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Early morphological effects in word recognition in Hebrew: Evidence from parafoveal preview benefit

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Hebrew words are composed of two interwoven morphemes: a triconsonantal root and a word pattern. Two experiments examined the effect of the root morpheme on word identification by assessing parafoveal preview benefit effects. Although the information of the preview was not consciously perceived, preview of the root's letters facilitated both naming and lexical decisions of target words derived from these roots. These results converge with previous results in Hebrew using the masked priming paradigm, suggesting that morphological units mediate early stages of word identification in Hebrew.

There is ample evidence indicating that morphological factors affect word identification. For example, a common finding is that morphologically related words induce a priming effect. This has been demonstrated in various types of priming procedures in different languages (Bentin & Feldman, 1990; Burani & Laudanna, 1992; Colé, Beauvillain, & Segui, 1989; Drews & Zwitserlood, 1995; Fowler, Napps, & Feldman, 1985; Marslen-Wilson, Tyler, Waksler, & Older, 1994). The finding that

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morphological manipulations affect word recognition led many researchers to suggest that morphological units are explicitly represented in the mental lexicon, and thereby facilitate the recognition of words. Within this framework, various models have been developed to describe how complex words are organised and represented in the mental lexicon, and which factors determine the lexical status of any given morpheme as an independent lexical unit (Baayen, 1991; Burani & Laudanna, 1992; Fraunfelder & Schreuder, 1991; Marslen-Wilson et al., 1994). However, the time course of these morphological effects is not certain. Do they reflect early morphological processes that mediate lexical access, or do they reflect late, post-lexical, processes that take place only after the phonological unit is located in the lexicon? (See Giraudo & Grainger, this issue, for a discussion.) This question is crucial for defining the scope of any suggested model of morphological processing: does it describe mainly the role of morphology in lexical representation, or does it have implications for the initial process of lexical access?

The present study approaches this question by measuring parafoveal preview benefit for morphological effects that have previously been found using the masked priming paradigm (Frost, Forster, & Deutsch, 1997). These masked priming effects led us to suggest that morphological units serve as an organising principle of the mental lexicon and can mediate processes of lexical access. However, firm arguments concerning the early time course of morphological effects require the use of complementary experimental procedures, which tap relatively early processes of lexical access.

All our studies were carried out in Hebrew, which like other Semitic languages, has a non-concatenated derivational morphology. Before describing previous results on morphological processes of decomposition and discussing the experimental procedure of masked priming and parafoveal preview benefit, we will briefly outline some special characteristics of 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 are comprised of two basic derivational morphemes: the root and the word-pattern. The root usually consists of three consonants while the word-pattern either consists of vowels, or of a mixture of vowels and consonants. Whereas the root usually carries the core meaning of the word, the word-pattern creates variations on its meaning, and determines its word class and other grammatical characteristics. It should be noted that even though word-patterns shape the meaning of words, the semantic characteristics of a word-pattern often vary, so that the exact meaning of a word cannot be unequivocally predicted by considering each of its constituent morphemes (the root and the word-pattern) independently.

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 word *mibreʃet* (meaning "a brush") is composed of the root *brʃ* (meaning "brushing") interwoven with the nominal-pattern *mi- -e-et* (the dashed lines present the places where the root's consonants are inserted), which denotes a feminine nominal form. The same principle also applies to the verbal system, as illustrated by the verb *hibriʃ* (meaning "he brushed"), in which the root *brʃ* is embedded in the verbal pattern *hi- -i-,* which denotes a causative verb.

The non-linear structure makes the investigation of morphological decomposition processes in Hebrew particularly interesting, because morphemes are not necessarily contiguous units within a given word. This often obscures the phonological and orthographic transparency of the two constituent morphemes. Perhaps to make up for this obstacle to morphemic decomposition, Hebrew derivational morphology is characterised by very salient and defined recurring structural principles. As a result, evidence for morphological decomposition during lexical access in non-concatenated languages such as Hebrew is especially interesting, because of the contrast with the feature of contiguity that usually characterises sub-lexical units previously suggested as mediating word recognition. Furthermore, because of its rich morphological environment, Hebrew has great internal variability in the distributional properties of the morphemes, semantic transparency, and the amount of grammatical information that they carry. Thus, Hebrew provides an opportunity to assess the relative contribution of all these factors which have been traditionally suggested to account for morphological decomposition (Baayen, 1991; Fowler et al., 1985; Frauenfelder & Schreuder, 1991; Soltz & Feldman, 1995).

