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Verbs and Nouns Are Organized and Accessed Differently in the Mental Lexicon: Evidence From Hebrew

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A masked priming paradigm was used to examine the role of the root and verbal-pattern morphemes in lexical access within the verbal system of Hebrew. Previous research within the nominal system had showed facilitatory effects from masked primes that shared the same root as the target word, but not when the primes shared the word pattern (R. Frost, K. I. Forster, & A. Deutsch, 1997). In contrast to these findings, facilitatory effects were obtained for both roots and word patterns in the verbal system. In addition, verbal pattern facilitation was obtained even when the primes were pseudoverbs consisting of illegal combinations of roots and verbal patterns. Significant priming was also found when the primes and the targets contained the same root. The results are discussed with reference to the factors that may determine the lexical status of morphological units in lexical organization. A model of morphological processing of Hebrew words is proposed.

The role of morphological units in determining the organization of the mental lexicon is a much debated issue in the psycholinguistic literature (for a review, see Marslen-Wilson, Tyler, Waksler, & Older, 1994). The major controversy concerns the representational organization of morphologically complex words, and consequently the processing stages of their printed forms. Some investigators have suggested that all morphologically complex words are listed in the lexicon independently of the base forms from which they are derived (e.g., Butterworth, 1983; Henderson, Wallis, & Knight, 1984). This view entails that lexical access does not require the decomposition of polymorphemic words into their morphemic constituents, and morphological decomposition is thus a postaccess process (Henderson et al., 1984; Manelis & Tharp, 1977). In contrast, other investigators have suggested that polymorphemic words are mandatorily decomposed into their morphemic units prior to lexical access. According to this model, the base morphemes of words serve as access units in the process of word recognition, rather than their full form (e.g., Taft, 1981; Taft & Forster, 1975). Between these two conflicting suggestions are theories supporting morphological decomposition for some polymorphemic words, but full listing for others (e.g., Stanners, Neiser, Hernon, & Hall, 1979). According to this view, both types of lexical representation may exist simultaneously for multimorphemic words, and the actual process by which a specific word is accessed is a function of various factors, such as the familiarity and frequency of the whole word, as well as the frequency of its morphological components (Burani & Laudanna, 1992; Caramazza, Laudanna, & Romani, 1988; Laudanna & Burani, 1985), or their semantic and phonological transparency (Baayen, 1991; Frauenfelder & Schreuder, 1991).

A requirement for a successful decompositional theory of morphological processing is a clear statement of the parameters that determine which morphological units could serve as access representations for multimorphemic words. For example, studies in English have suggested that the semantic transparency of the base morpheme largely determines its independent status as an access unit (Marslen-Wilson et al., 1994). In another study, Rueckl, Mikolonski, Raveh, Miner, and Mars (1997) showed that both semantic and orthographic transparency may account for morphological processing during word recognition. Fowler, Napps, and Feldman (1985) emphasized, however, the role of orthographic transparency in determining whether a specific morpheme unit can serve as an access representation for a morphologically complex word.

This question, however, is not language-independent. Multimorphemic words are composed according to different morphological principles in different languages. These principles refer, for example, to the distinction between concatenative and nonconcatenative structure (i.e., whether each of the bound morphemes appears as a continuous phonological unit or whether the bound morphemes are interwoven one within the other), or to the distinction between inflectional versus agglutinative structure (i.e., whether the phonological structure of each of the bound morphemes remains unchanged, or whether morpheme bounding entails possible changes in the phonological structure of the constituting

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elements). Because these differences may have important implications for the salience of a word's components they may affect its analysis in the recognition process. For example, results from Hebrew (a highly inflected language based on a nonconcatenative morphology) seem to challenge the findings obtained in English concerning the effect of semantic factors on morphological organization of the lexicon (Bentin & Feldman, 1990; Frost, Forster, & Deutsch, 1997). Based on the examination of the role of the root morpheme in lexical access, Frost et al. (1997) argued that the phonological and orthographic salience of root morphemes in Hebrew gives rise to an efficient and fast decomposition process that is not dependent on semantic transparency.

Note, however, that an unequivocal description of morphological decomposition principles is not simple even within a given language. Differences in the magnitude of morphological priming effects induced by inflectional versus derivational relatedness have been reported in various languages, suggesting different types of representation for inflectional and derivational morphological relations (see, e.g., Stanners et al., 1979, for evidence in English; see Schriefers, Friderici, & Graetz, 1992, for evidence in German; and see Feldman, 1994, for evidence in Serbo-Croatian). Laudanna, Badecker, and Caramazza (1992) found that in Italian, inflections and derivations with the same base morpheme are represented and processed differently: A particular base morpheme served as an independent access unit when it was embedded in a derived form, but not when it was embedded in an inflected form. Laudanna et al. (1992) have therefore suggested that this complex architecture may reflect multiple levels of representation of morphological units.

