. There were also 12 filler sentences, in which the display change took place in a different syntactic element of the sentence (the predicate rather than the object).

These target words, as well as the sentences in which they were embedded, are the same as those that had previously been used to investigate the benefit induced by presenting a parafoveal preview word derived from the same root as the foveal target word (Deutsch et al., 2003). In that experiment we kept the semantic context of the sentence neutral. As the root carries the core semantic meaning of the word, we applied two preliminary procedures to ensure that there was little or no contextual semantic bias. The first was a completion task: 21 participants who did not take part in the reading experiment were asked to read the beginning of each of the experimental sentences (i.e., the words preceding the target) and complete them. Any sentential context that was completed with the target word by at least four participants was replaced (six sentences were replaced for this reason). The second was a predictability rating procedure. These ratings were gathered after the completion task to ensure that no

odd sentences were included: 20 participants who had not participated in the completion task were asked to assess the target's predictability for each of the sentences, on a 1 (low)–7 (high) scale. Only sentences that scored between 3 and 6 were included in the experiment. Since all sentences included in this semantic scoring procedure were moderately predictable, another eight filler sentences, in which the noun that was located in the same position as in the target sentences was not predictable, were added to the final list to increase the variability in predictability within the list of sentences to be scored.

*Design and procedure.* The design and procedure were identical to those of Experiment 1.

## Results

Twenty-eight per cent of the total observations were excluded on the basis of the same exclusion criteria described in Experiment 1: (a) skipping the word prior to the target word, and (b) fixation duration distribution cutoffs. As can be seen in Table 2, the per cent of times that the target word was skipped was somewhat higher than in Experiment 1. However, again, there were no significant differences among the conditions ( $F_s < 1$ ).

The pattern of results in the first pass measures was different from that in Experiment 1, as the identical preview condition differed from the other two conditions, but there was no facilitation from the morphemically related prime. For first fixation duration, there was a significant effect of preview condition,  $F_1(2, 82) = 4.98$ ,  $MSE = 192$ ,  $p < .01$ ,  $F_2(2, 94) = 5.12$ ,  $MSE = 214$ ,  $p < .008$ , which was due to fixation times in the identical preview condition being 9 ms shorter than in the orthographic control

TABLE 2  
Percentage of time the target word was skipped and mean (and SD) of first fixation duration, gaze duration, and second-pass time (in ms) on the target word for the three preview conditions in Experiment 2

<i>Dependent variable</i>	<i>Identical preview</i>	<i>Morphologically related preview</i>	<i>Orthographic control preview</i>
Percent of trials target word was skipped	11.0%	9.6%	9.7%
First fixation duration	222 (15.3)	230 (17.1)	231 (21.7)
<b>Preview effect</b>	<b>9</b>	<b>1</b>	–
Gaze duration	250 (24.1)	263 (24.6)	262 (38.0)
<b>Preview effect</b>	<b>12</b>	<b>–1</b>	–
Second pass	61 (42.5)	52 (39.9)	57 (38.6)
<b>Preview effect</b>	<b>–4</b>	<b>5</b>	–