Evidence for morphological processing in Hebrew derived from masked priming

Previous work in Hebrew used the masked priming paradigm to examine the effect of morphologically related primes (a word's root or its word-pattern) on word identification (Deutsch et al., 1998; Frost, Deutsch, & Forster, in press; Frost et al., 1997). In the masked priming paradigm (see Forster & Davis, 1984) a forward pattern-mask is presented followed by the prime and then the target. The temporal interval between the onset of the priming stimulus and the subsequent target stimulus—the backward mask—is very brief (42 ms in our experiments). Because the prime is presented briefly and is masked by a combination of forward and backward masking, the prime itself is usually unavailable for report, so that the participants' responses are not based on, or influenced by, a conscious appreciation of the relation between the prime and the target. Another feature of the masked priming technique is that it is highly sensitive to overlap at the level of orthographic form but not to semantic factors (Forster, Davis, Schoknecht, & Carter, 1987; Forster & Taft, 1994; Perea, Gotor, Rosa, & Algarabel, 1995; but see Sereno, 1991). Since morphological relatedness between derived words usually entails semantic relatedness, this feature of masked priming is very important for assessing morphological effects, as it allows to separate morphological effects at the level of form from simple semantic factors. The priming effect obtained in this procedure is usually considered to reflect a transfer effect; that is, the information extracted from the prime is transferred to the subsequently presented target, and is integrated into its processing.

The masked priming procedure was originally used to examine the effects of primes and targets that share similar orthographic structure (i.e., form priming). Accordingly, the extent of the priming was measured by comparing performance in a related condition with a baseline condition in which the prime is orthographically different from the target. The common finding is facilitation for primes that are the same word as the target (identity priming), but also strong facilitation for non-identical primes that share all but one letter (form priming). In line with the interpretation of a transfer effect between the briefly presented prime and the target, Forster and his colleagues have suggested that the orthographical units of the prime serve the processing of the target, thus making it easier to recognise. However, in the case of morphological priming, this account must be extended. This is because the morphological priming effect is measured relative to an orthographic control condition which is as orthographically similar to the target as the morphologically related prime is (i.e., shares the same number of letters with the target). But, whereas the control primes do not share any morphological origin with the targets, the primes in the morphological related condition also have common morphological units with the targets. Thus, the priming effect must reflect the *additional contribution* of the morphological manipulation to pure orthographical similarity. By this view, morphological priming should reflect the activation of morphological units in service of lexical access.

All our experiments using masked priming in Hebrew included three basic conditions: an identity condition, a morphologically related condition, and an *orthographic control* condition. The difference between the various experiments was the specific morphological manipulation, which always involved either the root or the word-pattern morpheme. For example, to examine morphological priming of root morphemes, we employed a target word such as מברשת */mibreʃet/* (meaning "a brush") which was primed by itself (the identity condition), by its root letters - ברש, *brʃ* (the morphologically related condition), or by three letters which appeared in the target but did not constitute the target root - ברת, *brt* (an orthographic control condition). The results of these experiments were straightforward:

(1) Root primes facilitated lexical decision and naming of nouns and verbs derived from these roots. This effect was found to be very robust; it was demonstrated within the nominal as well as the verbal system, and similar priming effects were obtained regardless of whether or not the three-consonant sequence of the root primes in isolation could be read as a meaningful word.[1] The same effect was obtained even when the prime consisted of a word derived from the same root as the target, so that the root was not presented explicitly as a unit in the prime. Furthermore, the priming effect was found to be independent of the existence of semantic transparency between the prime and the target (Deutsch et al., 1998; Frost et al., 1997).

(2) Word-pattern primes facilitated lexical decision and naming in the verbal system, but not in the nominal system. In other words, although word-patterns basically represent the same type of morphological unit in the nominal and verbal system, the verbal and nominal patterns seem to have a different role in the lexical organisation and processes of lexical access (Deutsch et al., 1998; Frost et al., 1997).

Note that in all of these effects the morphological unit that induced the priming effect is usually not orthographically contiguous in the target and it never represents a phonological sequence. Based on these results, we suggested a model for lexical organisation and lexical access in Hebrew. This model regards the Hebrew lexicon as including a multiple system of connections between a whole-word level (nouns and verbs) and a sub-word morphological level, which consists of root and verbal-pattern morphemes. By this view, all word units, whether nouns or verbs, are connected to root morphemic units. In addition, verbal forms are also connected to verbal-pattern units. This organisation is independent of semantic factors. The process of lexical access may consist of both lexical retrieval of whole words and a mandatory parallel process of morphological decomposition.