Thus, a comprehensive metatheory, which describes the general principles by which morphologically complex words are decomposed and accessed, needs to examine different types of morphologically complex words within a language, as well as different linguistic systems with different morphological structures. Thus, while considering the empirical value of mapping the Hebrew Lexicon, or any other lexicon for that manner, we should emphasize that our present investigation is not aimed to offer yet another description of another lexical system. Rather, we assume that studies in other languages with different writing systems could provide converging or contrasting evidence that would allow the formulation of a more general theory of morphological processing: a theory that takes into account the specific characteristics of the orthography and morphology of each language, and determines their implications for the reading processes. Such a metatheory could analyze and predict systematic variations of morphological analyses given systematic variations in morphological structures (Schreuder & Baayen, 1995). Our previous investigation of morphological processing in Hebrew took a step in this direction by examining the role of two morphemes, the root and the word pattern, in lexical access within the nominal system. With the present study, we intend to take another step by providing contrasting and converging evidence from the verbal system. As described in the following section, word-pattern morphemes differ in their semantic transparency characteristics, and in the extent to which they convey morphosyntactic information in the verbal and the nominal systems. Furthermore, they differ in their distributional properties. In this context, Hebrew provides a unique opportunity to examine the implications of these factors for lexical organization and morphological representation.

Derivational Morphology in Hebrew

In Hebrew, as in other Semitic languages, all verbs and the vast majority of nouns and adjectives are comprised of roots that usually consist of three consonants (or sometimes two or four). These roots are embedded in preexisting phonological word patterns to form specific words. Word patterns can be either a sequence of vowels or a sequence consisting of both vowels and consonants. Thus, in general, Hebrew words can be decomposed into two abstract morphemes, the root and the word pattern, but these morphemes are not appended one to the other linearly. Rather the phonemes (and therefore the corresponding letters) of each morpheme are interleaved. It is this feature that makes Hebrew morphology an interesting case for investigating morphological decomposition.[1]

Roots and word patterns are abstract structures; only their joint combination (after the application of phonological rules) forms specific words. For example, the Hebrew word *midraxa* (meaning *pavement* [the international phonetic alphabet character /x/ stands for the fricative velar phone]), consists of the combination of the root morpheme *drx* (conveying the meaning of *stepping*) with the nominal pattern *mi__a_a* (the dashed lines stand for the places where the root's consonants are to be inserted). The same principle also applies to the verbal system. For example, the word *hidrix* (meaning *he directed*) is formed by the same root *drx* interwoven with the verbal pattern *hi__i_*. Thus, the roots usually carry the core meaning of words, whereas grammatical form, word class information, and some vague semantic features are provided by the word patterns. For example, embedding the above root *drx* within the word pattern *_e_e_* forms the word *derex* (meaning *road*). *Derex* and *midraxa* (*pavement*) are semantically related because of the root they share, but their exact meaning cannot be predicted by considering each of their constituting morphemes independently.

It should be noted that because there are many more nominal patterns (above 100) than verbal patterns (only seven), the variety of affixes used by the nominal system is much greater than the variety used by the verbal system. However, the structure of the patterns of the two systems is similar in principle: All patterns include vowel infixes. Furthermore, the same orthographic rules that determine whether a word-pattern vowel would be represented in print

[1] Note that there are also additional morphemes in Hebrew, which are used much less frequently. These morphemes are attached to the stem (which is usually a complex form of a root and a word pattern) linearly, as prefixes or more frequently as suffixes. The present study is limited to the nonconcatenative structure of roots and word patterns.

as a letter or by diacritical points apply for the verbal as well as to the nominal patterns. Despite these similarities, the huge difference in size of the two systems precludes the possibility of having a systematic comparison of the structural aspects of the nominal and the verbal patterns. For example, whereas the verbal patterns may consist of infixed vowels only, or infixed vowels and a prefix, the nominal patterns may also include a suffix (with or without a prefix).

Although Hebrew words are basically composed of two morphemes, these morphemic units play different linguistic roles in the derivational system of Hebrew nouns and verbs. The relative contribution of roots and word patterns to the specification of meaning in the nominal system may differ for specific word patterns. There are word patterns whose grammatical identity and semantic meaning are very clear. For example, the word pattern _a__a_ often denotes a nominal form with the meaning of a profession, such as *nagar* (*a carpenter*) or *tabax* (*a cook*).[2] In contrast, there are word patterns such as _a__i_ that are used in a variety of nouns and adjectives and do not convey any specific meaning.

In the verbal system, however, the role of word patterns is quite different. In contrast to the more than 100 different nominal patterns in which any root can be embedded to form a noun or an adjective, there are only seven different verbal patterns, and each conjugated form must be derived using one of them (Ben-Asher, 1971). Because it is impossible to have a verbal form in Hebrew that is not derived by one of these seven verbal patterns, the same group of seven members repeats itself in the various conjugated verbs, making each form very frequent. The linguistic distinction between word patterns in the verbal and the nominal systems is illustrated also by the use of different linguistic terms to denote them in the two systems: *mishkalim* for the nominal patterns and *binyanim* for the verbal patterns. (For a thorough linguistic description of Hebrew morphology, see Ben-Chaim, 1971.) The huge difference in size of the verbal and the nominal pattern groups can be described as the difference between an open and a closed class system. Whereas no new verbal patterns have been added to the verbal system throughout the known history of the Hebrew language, many new nominal patterns have been added in various periods (Ben-Asher, 1971). Thus, the verbal patterns constitute a very stable element of Hebrew grammar, making the morphological structure of verbal forms very prominent. This characteristic of the verbal pattern system is reflected, for example, in the process by which new words are coined in Hebrew. There are numerous examples of foreign nouns that have been imported into Hebrew and are used in the language in almost their original forms. However, this process in the verbal system is much more constrained. In order for a foreign word to be used as a verb in Hebrew it must be adapted to the grammatical rules of Hebrew grammar: A pseudoroot (usually of three or four consonants) must be extracted from the foreign word in order to be embedded in one of the verbal patterns (Ben-Chaim, 1953). For example, the verbal form *tilpen* (meaning *he called*), contains the four-consonant pseudoroot *tlpn*. This pseudoroot was extracted from the foreign word *telephone* and embedded in the verbal pattern _i__e_, forming a verb analogous to other verbal forms containing a four-consonantal Hebrew root (e.g., *tiftef*, meaning *it dripped*). However, if a root cannot be extracted from a foreign word (if the word contains, e.g., fewer than two or more than four consonants), no new verbal forms can be derived from that word. This feature makes the structure of word patterns in the verbal system very salient, contrasting with the nominal system, which imposes few constraints on the possible nouns (and patterns) imported into Hebrew, and allows the inclusion of words that cannot be decomposed into roots and word patterns.