condition,  $F_1(1, 41) = 8.59$ ,  $MSE = 382$ ,  $p < .01$ ,  $F_2(1, 47) = 9.28$ ,  $MSE = 399$ ,  $p < .01$ , and 8 ms shorter than in the morphologically related condition,  $F_1(1, 41) = 8.78$ ,  $MSE = 271$ ,  $p < .005$ ,  $F_2(1, 47) = 9.27$ ,  $MSE = 299$ ,  $p < .005$ . The 1 ms difference between the morphologically related and orthographic control conditions was clearly not close to significance ( $F_s < 1$ ). The pattern was the same for gaze duration, as there was a main effect of preview condition,  $F_1(2, 82) = 4.49$ ,  $MSE = 534$ ,  $p < .01$ ,  $F_2(2, 94) = 6.50$ ,  $MSE = 424$ ,  $p < .005$ , with first fixation duration in the identity condition being 12 ms shorter than in the orthographic control condition,  $F_1(1, 41) = 6.57$ ,  $MSE = 1045$ ,  $p < .001$ ;  $F_2(1, 47) = 9.64$ ,  $MSE = 806$ ,  $p < .005$ , and 13 ms shorter than in the morphologically related condition,  $F_1(1, 41) = 10.04$ ,  $MSE = 747$ ,  $p < .005$ ,  $F_2(1, 47) = 9.94$ ,  $MSE = 879$ ,  $p < .005$ . Again, the 1 ms difference between the morphologically related and orthographic control conditions was not close to significant ( $F_s < 1$ ). As in Experiment 1, there was no main effect of morphological preview condition in second pass time,  $F_1(2, 82) = 1.56$ ,  $MSE = 551$ ,  $p > .20$ ,  $F_2(2, 94) = 1.46$ ,  $MSE = 672$ ,  $p > .20$ . The small differences in second pass times would be hard to interpret (even if reliable) as the second pass times in the morphologically related condition were less than the control condition, but the second pass time in the identical condition was actually greater than in the control condition.

## Discussion

In Experiment 2, previews that were morphologically related to the foveal target words, in that they shared a nominal pattern, did not facilitate first pass processing of the target word. This outcome replicates the results obtained in the masked priming paradigm for single-word identification (Frost et al., 1997). In both paradigms, no effect was observed for nominal patterns. The null priming effect for nominal patterns was previously explained as anchored in some salient characteristics of the nominal patterns, which are (a) low frequency of most patterns relative to the frequency of each verbal pattern, (b) vague semantic characteristics, and (c) no specific prominent structural property such as the three-consonantal structure that most roots have. Thus, as a group, nominal patterns do not have any prominent property that would assist lexical access (for a detailed discussion, see Deutsch et al., 1998). It should be noted that a dissociation between two types of morphemes was recently observed in French. Using the masked priming paradigm, Giraudo and Grainger (2003) obtained a significant facilitation effect for primes that shared a prefix with the target, but no hint of an effect for primes that shared a derivational suffix with the target. The results may be parallel because, like the difference between verbal and nominal patterns in Hebrew, prefixes in French are more

limited in number and have more systematic meanings than derivational suffixes in French.

### EXPERIMENT 3

In the next two experiments we moved to examine the effect of contextual factors on morphological preview benefit. The aim of Experiment 3 was to assess whether prior semantic context influences the extraction of morphological information in reading. The parafoveal preview technique allows one to assess the influence of prior context on the initial phases of extraction of information from a word before it is actually fixated. In particular, previous studies have shown that there was greater benefit in extracting orthographic information from a parafoveal preview when the target word was predictable from the preceding context (Balota, Pollatsek, & Rayner, 1985). In the current experiment we investigated whether morphological processing is also more efficient when the meaning of a morpheme is predictable from the prior sentence context. This was tested by employing a preview in the morphologically related condition that was derived from the same root as the foveal word, and embedding it in either a semantically neutral or in a biasing context. The key question was whether the size of the benefit from a preview of the root morpheme would be larger when the meaning of that morpheme was predictable from prior sentence context than when the prior context was neutral with respect to the target word (and hence the meaning of the root morpheme was not predictable). We focused on the interaction between *semantic* contextual effects and the morphological parafoveal preview benefit induced by the root morphemes, as the root carries the core meaning of a word.

#### Method

*Participants.* The participants were 56 undergraduate students at the Hebrew University. All were native speakers of Hebrew, who participated in the experiment for course credit or payment. All had normal vision or wore corrective lenses.

*Stimuli and design.* The 64 target words were nominal forms that were 4–5 letters long. Each target word was paired with two different previews to form the morphologically related and orthographic control conditions. (There was no identical preview condition in this experiment.) The morphologically related preview had the same root morpheme as the target. The target and the two non-identical previews in each set of sentences were equated for length. The morphologically related previews and control previews both shared, on average, 2.3 letters with the target, and the shared letters in the non-identical previews and the target always

appeared in the same order. However, the original position of the common letters and their contiguity was not necessarily preserved, as it is close to impossible to control all these aspects within each set of stimuli, when the root morpheme is under investigation. No previews had the same initial letter as the target. (See Figure 3 for an example of the stimulus materials.)