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[1] It should be noted that since the stimuli in our experiments were always written in unpointed print (where most of the vowel marks are omitted), the three consonantal sequence of many roots can be read as words. For example, the orthographic sequence drx, read as /derex/, meaning "a way".

Whereas the former involves the search or activation of lexical units at the word level, the latter involves the extraction and location of morphemic constituents. For nominal forms, the decomposition appears to involve only the extraction and location of the root morpheme, whereas for complete verbal forms both the root and the verbal-pattern are extracted and located on the sub-word morphological level. These two processes may occur in parallel, and may facilitate each other through bi-directional connections between the two levels (Deutsch et al., 1998).

In light of the differences in the specific linguistic characteristics of the roots and the verbal and nominal patterns—mainly their distributional properties and semantic transparency and structural properties, we had suggested (Deutsch et al., 1998) that the independent lexical status of a morphological unit and its role in mediating processes of lexical access may reflect a fine tuning of these factors.[2]

These conclusions, however, are based on a single procedure, which focuses on the identification of isolated words under masked conditions. In general, evidence from different experimental procedures is necessary for enhancing the validity of any model derived from empirical findings. Thus, we wanted to obtain converging evidence from another experimental procedure—one which plausibly taps early processes of lexical access, but which also more closely mimics the natural processes through which words are recognised. As indicated in the following section, the procedure of measuring parafoveal preview benefits seems to satisfy these requirements.

Parafoveal preview benefit effects and morphological processing:

A good procedure for tapping into the initial processes of lexical access is measuring *preview benefit*—that is, the benefit of information perceived in the parafovea before the eyes actually land on a target word. This procedure is based on extensive research on eye movements in reading

[2]In general, the main advantages of the roots relate to their semantic transparency, and to the fact that they are associated with a prominent and rigorous structural pattern of a three-consonantal cluster. As to the verbal patterns, their main advantage relates to their relatively high distribution, since they represent a grammatically closed class system, that every verb in the language must be conjugated with one of the seven available morpho-phonological patterns. Furthermore, the system of the verbal-pattern is based on relatively consistent semantic relations, where each of the pattern can be associated with some characterising semantic features. However, neither the semantic characteristics nor the distributional properties of the nominal patterns are distinctive, which apparently preclude them from gaining the status of independent lexical units (for further elaboration see Deutsch et al., 1998).

(Rayner, 1998), which has revealed that the perceptual span from which readers extract information is not restricted to the fixated word, and that readers can extract information from the next word or two (i.e., in the parafovea). Furthermore, the perceptual span is asymmetrically spread around the fovea, being more extended to the right when reading from left to right (Rayner & Pollatsek, 1989), or to the left when reading from right to left (Nazir, Deutsch, Grainger, & Frost, 2000; Pollatsek, Bolozky, Well, & Rayner, 1981). This asymmetry is associated with an attentional shift from the currently fixated word to the following words in the text (Morrison, 1984; Reichle, Pollatsek, Fisher, & Rayner, 1998). Since readers often extract information from words seen in the parafovea before they fixate them, word identification often starts before the eye is fixated on the target word.

The parafoveal preview benefit effect is usually measured with the boundary technique (Rayner, 1975, 1978). This technique consists of a single rapid display change during a saccade involving a single target word location. The change is from a preview word seen in the parafovea before the saccade to a target word seen near fixation after the saccade. The display change is triggered when the eyes cross an invisible boundary just prior to the target word. A major feature of the boundary technique is that readers are usually unaware of the display changes, and, in spite of the parafoveal preview benefit, are unable to consciously identify the stimuli in the parafovea. Note that this feature greatly resembles the major characteristic of priming under masking procedures. However, the preview benefit has the advantage of being based on a natural process in reading.

An explanation that has been suggested for the mechanism underlying parafoveal preview benefit resembles the account given for masked priming effects: the information extracted from the parafovea causes partial activation of the lexicon. This activation is integrated with the subsequent activation obtained from accessing the foveal word, thereby facilitating the completion of a full and unequivocal identification of a lexical entry (Rayner, McConkie, & Zola, 1980).

It should be noted that there are many similarities between the findings from the parafoveal preview technique and those from the masked priming technique in English. First, both procedures reveal orthographic effects; that is, word identification is facilitated by orthographic similarities. This facilitation seems to be based on an abstract representation of the letters rather than their visual features, since it is unaffected by factors related to the visual form of the prime or the target, such as case or font (masked priming: Forster et al., 1987; preview benefit: McConkie & Zola, 1979; Rayner et al., 1980). Furthermore, both procedures are sensitive to the position of the overlapping letters. In measuring parafoveal preview effects, a particular advantage for the first 2 or 3 letters was observed

(Rayner et al., 1980).[3] Masked priming reveals similar trends (e.g., Humphreys, Evett, & Quinlan, 1990). Another point of similarity between the two procedures is that both seem to be unaffected by semantic factors (masked priming: Frost et al., 1997; Forster, 1987; parafoveal benefit: Inhoff, 1982; Inhoff & Rayner, 1980; Rayner, Balota, & Pollatsek, 1986; Rayner, McConkie & Ehrlich, 1978).