Another difference between word patterns in the nominal and the verbal systems concerns the consistency of meaning they convey. The derivational process by which roots are derived in many different word patterns is a primary tool to create variations of meanings in Hebrew. For example, the root *zkr*, which has the basic meaning of *memory*, is used with various nominal patterns to express different terms related to this concept. Such derivations are *zikaron (memory)*, *mazkeret (souvenir)*, *mazkir (secretary)*, *mazkirut (secretariat)*, *mizkar (a memorandum)*. A close examination of these derivations reveals a great variation and inconsistency in the meanings conveyed by their nominal patterns. The meaning of the word *mazkir* (*secretary*), for example, is derived from the core meaning of memory (expressed by the root *zkr*) and the nominal pattern *ma__i_*, which sometimes carries a general meaning of *profession*. However, the same nominal pattern may appear in words that do not denote a profession, such as *makshir* (*instrument* [the sequence *sh* stands for the postalveolar voiceless fricative phone]). Furthermore, the meaning of a profession can also be expressed by other nominal patterns, such as _a__a_ in the word *nagar* (*carpenter*), or _a__an, as in the word *kablan* (*contractor*). In most cases, the nominal patterns (*mishkalim*) do not convey clear semantic information. This contrasts with the verbal patterns (*binyanim*), which are often more transparent and consistent, as described below.

The Verbal Patterns

Within the group of seven verbal patterns one can identify an internal system of mutual connections based on relatively consistent semantic relations (Ben-Asher, 1971). It is assumed that the current system of verbal patterns is a remnant of a historically larger system that consisted of three active word patterns, each of which was interrelated with two other patterns to express the passive and the reflexive meanings of the active action. Because the present system of modern Hebrew lacks some patterns, its symmetry is not complete. However, it is possible to link each of the seven existing word patterns to the above-specified meanings of an active, passive, and reflexive action, and outline the interrelation between the various patterns (Blau, 1971). In the following,

[2] The two dashed lines between the two vowels in the pattern _a__a_ represent germination of the second consonant of the root. In pointed Hebrew print this is indicated by a dot inserted in the middle of the second root consonant.

we briefly describe the seven verbal patterns that are traditionally named according to the morphological structure of the base form (i.e., the unmarked inflected form of the singular, third person, in past tense). The unique structural properties of each of the verbal pattern is detailed in Table 1.

The Active Patterns

There are three active patterns: *_a_a_*, *_i__e_*, and *hi__i_*.

*_a_a_*. This usually denotes an active action or a stative verb.

*_i__e_*. A common semantic characteristic ascribed to the *_i__e_* pattern is that of an intense, repetitive action. Another semantic meaning that often characterizes verbs of this pattern is a factitive action, that is, making someone to be or to do something.

*Hi__i_*. This often denotes a causative action of verbs in the *_a_a_* pattern: for example, *kapats* (*he jumped;* the sequence *ts* stands for the alveolar africative voiced phone), and *hikpts* (*he caused something to jump*). But there are many examples of roots derived in the *_a__a_* pattern that do not have a corresponding form in the *hi__i_* pattern, and vice versa (although the latter cases are much less frequent than the former).

The Passive Patterns

The most typical passive patterns are the *_u__a_*, and the *hu__a_*.

*_u__a_* and *hu__a_*. These two passive patterns correspond to the active forms of *_i__e_* and *hi__i_*, respectively. (See the doubling of the second root consonant in both the active *_i__e_* and the passive *_u__a_* patterns, and the prefix *h* in both the active *hi__i_* and the passive *hu__a_* patterns). For example, *hikpits* (*he caused something to jump*) and *hukpats* (*was made to jump*). Thus, for most roots in the *_i__e_* or *hi__i_* active patterns, there are corresponding passive forms in the *_u__a_* or *hu__a_* patterns.

*Ni__a_*. Its original semantic meaning was a reflexive action of the active pattern *_a_a_*. However, presumably as a result of the disappearance of a passive pattern that corresponded to the *_a_a_* pattern, it may also express its passive meaning (Blau, 1971). *ni__a_* may denote active actions as well.