All target words were embedded in sentences of 7–10 words that had the same syntactic structure as the previous experiments. Each target word was embedded in two different sentential contexts—one was semantically neutral and the other was semantically biased. The semantically biased context was constructed by replacing one (or sometimes more) of the content words preceding the target with a word that was semantically related to the target.

The semantic biasing manipulation was assessed by two preliminary procedures. The first was a predictability completion task: 40 participants who did not take part in the reading experiment were asked to read the beginning of each of the experimental sentences (i.e., the words preceding the target) and complete them. Half of the sentences were candidates for the semantically neutral condition, and half were candidates for the semantically biasing condition. For the former, any sentential context that was completed by at least 10 participants with the actual target word was replaced. For the latter, only sentences that were completed with the actual target word by at least 10 participants were included. After this step, the sentences were rated for semantic plausibility by 40 participants who had not participated in the completion task, on a 1 (low)–7 (high) scale. Only pairs of sentences that scored between 3 and 6 in the semantically neutral context, and not less than 4 in the semantically biased context, were included in the experiment. These ratings were gathered after the completion task to ensure that no odd sentences were included. As in Experiment 1 and 2, we included another eight filler sentences with very low predictability.

The sentences were divided into four lists. Each list contained 64 sentences: 32 provided a semantically neutral context and 32 provided a semantically biased context. Each of these sentences in the list had either a morphologically related or an orthographic control preview. Each list thus contained 16 sentences in each of the four experimental preview conditions: (1) Semantically neutral—Morphologically related, (2) Semantically neutral—Orthographic control, (3) Semantically biased—Morphologically related, (4) Semantically Biased—Orthographic Control. The stimuli were rotated within the four conditions in each list by a Latin Square design. Fourteen participants were tested in each list, allowing each participant to provide data in each condition, yet avoiding stimulus repetition effects.

**Semantically neutral context:**

**Target Sentence:**

משטרת הגבולות תפסה מרגלל (/mragelet/) בביקורת הדרכונים

(The border police caught a **spy** at passport control)

**Preview Sentences:**

**Morphological Preview Condition:**

(spying /rigul/) ריגול

**Orthographic Control Condition:**

(a peddler /roxelet/) רוכלת

**Semantically biasing context:**

**Target Sentence:**

סוכנות הביון תפסה מרגלל (/mragelet/) בביקורת הדרכונים

(The intelligence agency caught a **spy** at passport control)

**Preview Sentences:**

**Morphological Preview Condition:**

(spying /rigul/) ריגול

**Orthographic Control Condition:**

(a peddler /roxelet/ ) רוכלת

**Figure 3.** Example of the stimuli used in Experiment 3. Target and preview words are underlined.

*Procedure.* The procedure was identical to that of the previous experiments.

**Results**

Thirty-one per cent of the total observations were excluded on the basis of the same exclusion criteria described in Experiment 1: (a) skipping the word prior to the target word, and (b) fixation duration distribution cut-offs. As in Experiment 1, the target word was rarely skipped (see Table 3) and there was little difference among the four conditions.