Only a few studies, conducted in English, have manipulated morphological factors in the parafovea while measuring preview effects. In one study (Lima, 1987) a preview effect of the initial morpheme (such as "rexxxx") for prefixed words (such as "remind") and pseudoprefixed words (such as "relish") was compared to a control condition of a random sequence of letters preview, or a preview consisting of a row of Xs during sentence reading. The results showed a significant, but equal, amount of facilitation for prefixed and pseudo-prefixed words. Likewise, Inhoff (1989b) found no more facilitation from a preview of the first 3 letters of six-letter compound words such as cowboy (cowxxx) than from the first 3 letters of a pseudo-compound words such as carpet (carxxx). Thus, these results from English do not support the notion that morphological information extracted from the parafovea is responsible for the facilitation effect from the parafoveal preview. Nonetheless, a parallel investigation of morphological preview effects in Hebrew seems appropriate. This is because of the robust morphological priming effects that were systematically observed using the masked priming procedure in Hebrew and the presumed similarity between the paradigms of masked priming and assessing parafoveal preview benefit.

Parafoveal preview benefit is assessed either in the context of sentence reading or single word identification. When it is assessed during sentence reading, the duration of fixations on a target word is usually measured. However, when the preview effect is assessed in single word reading, participants are usually required to name the target words. It should be noted that the findings from the two preview paradigms (sentence reading and single word naming) are virtually identical in terms of the effects obtained and even the sizes of the preview benefit. In the current study we assessed the preview effect in the context of single word identification, because it is more similar to the previous studies based on the masked priming paradigm. However, we hope in the future to be able to extend these results to reading of text to be sure that the effects do generalise.

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[3] Parafoveal preview benefit effect was obtained also by orthographic similarity of the three end letters of a word, only when the other characters of the preview stimulus consisted of a sequence of Xs rather than dissimilar letters (Inhoff, 1989a).

EXPERIMENT 1

In Experiment 1, we examined whether a preview of the letters of the root morpheme can facilitate naming of a foveal word. We employed the boundary technique, which consisted of a rapid display change during the saccade when the eyes crossed an invisible boundary between an initial fixation point and the preview stimulus, located to the left of the fixation point (note that Hebrew is read from right to left). It should be emphasised that, given the non-linear characteristics of Hebrew morphology, the root letters did not necessarily consist of a continuous cluster of 3 letters, but were distributed within the word. In the present experiment, the fixation point consisted of a plus sign and the preview stimulus consisted of one of four different types of preview stimuli, defining four experimental conditions. In the identity condition, the preview was identical to the foveal stimulus (i.e., the target word). In the morphologically related condition, the preview consisted of the root letters of the target. In the orthographic control condition, the preview shared three letters with the target, but these letters did not form the target's root. However, since the number of characters of the preview in these two conditions is smaller than the number of letters of the target word, we equated the number of letters of the preview and the target by adding Xs to the preview stimulus. This was done because there is evidence that information regarding word length is extracted from the parafovea to compute the location of the next fixation (Pollatsek & Rayner, 1982; Rayner, Sereno, & Raney, 1996). In the Xs control condition, the preview consisted of a row of Xs which had the same number of characters as the target. The first three conditions replicated the same conditions that were used in the masked priming experiments (without the addition of Xs to equalise the number of characters of the preview and the target stimuli). The fourth condition of the row of Xs was added, since preview effects were never demonstrated before in Hebrew, so that it served as a control baseline to measure the maximum effect that could be inferred for an identity preview.

Method

Participants. The participants were 80 undergraduate students at the Hebrew University, all native speakers of Hebrew, who participated in the experiment for course credit or for payment. All participants either had normal vision or wore corrective lenses.