Table 1
The Morphological Characteristics of the Seven Verbal Patterns in Hebrew

Word pattern	Salient morphological characteristics
*_a_a_*	No consonant affixes in the basic form
*_i__e_*	The doubling of the second root
*hi__i_*	The prefix *hi*
*_u__a_*	The doubling of the second root
*hu__a_*	The prefix *hu*
*ni__a_*	The prefix *ni*
*hit_a__e_*	The prefix *hit*

Table 2
The Seven Common Verbal Derivations of the Root ʔkl, Following Ben-Asher (1971)

Verbal pattern	Unpointed Hebrew script and phonetic transcription	English translation
*_a_a_*	אכל *ʔkl* /ʔaxal/	*ate* (active)
*ni__a_*	נאכל *nʔkl* /neʔexal/	*was eaten* (passive)
*_i__e_*	איכל *ʔikl* /ʔikel/	*consumed* (active; intense action)
*_u__a_*	אוכל *ʔukl* /ʔukal/	*was consumed* (passive)
*hi__i_*	האכיל *hʔkil* /heʔexil/	*fed* (active; transitive)
*hu__a_*	הואכל *huʔkl* /huʔaxal/	*was fed* (passive)
*hit_a__e_*	התאכל *huʔkl* /hitʔakel/	*got itself consumed* (rarely used) (reflexive)

Note. Because of phonetic rules, the plosive velar phone /k/ is sometimes pronounced as a fricative velar phone /x/. Similarly, because of the phonetic characteristics of the plosive glottal consonant /ʔ/, the preceding frontal, close vowel /i/ is pronounced as a frontal, half-close vowel /e/.

The Reflexive Pattern

There is only one typical reflexive pattern left in modern Hebrew, the *hit_a__e_* pattern, which is basically the reflexive form of the active *_i__e_* pattern (such as in the word *hitxadesh*, meaning *he renewed himself*). It may also denote a reciprocal action (such as in the word *hitnashek*, meaning *to kiss and to be kissed simultaneously*).

Table 2 illustrates the variation in meaning carried by the various verbal patterns, as it is reflected in the verbal forms derived from the root *ʔkl*, with the core meaning of *eating* (the character /ʔ/ stands for the plosive glottal phone).

Before concluding we would like to emphasize that although each verbal pattern can be characterized semantically in a way that distinguishes it from the other pattern, this description is rather general, and there are many counter examples in the system.[3]

In conclusion, the verbal and the nominal patterns differ in three interrelated aspects: (a) the size of the group—the verbal patterns form a much smaller group than the nominal

[3] A radical opinion, motivated by the existence of counter examples (which might be explained on historical grounds), opposes the attempt to characterize the verbal patterns on the basis of interelated semantic relations (Ornan, 1971).

patterns; (b) the rigidity of the system—the verbal patterns form a grammatically closed system in the sense that no new members can be added to the group, and any verbal form in the language must be adapted in form to one of the existing patterns. (These two aspects actually define the distributional characteristics of the verbal system as a system of small size that all its members repeatedly appear in the language.) (c) The third aspect is semantic transparency: The semantic characteristics of each pattern and the semantic relations between the various patterns are much more restricted in the verbal than the nominal system. Each of the verbal patterns can be characterized semantically in a way that distinguishes it from the other patterns.

Morphological Processes in Word Recognition in Hebrew

Several studies investigating the nominal system of Hebrew have suggested that the processing of printed nouns involves morphological decomposition into roots and word patterns (see Bentin & Frost, 1995, for a review). The influence of the root morpheme on the process of written word recognition was initially demonstrated in a study that examined the repetition priming effect of Hebrew derivations at short and long lags (Bentin & Feldman, 1990). Bentin and Feldman found strong priming effects for root derivations at both lags, for semantically related as well as for semantically unrelated pairs. They consequently suggested that root morphemes serve as an organizational unit in the Hebrew lexicon, and all words derived from the same root are bound to the root morpheme.

Feldman, Frost, and Pnini (1995) examined the morphological processing of Hebrew using the segment shifting task (see Feldman, 1991, 1994, and Stolz & Feldman, 1995, for a similar manipulation in English). Participants were presented with Hebrew words that contained transparent or opaque roots. Transparent roots are roots that appear in several words in Hebrew with a different word pattern each time, to create various semantic meanings. Opaque roots are specific consonant sequences that appear in a single Hebrew word and are not combined with any other word pattern. Although these consonants are formally considered "roots," they do not display the characteristic productivity of Hebrew roots. The participants in Feldman et al.'s (1995) study were required to detach the word patterns from each printed word, to reattach it to a pseudoroot that was subsequently presented, and to name the product of this morphological manipulation as fast as possible. The results showed that word patterns could be detached faster from words with transparent roots than from words with opaque roots. Thus, the "productive" characteristic of a transparent root that appears in more than one word in the language facilitated the morphological decomposition of the printed word into its two combining morphemes. These results suggest that root detachment is a psychologically real process, although not necessarily one that plays an essential part in printed word processing in Hebrew. However, decomposition is more difficult for nouns with nonproductive roots compared with nouns consisting of productive roots.