There were significant effects of a morphemically related preview in both measures of first pass processing, and the apparent modulation of this effect by the prior context was not consistent across the two measures. For first fixation duration, there was a 7 ms effect of preview condition,  $F_1(1, 55) = 4.98$ ,  $MSE = 169$ ,  $p < .001$ ,  $F_2(1, 63) = 11.73$ ,  $MSE = 245$ ,  $p < .001$ , and the main effect of context was 0 ms. The preview effect appeared to be bigger in the semantically neutral condition, but the interaction between the preview and the context condition was not close to significant,  $F_1(1, 55) = 1.82$ ,  $MSE = 197$ ,  $p > .10$ ,  $F_2(1, 63) = 1.90$ ,  $MSE = 223$ ,  $p > .10$ . Planned comparisons revealed that the 9 ms preview effect in the semantically neutral context was significant,  $F_1(1, 55) = 13.65$ ,  $MSE = 367$ ,  $p < .001$ ;  $F_2(1, 63) = 11.95$ ,  $MSE = 461$ ,  $p < .001$ , but the 4 ms preview effect in the semantically biased context was not,  $F_1(1, 55) = 2.47$ ,  $MSE = 385$ ,  $p > .10$ ,  $F_2(1, 63) = 2.29$ ,  $MSE = 476$ ,  $p > .10$ . For gaze duration, there was a 13 ms effect of preview condition,  $F_1(1, 55) = 13.70$ ,  $MSE = 608$ ,  $p < .001$ ,  $F_2(1, 63) = 17.27$ ,  $MSE = 551$ ,  $p < .001$ , and the main effect of context was again 0 ms. This time the preview effect was larger in the semantically biased condition, but again the interaction between the preview and the context condition was not close to significant,  $F_1(1, 55) = 1.87$ ,  $MSE = 532$ ,  $p > .10$ ,  $F_2(1, 63) = 1.81$ ,  $MSE = 629$ ,  $p > .10$ . Planned comparisons revealed that the 9 ms preview effect in the semantically neutral context was close to significant,  $F_1(1, 55) = 4.36$ ,  $MSE = 818$ ,  $p < .05$ ,  $F_2(1, 63) = 3.88$ ,  $MSE = 1050$ ,  $p = .053$ , and the 17 ms preview effect in the semantically biased context was significant,  $F_1(1, 55) = 10.32$ ,  $MSE = 1462$ ,  $p < .005$ ,  $F_2(1, 63) = 13.16$ ,  $MSE = 1309$ ,  $p < .001$ .

TABLE 3  
Percentage of time the target word was skipped and mean (and SD) of first fixation duration, gaze duration, and second-pass time (in ms) on the target word for the four preview conditions in Experiment 3

Dependent variable	Semantically neutral prior context		Semantically biased prior context	
	Morphologically related	Orthographic control	Morphologically related	Orthographic control
Percent of trials target word was skipped	1.4%	1.4%	1.7%	1.9%
First fixation duration	224 (19.1)	233 (20.8)	227 (19.0)	231 (23.4)
<b>Preview effect</b>	<b>9</b>	—	<b>4</b>	—
Gaze duration	279 (32.7)	288 (30.1)	275 (34.2)	292 (39.3)
<b>Preview effect</b>	<b>9</b>	—	<b>17</b>	—
Second pass time	98 (58.3)	105 (65.6)	75 (50.4)	90 (64.3)
<b>Preview effect</b>	<b>7</b>	—	<b>15</b>	—

There was also an 11 ms preview effect on second pass time,  $F_1(1, 55) = 6.28$ ,  $MSE = 1081$ ,  $p < .05$ ,  $F_2(1, 63) = 4.66$ ,  $MSE = 1666$ ,  $p < .05$ . In addition, second pass times were smaller in the semantically biased condition than in the control condition,  $F_1(1, 55) = 16.33$ ,  $MSE = 1201$ ,  $p < .001$ ,  $F_2(1, 63) = 9.00$ ,  $MSE = 2490$ ,  $p < .01$ , which indicated that when target words were easier to relate to the prior context, it facilitated the reading of the ensuing text. Again, the interaction between the preview and the context condition was not significant,  $F_s < 1$ , but planned comparisons revealed that in the semantically biased context the 15 ms preview effect on second-pass time in the morphologically related condition was significant,  $F_1(1, 55) = 6.2$ ,  $MSE = 2050$ ,  $p < .05$ ,  $F_2(1, 63) = 5.12$ ,  $MSE = 2837$ ,  $p < .05$ , but that the 7 ms preview effect on second pass time in the semantically neutral condition was not,  $F_s < 1$ .