Stimuli and design. Sixty-four target words were employed. All targets were nominal forms, 4 to 7 letters long and averaged 4.9 letters. The roots from which they were derived consisted of three letters that could not be read as a meaningful word in Hebrew with any possible vowel combination.[4] Similarly, the preview stimuli in the orthographic control condition were three letters that appeared in the target, but could not be read as a meaningful word. Each target word was paired with four different previews to create the four experimental conditions. The position of overlapping letters in the morphologically related and the orthographic control conditions were distributed throughout all positions within the target. However, because the initial letters of a word were found to have a special importance in inducing parafoveal preview benefit, we ensured that the number of overlapping initial letters across stimuli in the morphologically related and orthographic control conditions were balanced. In particular, there were 44 (out of 64) targets in which the first letter of the morphologically related preview overlapped with the target, v. 41 (out of 64) in the orthographic control condition. Among these targets, there were 26 cases in which the first *two* letters of the morphologically related preview overlapped with the target, v. 18 cases in the orthographic control condition. There were only five cases in which the *three* initial letters of the morphological related preview overlapped with the target, v. seven such cases in the orthographically related condition. The latter configuration of overlapping of the three first letters represents in fact a special case of a more general configuration in which the three overlapping letters appear in one sequence. Since the appearance of the preview letters in one sequence in the target may enhance orthographic transparency, we also balanced the number of cases in which the three overlapping letters appeared in one sequence in the morphologically related and the orthographic control conditions, either in the beginning, middle, or end, of the target. There were 20 examples like that in the morphological related condition v. 21 such cases in the orthographic control condition. An example of the stimuli used in the experiment is presented in Table 1.

The stimuli were divided into four lists. Each list contained 16 words in each of the four experimental conditions. The stimuli were rotated within the four conditions in each list by a Latin square design. Twenty participants were tested in each list, allowing each participant to provide data points in each condition, yet avoiding stimulus repetition effects. Stimuli were ordered randomly for one of the lists. This random order was fixed for all the other lists and for all participants.

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[4] Those are roots that are not conjugated with the first verbal-pattern (-A-A-) and are not embedded in any of the nominal-patterns that do not include consonants (such as - e - e-), to form any Hebrew words. Thus, their unpointed printed form represents in fact a non-word.

TABLE 1:
Examples of the stimuli used in Experiment 1

	Identical	*Morphologically related*	*Orthographic control*	*Xs*
Preview	גידוף gydwp[a] /giduf/[b] (cursing)	גדףXX gdp	גיףXX gyp	XXXXX
Target	גידוף	גידוף	גידוף	גידוף

ROOT: gdp, ג ד ף
[a]Orthographic transliteration [b]Phonetic transcription.

Procedure and apparatus. Eye movements were monitored by a SR Research Ltd. (Canada) EYELINK eyetracker. The eyetracker is an infrared video-based tracking system with two cameras (one for each eye) with two infrared 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 previews and the target words were presented on a video monitor (EIZO FlexScan F563/T) which was interfaced to a 586 computer, which in turn was interfaced to another 586 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 point at the centre of the screen, on which the subject had to fixate, while the eyetracker calibration was checked. After calibration was validated, the "preview screen", which consisted of a plus sign at the fixation point and a preview stimulus located to the left of the plus sign, was displayed. The distance between the centre of the plus sign and the first character of the preview stimulus was four character spaces, which was about 2.5 degrees of visual angle. An invisible boundary was located one character to the left of the plus sign. Participants were instructed to move their eyes toward the parafoveal stimulus and name it. When the participant's eyes crossed the invisible boundary, the preview stimulus was replaced by the target word. This display change was accomplished within 10 ms, and thus always took place during the saccade. The target word remained on the screen until participants had responded, and then was replaced by the fixation point to check calibration for the next trial. Naming responses were monitored through a voice key. The experimenter initiated a trial after the calibration was validated. The experiment started with 12 trials of practice.

Results and discussion

The mean latency of the saccade (i.e., the mean fixation duration on the plus sign before subjects moved their eyes towards the preview stimuli) was 216 ms, and was similar for all experimental conditions (Identity: 215 ms, morphology: 216 ms, orthographic control: 216 ms and Xs: 217 ms).

Naming latencies for correct responses in the four experimental conditions were averaged across subjects and across items. (Reaction time was measured from the display change until the onset of the verbal response.) Within each participant, naming latencies that were outside a range of two standard deviations from the participant mean, in each of the four conditions, were discarded. The results are presented in Table 2.

Naming time was fastest in the identical condition. More importantly however, is the fact that naming time in the morphologically related condition was faster than in the orthographic control condition. Naming time was slowest for the Xs preview condition.