Although the study by Feldman et al. (1995) clearly established the psychological reality of the morphological structure, it cannot be inferred from this study that the regular process of word identification requires an analysis of the word broken down into its constituents. These questions were investigated in a recent series of experiments (Frost et al., 1997) using the masked priming paradigm, in which participants are usually completely unaware of the nature of the prime (Forster & Davis, 1984). In this study, Frost et al. examined the effect that roots and word patterns exerted as masked primes on lexical decision and naming of nominal targets. For example, the target word *tizmoret* (*orchestra*) includes the root *zmr* (conveying the meaning of *singing*), and the word pattern *ti__o_et*. This target word could be primed by the root letters *zmr*, by another word containing that root (e.g., *zamir*, meaning *a nightingale*), or by a word having the same word pattern as *tizmoret* (e.g., *tikshoret*, meaning *communication*). The effect of these morphologically related primes was examined by assessing their facilitation on lexical decision and naming of the targets in comparison with orthographic controls. The results demonstrated significant priming effects by root letters or nominal derivations containing the root. In accord with previous data on masked priming that suggest that pure semantic facilitation effects are very weak or nonexistent in this paradigm (e.g., Perea, Gotor, Rosa, & Algarabel, 1995), no priming was found when primes and targets were semantically but not morphologically related. The facilitation induced by the root was very stable, occurring in four different experiments. Furthermore, identical facilitation was observed when the root letters could or could not have been read as a meaningful word. In contrast, facilitation was not observed when the primes shared the same word pattern as the targets.

Given these results, Frost et al. (1997) suggested that the lexical structure of the Hebrew lexicon consists of multiple levels of representations: a level of lexical units (i.e., words), and a level of sublexical units (i.e., root morphemes). These two levels are interconnected, so that the root morpheme can be accessed either by means of the lexical level from words containing that root, or directly following a process of morphologically decomposing the orthographic structure. According to this model, printed words can be identified directly from the orthographic structure, but this process can also be aided by access to their respective roots. Thus, the processing of printed words consists of two simultaneous processes: lexical retrieval and morphological decomposition. This duality allows for efficient reading in Hebrew, because morphological analysis in general, and the extraction of root morphemes in particular, provides essential information for integrating the printed word into the semantic context.

Because no priming effect for word patterns was observed, Frost et al. (1997) concluded that word patterns do not govern the process of lexical access. This conclusion seems to be justified in the nominal system, given the large number of nominal word patterns and their inconsistent manner of conveying semantic information. Whereas, in most cases, extracting the root morpheme is very important for integrating the printed noun into its semantic context, the nominal pattern is much less informative. Indeed, all of the experiments in the Frost et al. (1997) study included nominal forms exclusively. Note that the basic assumption underlying this argument is that morphemic units should have an optimal level of specification in order to have a role in lexical access. This assumption should predict, however, that word patterns might have a different effect in the verbal system, given their distributional properties and their greater semantic transparency.

In the present study, we examined the role of the root and word-pattern morpheme in lexical access within the verbal system. We hypothesized that in contrast to the nominal system, verbal patterns will have a more central role in lexical access. According to this suggestion, both roots and word patterns should facilitate lexical access within the verbal system. Confirmation of this hypothesis would suggest that the process of morphological decomposition is variable within a single language, and may be governed by the characteristics of the specific morphological unit. Evidence from the verbal system may add important information for defining the factors that determine the role of a morphological unit in governing lexical access. In particular, it would shed light on the effect of distributional factors and semantic factors in determining the lexical status of morphological units and their role in lexical access. Furthermore, examination of the role of root and word-pattern morphemes in the verbal system is a necessary step in obtaining a comprehensive description of the morphological organization of the mental lexicon in Hebrew, as an example of a nonconcatenative morphological system.

General Method

As in our previous investigation of the nominal system, all of the experiments in the present study were conducted using the masked priming technique developed by Forster and Davis (1984). In masked priming, a forward pattern mask is presented immediately before the prime, and the temporal interval between the onset of the priming stimulus and the subsequent target stimulus 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 latter coming from the target), the prime itself is usually unavailable for report. Participants have no, or very little, direct conscious awareness of the prime. The advantage of this procedure for the current purposes is that the participant's responses are not based on, or influenced by, a conscious appreciation of the relationship between the prime and the target. This reduces the possibility that any priming effect is due to the fact that the participant realizes that the prime and the target often share a common morpheme. A further advantage of the masked priming technique is that masked priming has been shown to be highly sensitive to overlap at the level of form (e.g., Forster, Davis, Schoknecht, & Carter, 1987; Forster & Taft, 1994), but not of meaning. Although masked priming effects for associatively related pairs have been reported (e.g., Sereno, 1991), previous study in our laboratory did not find any facilitation due to purely semantic relations (Frost et al., 1997, Experiments 4 and 5). In that study we had compared the facilitation effect induced by primes that were morphologically and semantically related to the targets with the facilitation effect induced by morphologically related primes that did not include any apparent semantic relation to the targets. A significant priming effect of similar size was found for both cases, regardless of the semantic relation. More important, when the morphologically related primes were replaced by purely semantically related primes, no priming was obtained.