## Discussion

The results of Experiment 3 revealed a significant morphological preview effect induced by the root morpheme in the first pass, but that there was no consistent effect of a semantically biasing context either on the overall duration of first pass fixations or on the size of the benefit from a morphologically related preview. The results for a semantically neutral context replicated previous results in Hebrew, where the morphological preview effect induced by the root morpheme was investigated for semantically neutral sentences (Deutsch et al., 2003). In contrast, both factors had an effect on second pass times: both a semantically biased context and a morphemically related preview shortened second pass time. This indicates that prior semantic contextual factors did not affect the initial morphological processes in word identification, but only came into play later, in post-lexical processing.

## EXPERIMENT 4

In Experiment 4, we investigated the interactions between early morphological processes and on-line *syntactic* processes in reading. The key question was whether seeing a preview that contained a verbal form in a syntactically constraining context that required the target word to have a nominal completion, would inhibit processing of the word, and moreover, whether this inhibition effect would occur in first-pass reading measures. We focused on verbal patterns because they provide important grammatical information for syntactic analysis. The expectation that a syntactically constraining context may affect the reader sensitivity to parafoveal information is supported by the well documented phenomenon of a higher skipping rate for function words (Gautier, O'Regan, & LaGargasson, 2000; O'Regan, 1979). As this higher skipping rate cannot be solely attributed to

perceptual factors such as word length (Brysbaert & Vitu, 1998), or orthographic familiarity (Koriat & Greenberg, 1994), it may imply, given an appropriately constraining syntactic context (Reichle, Rayner, & Pollatsek, 2003), that function words are identified quickly because of their high predictability and/or easy assimilation into the on-line process of building syntactic structures. In the present experiment we wanted to investigate whether on-line syntactic processes, which apparently affect the speed of word identification, may also affect the extraction of morphological information from the parafovea which is relevant to these analyses, and/or its impact on lexical access of the foveal word.

## Method

*Participants.* The participants were 42 undergraduate students at the Hebrew University. All were native speakers of Hebrew, who participated in the experiment for course credit or payment. All had normal vision or wore corrective lenses.

*Stimuli.* The sentences used in this experiment were the same as in Experiment 2 with the same (4–6 letter) nominal target words. Thus the target words were nominal completions required by the preceding verbs. Each target word was coupled with three different previews forming three experimental conditions: (1) identical, (2) syntactically incongruent, with a preview of a word containing a verbal rather than a nominal pattern, and (3) syntactically congruent control, with a preview of a word having a different root and a different nominal pattern from the target word, but sharing the same number of letters with the target as the syntactically incongruent preview (see Figure 4). Neither the syntactically congruent nor the syntactically incongruent previews were at all semantically related to the target word. The third preview condition served as an orthographic control condition for the syntactically incongruent condition. The target and the two non-identical previews within each triple were equated for length. Both the syntactically congruent and control previews shared, on average, 1.6 letters with the target, and the shared letters in the non-identical previews and the target always appeared in the same order, and in most cases (45 out of 48) in the same position within the word. Another 12 filler sentences, in which the display change took place in a different syntactic element of the sentence (the predicate rather than the object), were included.

## Results

Thirty five percent of the total observations were excluded on the basis of the same exclusion criteria described in Experiment 1: (a) skipping the word prior to the target word, and (b) fixation duration distribution

**Target Sentence**

סוכן הביטוח קיבל (Pred.) תשלום (/taʃlum/) בעבור שירותיו הנאמנים

(The Insurance agency received **payments** for his loyal service)

**Preview Sentences****Identical Preview Condition:**

(/taʃlum/) תשלום

**Syntactically Incongruent Context**

(browned) /hiʃxim/) השחים

**Syntactically Congruent Context – Control Condition**

(training of animals /iluf/) איילי

**Figure 4.** Example of the stimuli used in Experiment 4. Target and preview words are underlined.

cutoffs. The skipping rates for the target word were again low, and there were no significant differences among the three preview conditions (see Table 4).