These results were subjected to a one-way analysis of variance (ANOVA) with the variable of preview condition. The analysis revealed a significant preview effect both by subjects (F_1) and items (F_2), $F_1(3, 237) = 39.3$, $MSE = 913$, $p < .001$, $F_2(3, 186) = 35.9$, $MSE = 958$, $p < .001$. Planned comparisons revealed that the 12 ms difference between the morphologically related and the orthographic control condition was significant, $F(1, 79) = 8.6$, MSE 1210, $p < .005$, $F_2(1, 62) = 4.1$, $MSE = 1890$, $p < .05$. Analysis of the percentages of errors revealed a significant effect of preview condition $F_1(3, 237) = 2.9$, $MSE = 0.004$, $p < .05$, $F_2(3, 186) = 3.6$, $MSE = 0.002$, $p < .05$. Planned comparisons revealed that this effect stemmed from a higher percentage of errors in the Xs condition relative to the orthographic control condition, $F_1(1, 79) = 8.1$, $MSE = 0.008$, $p < .005$, $F_2(1, 63) = 13.7$, $MSE = 0.003$, $p < .001$.

Thus, the present results demonstrated a clear preview benefit effect, which was apparent whether it was assessed relative to a control condition of Xs [49 ms, $F_1(1, 79) = 100.2$, $MSE = 1977$, $p < .001$ $F_2(1, 63) = 99.8$, $MSE = 1900$, $p < .001$] or relative to an orthographical control condition [37 ms, $F_1(1, 79) = 70.3$, $MSE = 1565$, $p < .001$ $F_2(1, 63) = 62.8$, $MSE = 1720$, $p < .001$] in which the preview shared only three letters with the

TABLE 2

Reaction times (and SD) and percent errors for naming for target words in all conditions in Experiment 1

	Identical	*Morphologically related*	*Orthographic control*	*Xs*
RT (ms)	504 (78)	529 (68)	541 (77)	553 (81)
Errors (%)	4.4%	4.0%	2.6%	5.5%

target. Furthermore, a significant preview benefit effect of 12 ms was observed when the preview consisted of the root, as compared to the orthographic control condition. This outcome replicates the morphological priming effect observed in the masked priming paradigm. Interestingly, the size of the morphological effect obtained in the two paradigms is almost identical, around 12 ms.

EXPERIMENT 2

Prior investigations of parafoveal preview benefit effects indicated that similar results were obtained when the participants moved their eyes towards the parafoveal area (as was the case in Experiment 1), and when the stimulus pattern on the display was changed without participants moving their eyes (Rayner et al., 1978, 1980). Thus, an alternative procedure to assess preview effect is to have participants fixate on one point throughout a trial, and changing the display configuration at a fixed time, rather than being contingent on the eyes' movement towards the preview. That is, the first display consists of a fixation point with a preview stimulus, located in the parafovea. This display is then replaced by a second display, which consists of only the target word, located at the point of fixation. The display change takes place 200 ms after onset, approximating the saccade latency when the display change is contingent on the eyes' movement.

Although the procedure of changing the display contingent on the participants' eye-movements (i.e., the one used in Experiment 1) mimics the natural procedure of reading more closely, the current procedure has the advantage that the experimenter may have better control on the time parameters of the preview presentation. Since both procedures should reveal the same effects, in Experiment 2, we examined the preview benefit effect once again, aiming to replicate the morphological preview effect that was observed in Experiment 1. In addition, in Experiment 2 we investigated the preview benefit in yet another task, the lexical decision task.

Method

Participants. The participants were 72 undergraduate students at the Hebrew University, all native speakers of Hebrew, who participated in the experiment for course credit or for payment. All participants either had normal vision or wore corrective lenses. None of the participants had participated in Experiment 1.

Stimuli and design. The stimuli included the same stimuli that were used in Experiment 1. However, since we monitored latencies in lexical decision in this experiment, 64 nonwords were added as fillers. They had the same word patterns as the target words, but had pseudoroots instead of real roots. For the target words, there were the same four preview conditions (and the same previews) as in Experiment 1. As with the target words, there were four preview conditions for the target nonwords. Thus, the previews for the nonwords were either: (a) the pseudoroot that was the basis for constructing the nonword; (b) another meaningless sequence of three letters that appeared in the nonword target; (c) a row of Xs; (d) or the nonword itself.

The design and apparatus were identical to those of Experiment 1, with the exception that each of the four experimental lists included 128 trials, 64 words and 64 nonwords.

Procedure. Each trial started with a point at the centre of the screen, on which the subject had to fixate, while the eyetracker calibration was checked. After calibration was validated, the "preview screen", which consisted of a plus sign located at the fixation point, and a preview stimulus located to the left of the plus sign, was displayed. The distance between the plus sign and the first character of the preview stimulus was the same as in Experiment 1, i.e., a four character space which constituted about 2.5 degrees of visual angle. Participants were instructed not to move their eyes, and to fixate on the plus sign. After 200 ms the display was replaced, so that the preview stimulus disappeared and the target stimulus was displayed centred to the plus sign. The target stimulus remained on the screen until participants responded, and then was replaced by the fixation point to check calibration for the next trial. The initiation of each trial was controlled by the experimenter after the calibration was validated. The experiment started with 12 trials of practice. Stimuli were ordered randomly for each participant.