It is important to note that the masked priming procedure has been used mainly to examine the effects of primes on targets that shared a similar orthographic structure, that is, form priming (Forster, 1987; Forster & Davis, 1984; Forster et al., 1987). The extent of priming was traditionally measured by comparing performance in the primed condition with a baseline condition in which the prime was orthographically completely different from the target. However, Frost et al. (1997) extended these findings, showing consistent priming effects due to morphological overlap between prime and targets, in addition to pure orthographic overlap (i.e., number of shared letters), which was kept constant across experimental conditions (see also Forster et al., 1987; Grainger, Cole, & Segui, 1991). In the present study we used a similar strategy, examining whether a masked presentation of verbal patterns or root morphemes facilitates lexical decisions or naming of conjugated verbs. As in our previous study on morphological priming within the nominal system (Frost et al., 1997) morphological effects were assessed relative to orthographic control primes. The control primes always had the same number of letters as the related primes, and the number of shared letters of the related and control primes with the targets was always identical. Because the essence of word similarity in form priming is the orthographic configuration of the prime and the target, orthographic considerations preceded phonological considerations in constructing the stimuli. Thus, the priming effect for the morphologically related condition indicates the additional contribution of the morphological component to simple orthographic effects.[4]

The experiments also included an identity condition, that is a condition in which the prime was identical to the target word. Facilitation in the identity condition constituted an estimation of the maximal priming effect that could be obtained under the specific experimental condition. Another purpose of including that condition was to obtain a control procedure that would verify that the primes were processed and exerting their influence on the targets in spite of the brief exposure.

Experiment 1

This experiment examined the role of verbal patterns in governing lexical access. Both primes and targets were verbal forms that were conjugated with different roots but with identical verbal patterns (e.g., ***hi**lbi**sh**-**hi**kr**i**b*, both conjugated in the *hi__i_* pattern, in bold). Facilitation was determined relative to control primes that shared the same

[4] Facilitation in the related condition was measured relative to a control condition in which the primes had some letter overlap with the targets, and not relative to a neutral condition in which the primes did not overlap with the targets at all. It is possible that the advantage of related over control primes was in part due to some inhibition of the control primes on the targets. Recent results from our laboratory, however, suggest that when the primes are letters contained in the targets, lexical decisions to the targets are somewhat facilitated even if the letters are not the root letters. Thus, assessing the priming effect in the related condition compared to a pure neutral control would necessarily confound simple orthographic form priming with morphologically related priming. Our aim in setting the control baseline in the experiments was to measure the additional contribution of the morphological factor to simple orthographic overlap.

number of letters with the target as the morphologically related primes, but were derived with a different verbal pattern.[5]

In the present research, we used a lexical-decision as well as a naming task for each experiment. Both tasks have been shown to tap lexical processes in Hebrew, and were found to produce similar facilitation in priming experiments (e.g., Frost, 1994, 1995; Frost, Katz, & Bentin, 1987; Frost et al., 1997). The inclusion of the lexical-decision task is especially relevant in the present investigation, in which the influence of word pattern as a morphological unit on word identification was examined. This is because the word pattern determines the phonological structure of the word, so that a word pattern's prime also always entails a clear phonological similarity with the target. Because it is possible that naming would be sensitive to phonological overlap, it might be important to have converging evidence from the lexical-decision task that does not involve word pronunciation. However, because the lexical-decision task also involves a decision phase (e.g., Balota & Chumbley, 1984), data derived from a lexical-decision task only might not be sufficient to reach firm conclusions. The use of both tasks enabled us to obtain converging evidence from two independent experimental procedures, where each of these tasks can compensate for some of the weaknesses involved in the other task.

The experiment thus consisted of two separate subexperiments with different groups of participants in each one. Each subexperiment included three conditions. In the related condition, the primes and the targets were verbal conjugations with two verbal forms containing two different roots, but the same verbal pattern. In the orthographic control condition, primes and targets were verbs with the same number of shared letters as in the related condition, but with different verbal patterns and roots. The third condition was an identity condition in which the primes were identical to the targets.

Method

Participants

The participants were 96 undergraduate students at the Hebrew University, all native speakers of Hebrew, who participated in the experiment for course credit or payment. Forty-eight participants participated in the lexical-decision experiment and 48 in the naming experiment.

Stimuli and Design

The stimuli consisted of 48 target words that were derived from one of the base forms (past, singular, masculine) of one of the following verbal patterns (the numbers in parenthesis denote the number of items derived in each pattern): _i__e_ (10), *hi__i_* (14), *ni__a_* (7), or *hit_a__e_* (10). The target words were four (_i__e_, *ni__a_*) or five (*hi__i_*, *hu__a_*, *hit_a__e_*) letters long and contained two (_i__e_, *hi__i_*, *ni__a_*, *hu__a_*) or three (*hit_a__e_*) syllables with five (_i__e_), six (*hi__i_*, *ni__a_*, *hu__a_*) or eight (*hit_a__e_*) phonemes. The mean number of letters was 4.6 and the mean number of phonemes was 6.2. (We did not use the verbal pattern _a_a, because it represents an ambiguous form: It cannot be distinguished from the root morpheme in unpointed Hebrew, as both consist of a string of three consonants. Furthermore, in unpointed Hebrew, forms derived in this pattern usually represent homophone and/or heterophone pairs of words in which one form of the homograph represents a nominal form and the other a verbal form. Because lexical ambiguity can affect the process of word identification, we could not include forms derived on that verbal pattern within our stimuli.) Each target word was paired with three primes to form the identity, related, and control conditions. Primes and targets overlapped on the average by 2.1 letters and 3.8 phonemes in the related condition, and by 2.0 letters and 3.2 phonemes in the control condition. The position of overlapping letters and phonemes in the related and the control conditions could be initial, middle, or final, with similar distributions in the related and the control conditions. Because the initial letter of a word has a relatively greater role in lexical access, we ensured that the number of overlapping initial letters in the related and control conditions was identical.