However, the type of preview did affect first pass processing times. As can be seen from Table 4, having an identical preview speeded processing of the target word relative to a control preview that shared several letters and which was syntactically congruent with the target word. Of greatest interest was that a syntactically incongruent preview slowed processing relative to a syntactically congruent preview, even though neither preview shared any morphemes with the target. For first fixation duration, there was a significant effect of preview condition,  $F_1(2, 82) = 5.91$ ,  $MSE = 210$ ,  $p < .01$ ,  $F_2(2, 94) = 4.14$ ,  $MSE = 342$ ,  $p < .05$ . Planned comparisons indicated that the 8 ms facilitation due to having an identical preview (compared to the orthographic control condition) was significant,  $F_1(1, 41) = 7.06$ ,  $MSE = 405$ ,  $p < .01$ ;  $F_2(1, 47) = 7.47$ ,  $MSE = 4.37$ ,  $p < .05$ , but that the 5 ms inhibition due to having an incongruent verbal preview (compared to the orthographic control condition) was not,  $F_s < 1$ . For gaze duration, the effect of preview condition was also significant,  $F_1(2, 82) = 16.25$ ,  $MSE = 377$ ,  $p < .001$ ;  $F_2(2, 94) = 11.09$ ,  $MSE = 632$ ,  $p < .001$ , and both the 12 ms facilitation in the identity condition (relative to the orthographic control condition),  $F_1(1, 41) = 7.85$ ,  $MSE = 723$ ,  $p < .01$ ;  $F_2(1, 47) = 5.74$ ,  $MSE = 1131$ ,  $p < .05$ , and the 13 ms inhibition effect in the verbal preview condition (relative to the orthographic control condition),  $F_1(1, 41) = 8.86$ ,  $MSE = 743$ ,  $p < .01$ ;  $F_2(1, 47) = 4.71$ ,  $MSE = 1599$ ,  $p < .05$ , were significant.

TABLE 4

Percentage of time the target word was skipped and mean (and SD) of first fixation duration, gaze duration, and second-pass time (in ms) on the target word for the three preview conditions in Experiment 4

<i>Dependent variable</i>	<i>Identical preview</i>	<i>Syntactically incongruent preview</i>	<i>Syntactically congruent control preview</i>
Percent of trials target word was skipped	3.6%	2.9%	1.8%
First fixation duration	226 (21.6)	239 (22.2)	234 (28.7)
<b>Preview effect</b>	<b>8</b>	<b>-5</b>	<b>-</b>
Gaze duration	258 (45.1)	282 (43.3)	269 (42.1)
<b>Preview effect</b>	<b>12</b>	<b>-13</b>	<b>-</b>
Second pass time	73 (58.6)	91 (64.8)	66 (52.4)
<b>Preview effect</b>	<b>7</b>	<b>-25</b>	<b>-</b>

The pattern of results was somewhat different in the second-pass times. There was a significant effect of preview condition,  $F_1(2, 82) = 7.19$ ,  $MSE = 937$ ,  $p < .001$ ;  $F_2(2, 94) = 6.38$ ,  $MSE = 1207$ ,  $p < .01$ , and planned comparisons indicated that although the 7 ms difference between the identical condition and control condition was not close to significant,  $F_1 < 1$ ,  $F_2(1, 47) = 1.18$ ,  $MSE = 1686$ ,  $p > .20$ , the 25 ms inhibition induced by the syntactically incongruent preview was significant,  $F_1(1, 41) = 13.25$ ,  $MSE = 1892$ ,  $p < .001$ ,  $F_2(1, 47) = 9.19$ ,  $MSE = 3117$ ,  $p < .01$ .

## Discussion

The results of Experiment 4 revealed a clear inhibition effect induced by presenting a preview of a verbal form that was syntactically incongruent, because it was in a syntactically constraining context that required a nominal form. The gaze duration on the nominal foveal word was lengthened as was the second pass measure. This supports our claim, based on Experiment 1, that verbal pattern information is indeed extracted from the preview. Furthermore it indicates that whether or not this information is congruent with on-line syntactic processing has a fairly immediate impact on processing the foveal target word. This outcome contrasts with the findings of Experiment 3 which did not reveal early contextual effects in the semantic domain on morphological processing. However, note that the inhibitory effect on first fixation duration was not significant, so that the morphological information that was extracted from the parafovea, and was relevant for the construction of the syntax of the sentence, did not seem to affect the earliest stages of word recognition when the word is initially fixated.