Results and discussion

Before analysing the RT, all trials in which participants moved their eyes during the presentation of the plus sign, and deviated more than half a degree of visual angle to the right or to the left of the centre of the plus sign were omitted from the analysis. This procedure was employed to ensure that participants did not fixate on the preview during the 200 ms of preview presentation. The results are presented in Table 3.

As in Experiment 1, reaction time (in the word condition) was fastest in the identity condition. Furthermore, reaction time in the morphologically related condition was faster than in the orthographic control condition. The size of the difference between the morphologically related and orthographic control conditions (15 ms) was very similar to the one

TABLE 3
Reaction times (and S. D.), percent of errors for lexical decision, and percent of deviation from the fixation point for words and nonwords in all conditions in Experiment 2.

	Identical	*Morphologically related*	*Orthographic control*	*Xs*
Words				
RT (ms)	559 (93)	566 (79)	581 (81)	564 (86)
Errors (%)	2.6%	2.0%	3.0%	2.1%
Deviations (%)	14.6%	13.7%	12.7%	10.0%
Nonwords				
RT (ms)	715 (147)	735 (152)	728 (161)	723 (144)
Errors (%)	5.5%	6.3%	5.4%	5.1%
Deviations (%)	14.6%	12.2%	12.5%	8.4%

observed in Experiment 1 (12 ms). A less expected outcome was the relatively fast reaction time in the Xs condition, which was almost as fast as the identical condition.

The response times for words were subjected to a one-way analysis of variance (ANOVA) with the variable of preview condition. The analysis revealed a significant preview effect, $F_1(3, 213) = 4.2$, $MSE = 1483$, $p < .005$, $F_2(3, 189) = 5.7$, $MSE = 2170$, $p < .001$. Planned comparisons revealed that the 15 ms difference between the morphologically related and the orthographic control condition was significant, $F_1(1, 71) = 8.9$, $MSE = 1707$, $p < .005$, $F_2(1, 63) = 4.1$, $MSE = 4758$, $p < .05$. Similar to Experiment 1, the 22 ms difference between the identity and the orthographic control condition was significant, $F_1(1, 71) = 9.9$, $MSE = 3780$, $p < .005$, $F_2(1, 63) = 17.0$, $MSE = 3792$, $p < .001$. A parallel analysis of errors revealed no significant differences, $F_1(3, 213) = 1.1$, $MSE = 0.002$, $p > .05$, $F_2(3, 189) = 1.2$, $MSE = 0.002$, $p > .05$. In addition, the effect of preview condition for the nonwords was not reliable either for RT, $F_1(3, 213) = 1.6$, $MSE = 3168$, $p > .05$, $F_2(3, 189) = 2.3$, $MSE = 3475$, $p > .05$, or for errors, $F_1 < 1$, $F_2 < 1$.

A close inspection of the percentage of "deviations", in which participants moved their eyes from the plus sign before the target was presented, indicates that whereas the percentage of deviations was similar in the identity, morphologically related and orthographic control condition, (about 13%), it was lower in the Xs condition (about 10%). This observation was confirmed by a post-hoc analysis of variance for the percentages of deviations in the four experimental conditions, reflected by a main effect of the preview condition, for words, $F_1(3, 213) = 4.3$, $MSE = 0.007$, $p < .005$, $F_2(3, 189) = 3.7$, $MSE = 0.008$, $p < .012$, as well as for nonwords, $F_1(3, 213) = 7.8$, $MSE = 0.006$, $p < .001$, $F_2(3, 189) = 5.5$, $MSE = 0.008$, $p < .001$.