Table 3
Examples of Stimuli Used in Experiment 1 in the Identity, Related, and Control Conditions

Stimulus type	Identity	Related	Control
Forward mask	########	########	########
Words			
Prime	/hugdar/	/huklat/	/hitgalesh/
	(*was defined*)	(*was recorded*)	(*he slided*)
	hugdr	*huklt*	*htglsh*
	הוגדר	הוקלט	התגלש
Target	*hugdr*	*hugdr*	*hugdr*
	הוגדר	הוגדר	הוגדר
Nonwords			
Prime	/huldar/	/hublaz/	/hitlagez/
	huldr	*hublz*	*htlgz*
	הולדר	הובלז	התלגז
Target	*huldr*	*huldr*	*huldr*
	הולדר	הולדר	הולדר

Note. Verbal pattern: The passive *hu__a_*. Stimuli were presented in unpointed Hebrew script (which is read right to left) and, therefore, not all of the word pattern vowels were necessarily printed. For example, the vowel /a/ of the word pattern *hu__a_* does not appear in print. The English transliterations above the Hebrew stimuli reflect the actual orthographic structure of the print.

An example of the stimuli used in the experiment is presented in Table 3.

The stimuli were divided into three lists. Each list contained 16 words and 16 nonwords in each of the three experimental conditions. The stimuli were rotated within the three conditions in each list in a Latin-square design. Sixteen different participants were tested on each list, performing a lexical-decision or a naming task. This procedure allowed each participant to provide data points in each condition within one of the experimental tasks, while avoiding stimulus repetition effects.

As in our previous investigation of the nominal system, the stimuli were presented in unpointed Hebrew characters. However,

[5] Note however that although the prime and the target in the control condition were derived from different verbal-patterns, no active–passive pairs of _i__e_–_u__a_ or *hi__i_*–*hu__a_* were included in Experiments 1 and 2. This is because the interrelation between these pairs may resemble an inflectional automatic relation, as was explained in the introduction.

Table 4
Reaction Times (RTs) and Percentage of Errors for Lexical Decision and Naming of Target Words and Target Nonwords in the Identity, Related, and Control Conditions of Experiment 1

	Words			Nonwords		
	Identity	Related	Control	Identity	Related	Control
			Lexical decision			
RT	577	613	627	663	665	677
% error	3.9	8.3	7.5	8.2	8.1	7.7
			Naming			
RT	554	570	581	590	610	610

Note. Related targets shared the same verbal pattern with the primes.

all the words selected for the experiment were phonologically unambiguous, and could be read as a meaningful word in only one way. We used unpointed script because this is the usual way that adults read Hebrew.

From each prime–target word pair, prime–target nonword pairs were constructed, so that the nonwords were composed of the same word patterns as above, but with nonexistent roots. For example, the pseudoword ***huldr*** was generated from the target word ***hugdr,*** which is composed of the root ***gdr*** and the verbal pattern ***hu__a.*** The sequence ***ldr*** is not a root in Hebrew. (See Table 3 for a complete example of nonwords stimuli in the identity, related, and control conditions.) As with the word targets, the nonwords too were divided into three experimental conditions (identity, related, control).

Procedure and Apparatus

The experiment was conducted on an IBM 386 computer. The software used for presentation of stimuli and for measuring the reaction times was the DMASTR display system developed by Kenneth I. Forster and J. C. Forster at the University of Arizona. Each trial consisted of three visual events. The first was a forward mask consisting of a row of eight hash marks that appeared for 500 ms. The mask was immediately followed by the prime with an exposure duration of 42 ms. The prime was in turn immediately followed by the target word, which remained on the screen until participants responded. All visual stimuli were centered in the viewing screen and were superimposed on the preceding stimuli. Although only one Hebrew square font was used, two versions of this font, which differed in their relative size, were used. Targets were always presented in the larger font (20% larger than the primes). This guaranteed complete visual masking of the primes by the targets, and also made the primes and the targets physically distinct stimuli.[6] Stimuli were presented in a random order that varied for each participant.

Participants were instructed to make lexical decisions to the targets by pressing a *yes* or a *no* key on the computer keyboard. Their responses were immediately followed by feedback, printed on the screen, which indicated whether the response was correct, and what was the latency of the response. In the naming experiments latencies were monitored by a Mura DX-118 microphone connected to a voice key. The accuracy of timing depends on two factors: (a) whether the display is synchronized with the position of the video raster, and (b) the method of polling the keyboard. The DMASTR system is synchronized with the video raster, but not with the polling routines. The size of the consequent error in the measurement of the reaction time (RT) was estimated using a photocell and a relay switch, and the mean error was found to be 17.5 ms with a range of 13–23 ms. This means that RTs were effectively overestimated by 17.5 ms, with a random component of no more than 5 ms. The initiation of each trial was controlled by the participants, who pressed the space bar when they were ready. No mention was made of the existence of the primes.