## GENERAL DISCUSSION

In the present experiments, we investigated the effects of morphological information in the parafovea on the identification of an up-coming Hebrew word in the course of sentence reading. In the first two experiments, we examined whether there would be a benefit from presenting a preview that was a word that shared either a verbal or a nominal pattern with the target word. We found a clear benefit from having a preview of the verbal pattern in Experiment 1, but no benefit from presenting a preview of the nominal pattern in Experiment 2. These results complement previous studies which demonstrated a morphological preview benefit effect induced by the root morpheme (Deutsch et al., 2003). Thus, it appears that of the three derivational morphemes that exist in Hebrew—the root, the verbal pattern, and the nominal pattern—only a preview of the nominal pattern fails to provide any benefit. In all cases, a significant benefit from the preview only occurred in first-pass reading measures. These findings parallel those in single-word identification in masked priming, where a priming effect was observed for roots and verbal-pattern primes, but not for nominal patterns. Furthermore, the size of the effects observed in masked priming was very similar to the effects found on gaze duration in the sentence reading studies (about 12 ms), suggesting that the two paradigms tap similar encoding processes. This is in spite of obvious differences in the paradigms, such as differences in the exposure duration of the ‘prime’ and differences in the location of the ‘prime’. Perhaps this means that information extraction in the parafovea is not fundamentally different than in the fovea. It should also be noted that although most of the parafoveal preview experiments cited here involved reading words in sentence context, there is a variant of the parafoveal preview paradigm involving naming of isolated words that has obtained quite similar results as the sentence reading version with respect to obtaining benefit from orthographically and phonologically previews but not obtaining benefit from semantically similar previews (Altarriba, Kambe, Pollatsek, & Rayner, 2001; Pollatsek et al., 1992; Rayner, 1975).

One difference between the masked priming and the parafoveal preview experiments should be noted, however. In masked priming the priming effect for identical primes is typically about twice as large as for morphologically related primes (Frost et al., 1997, 2000). In contrast, for parafoveal previews, there was no advantage of an identical preview over a root preview in Deutsch et al. (2003) and a significant advantage of an identical preview over a verbal pattern preview in Experiment 1, but only for the first fixation measure. This indication of a difference between root previews and verbal pattern previews suggests that the root morpheme is identified earlier than the verbal-pattern morpheme, at least in the

parafovea. That is, if the completion of encoding the root occurs prior to the completion of the encoding of the verbal pattern, one might observe no advantage for seeing the whole word in the parafovea (i.e., the identical preview condition) over seeing only the root, but observe an advantage of the identical preview over the verbal-pattern preview early in processing (indexed by the first fixation duration). However, this advantage should diminish later in processing.

The present results thus indicate that extraction of the root morpheme precedes the extraction of the verbal pattern, although both are extracted relatively early in the process of identifying a word. Another study (Frost et al., 2000) suggested that extraction of the root morpheme not only precedes the extraction of the verbal pattern, but that the extraction of the verbal pattern depends on extracting the root morpheme. Frost et al. investigated the extraction of the verbal-pattern morpheme from verbs derived from *weak roots* (Frost et al., 2000). (Weak roots are roots that do not possess the regular structure of a three-consonantal root.) Using the masked priming paradigm, they obtained no evidence for a verbal pattern priming effect, in contrast to the robust verbal pattern priming effect observed for other verbal forms in Hebrew. They concluded that extraction of the verbal pattern from the prime failed because the extraction of the root morpheme failed (probably because of violation of structural constraints) and thus the whole process of decomposition could not proceed. Thus, there are several converging clues for the time course of decomposing the root and the verbal pattern. However, it should be noted that our suggestion that the verbal pattern lags behind the root, in the present research, is a post-hoc explanation based on fairly subtle differences between the identical and the morphologically related conditions in first fixation and gaze duration in Experiment 1. This issue deserves further investigation.