Although a morphological facilitation relative to an orthographic control was obtained, the relatively low reaction time for the Xs condition certainly requires clarification. Fast RTs to a control condition composed of Xs using this exposure paradigm was previously reported (McClelland & O'Regan, 1981). In that study, a control condition of Xs yielded a shorter naming latency than a control condition composed of letters. We believe that the significantly lower percentage of deviations from the fixation point during the preview presentation may clarify this result. Assuming that parafoveal information is perceived due to an attentional shift from the fovea, the low percentage of deviations in the Xs condition may indicate that the temptation to move the eyes toward the preview was weaker in the Xs condition than in the other conditions composed from letters. This is probably because the Xs being overtly uninformative do not attract much attention as real alphabetic printed stimuli. In other words, after superficial and fast recognition of this type of preview, there is no additional attention that is allocated to further elaborate lexical meaning. Thus, when the target appeared and replaced the plus sign under fixation, participants were attending to it more closely than in the other conditions, in which the preview consisted of Hebrew letters, resulting in a relatively low reaction time for recognising the target. We did not encounter this bias in Experiment 1, because in that experiment participants were instructed to move their eyes towards the preview, and therefore the longest latency in the uninformative Xs condition was obtained. This post-hoc analysis of the deviation percentages may indicate once again, that the parafoveal preview benefit is associated with deeper linguistic levels mediated by attentional factors than mere perceptual processes.

GENERAL DISCUSSION

The present study demonstrated clear evidence for preview effects induced by morphological information while reading single Hebrew words. In Experiment 1, we found that naming target words preceded by a preview of the letters belonging to the root morpheme was faster than naming the same target words preceded by an orthographic control preview. In Experiment 2 we extended our findings to the lexical decision task, using a different preview manipulation which enabled us to provide more precise control of the duration of the preview presentation. Although the information of the preview was not consciously perceived, the presentation of letters belonging to the root morpheme in the preview facilitated lexical decision performance. Taken together, the findings of both experiments converge with previous results in Hebrew using the masked priming paradigm: a robust morphological priming effect was obtained when the briefly presented prime included the root morpheme letters. Thus, these results further support our suggestion that morphological units mediate word identification in Hebrew.

Previous research on the effect of parafoveal preview information on word identification in English indicated that preview benefit is influenced by the spatial location of the shared letters. In particular, the overlap of the first two or three letters seems to be a major contributor to preview benefit. Although a simple account of the impact of the initial letters could be based on low-level visual factors, several experimental findings indicate that a major portion of preview benefit cannot be accounted for by merely considering the spatial location of the initial letters. Instead, it has been suggested that the relative importance of the initial letters reflects their special role in activating lexical entries (e.g., Inhoff, 1989a; Rayner et al., 1980). The results from Hebrew are particularly interesting in the present context because, in contrast to experiments in English, the preview letters in Hebrew, i.e., the root letters, are distributed in all possible positions within the words, causing facilitation regardless of their spatial location. The advantage of a morphologically related condition relative to an orthographic control condition suggests that higher-level linguistic information is used in integrating information across fixations in Hebrew. Our findings indicate that Hebrew readers can extract morphological information from the preview, which may assist them during reading. Thus, the parafoveal presentation of the letters which constitute the root morpheme facilitates the identification of the target word. Since the root letters are not necessarily contiguous units, but are dispersed within the word, Hebrew presents a unique case in which a sub-lexical unit that mediates lexical access and word recognition does not have linear characteristics. Thus, in languages such as English or French, readers may attend more to the first letters of a word, because of their special role in initiating lexical access processes. In contrast, Hebrew readers may be tuned to attend to morphological units, such as the root morpheme, which facilitate the identification of Hebrew words. This status of the root morpheme may represent a special constellation of non-concatenated morphology, in which orthographically non-linear units gain an independent lexical status due to their repetitive occurrence as a three consonantal unit, and/or semantic transparency.

Finally, we would like to point out that although the present results demonstrated morphological preview benefit effects, one should generalise the present results to the natural process of word identification during reading with caution. Note that although the root letters (as well as the letters of the orthographic control condition) in most examples used in the present experiments did not constitute the first two or three letters of the target word, they were indeed presented as the first three letters of the preview. However, in the natural process of reading, if a given root is embedded in a word, its letters are distributed within the previewed word, so that they do not necessarily constitute the first letters of either the preview or the target. At this point, we can only speculate that the same facilitatory effect would be obtained if the preview consisted of a word derived from the same root as the target. This prediction, however, is supported by previous results in the masked priming paradigm which have revealed the same size of morphological priming effect whether the root letters were presented in isolation or whether they were embedded in a word derived from the same root as the target (Frost et al., 1997). Given the present similarities in the results measuring parafoveal preview benefit and masked priming, we assume that the same preview effect would also be obtained if the root was distributed within a preview word. This, however, requires further investigation.

In conclusion, the present study provides evidence of morphological facilitation from a parafoveal preview in a nonconcatenated morphology. As such, our study furnishes corroborating evidence to previous experiments that employed masked priming. Our findings therefore, have implications for models of morphological processing in Hebrew, as well as to current discussions concerning the integration of information across fixations in reading.

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