Experiments 3 and 4 investigated whether prior semantic or syntactic context can interact with early morphological processing. The answer was different in the two cases: a semantically biasing context did not influence the processing of a parafoveal preview of the root morpheme in the first pass. In contrast, a preview of a verbal pattern in a syntactically incongruent context lengthened the fixation duration of a nominal word even on the first pass. The latter findings suggest that contextual syntactic constraint can modulate the use of parafoveal morphological information in the process of identifying the foveal word. In contrast, there was no clear indication of such an interaction with prior semantic context. That is, if the meaning of the root morpheme seen in the parafovea was more easily recognised and/or more quickly utilised given a strongly biasing semantic context, then one would have expected a larger preview benefit from this information in the biasing context than in a more neutral context.

Although there was a hint of such an effect in the gaze duration data, it was far from significant, and the effect in the first fixation data actually went in the opposite direction. The absence of any contextual effect on early morphological processes in the semantic domain supports bottom-up models for word recognition, where the process of word recognition is not affected by higher contextual processes. Thus it seems that the process of root extraction is an initial and thus fast process that is not affected by on-line higher semantic processing. However, the findings from manipulating syntactic contextual effect do suggest a top-down influence in which information from higher levels feeds back and interacts with processing at lower levels.

This discrepancy between the semantic and syntactic effects, however, could be because the syntactic domain is much more highly constrained than the semantic domain. It could also reflect the linguistic characteristics of the root and the verbal-pattern morphemes. That is, there are many roots, each of them with a global (i.e., not very precise) semantic meaning, and each having a large number of homonyms. In contrast, there are only seven verbal patterns, each of them with fairly well-defined syntactic characteristics, such as transitivity and mode. Accordingly, the preview of a verbal pattern provides well-defined syntactic information whereas the semantic information provided from the root preview morpheme is vague. Thus, the way prior context interacts with early morphological decomposition processes may depend not only on the type of contextual factor (semantic or syntactic), but on the linguistic characteristics of the specific morpheme. This issue should, however, be investigated further, where the next step would be to examine whether contextual effects in the semantic domain can interact with early morphological processes of nominal patterns, which usually reveal no morphological effects. The critical question is whether supporting contextual semantic context can enhance early morphological effects of decomposing nominal patterns that are usually not expressed in single word identification paradigms or in a semantically neutral context.

Finally, our results contrast with studies in English, where no morphological preview effects have been observed in sentence reading (Inhoff, 1989a; Kambe, 2004; Lima, 1987). Similarly, as indicated earlier, although morphological priming effects in Hebrew are very robust in masked priming paradigm, they are more fragile in English (Forster & Azuma, 2000; Rastle & Davis, 2003). However, interestingly, the opposite pattern is observed with form priming in the two languages. That is, in English (as well as in other Indo-European languages) pure *orthographic similarity* between prime and target (i.e., matching letters in the same letter positions) strongly facilitates the identification of written words both in the masked priming paradigm (Forster, Davis, Schoknecht, & Carter,

1987; Forster & Veres, 1998) and in parafoveal preview (Altarriba et al., 2001, Rayner, 1975). In contrast, there is recent evidence that there is no form priming in Hebrew (Frost, Kugler, Deutsch, & Forster, 2004). This discrepancy between the two languages could reflect differences in the principles by which the two lexicons are organised: lexical organisation guided primarily by orthographical principles based on letter sequentiality and letter position as opposed to lexical organisation primarily guided by morphological principles. (See Frost et al., 2004, for a detailed discussion.). In the latter case, the organising units are morphological units with non-concatenated repeated structures. The differences in the principle of lexical organisation may be anchored in the linguistic differences between Hebrew and English both with respect to morphological structure and to the role of morphology in the grammar. If so, this suggests that the organisation of the lexicon may differ depending on many aspects of the language one is studying.

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