Results

RTs for correct responses in the three experimental conditions in each experiment were averaged across subjects and across items. The effect of outliers was minimized by establishing cutoffs of 2 *SD* units above and below the mean for each participant. Any RTs exceeding these cutoffs were replaced by the cutoff value (i.e., the individual participant mean plus 2 *SDs*). Trials on which an error occurred were discarded. This procedure was repeated in all of the following experiments. The effects of the identity and related primes were assessed relative to the control baseline. We report first the results in the lexical-decision task and subsequently those obtained in the naming task. The results are presented in Table 4.

Lexical Decision

Lexical decisions to targets were facilitated in the identity condition (50 ms) when the prime and the target were the same word. The more interesting result, however, is that lexical decisions to target words in the morphologically related condition were faster than in the control condition (14 ms).

The results were subjected to a two-way analysis of variance (ANOVA) in which the prime condition was one

[6] If the primes and the targets are not cognitively separated, the masked presentation consists virtually of displaying the mask and the target as one prolonged single presentation. Practically, such a display procedure is equivalent to measuring latencies to the targets from primes rather than from target onsets. In English, the separation of primes and targets is often achieved by using uppercase and lowercase scripts. Although Hebrew has two forms of scripts (regular print and cursive), the cursive script is not often used in print, and we therefore adopted the manipulation of size rather than form.

variable and the word list was the other. This procedure was used in all of the following experiments, but we only report the main effect of the prime because the list variable was introduced merely to extract any variance due to counterbalancing.

The prime condition variable was significant in both subject and item analyses, $F_1(2, 90) = 38.3$, $MSE = 825$, $p < .001$; $F_2(2, 90) = 27.4$, $MSE = 1{,}187$, $p < .001$. Planned comparisons revealed that the difference between the related and the control conditions was significant for subjects and for items, $F_1(1, 45) = 4.8$, $MSE = 891$, $p < .03$; $F_2(1, 45) = 4.2$, $MSE = 1{,}196$, $p < .05$. The error analysis revealed a significant effect of prime condition, $F_1(2, 90) = 5.8$, $MSE = 46$, $p < .004$; $F_2(2, 90) = 5.6$, $MSE = 48$, $p < .004$. This was mainly due to fewer errors in the identity condition. The number of errors in the related and the control condition did not differ significantly (F_1, $F_2 < 1.0$). The prime condition appeared to have a slight effect on latencies to nonwords, as RTs in the identity condition were 14 ms faster than in the control condition. This trend did not reach significance, $F_1(2, 90) = 2.9$, $MSE = 969$, $p < .06$; $F_2(2, 90) = 2.6$, $MSE = 967$, $p < .08$, and unlike the results for words, it was not replicated in the error analysis (F_1, $F_2 < 1.0$).

Naming

Naming of targets was facilitated in the identity condition (27 ms). More important, naming latencies in the morphologically related condition were faster than in the control condition (11 ms). ANOVA revealed a significant effect of prime condition in both the subject and item analyses, $F_1(2, 90) = 14.8$, $MSE = 580$, $p < .001$; $F_2(2, 90) = 14.7$, $MSE = 603$, $p < .001$. Planned comparisons revealed that the difference between the related and the control conditions was significant for subjects and for items, $F_1(1, 45) = 3.9$, $MSE = 707$, $p < .05$; $F_2(1, 45) = 3.8$, $MSE = 675$, $p < .05$.

The results for nonwords show a facilitation of 20 ms in the identity condition relative to the control condition, but identical latencies in the related and control conditions. The prime condition effect was significant by subjects and by items, $F_1(2, 90) = 13.4$, $MSE = 484$, $p < .001$; $F_2(2, 90) = 10.3$, $MSE = 756$, $p < .001$. The errors in the naming task were too few to allow a reliable analysis.

Discussion

The results from the lexical-decision and the naming tasks converge and present a similar pattern: A previous exposure to a verb conjugated with a specific verbal pattern facilitated the subsequent recognition of another verb that preserved the verbal pattern but was conjugated with a different root. Facilitation was similar in size in the lexical-decision and the naming tasks (14 and 11 ms, respectively). The facilitation effect induced by verbal patterns presents a striking contrast to parallel experiments within the nominal system, in which word patterns were not found to facilitate lexical decision or naming of the targets. These results lead us to conclude that verbal-pattern morphemes have a role in lexical organization within the verbal system.

Although of a minor theoretical significance, some other findings should be discussed as well. First, a strong facilitation effect was observed in the identity priming condition in both subexperiments (50 and 27 ms for lexical decision and naming, respectively). This condition was expected to produce strong priming effects, and was included merely to confirm that the primes were indeed processed, exerting their influence on the targets in spite of their exposure parameters. A second finding that cannot be easily explained involves the results for nonwords in the lexical-decision task; some facilitation, although marginal, was revealed in the identity condition. Because facilitation in masked priming is related to lexical processes (Forster & Davis, 1984), nonwords should not produce priming because they are not lexically represented. However, such effects do occur occasionally (for a discussion of this issue, see Forster, 1998), but until this effect can be replicated, it may be best to treat it simply as a Type I error. (The results obtained with nonwords in the next experiment reinforce this conclusion.) In contrast to lexical decision, facilitation in the naming task is indeed expected for nonwords. The source of this facilitation is the similar pronunciation routine that is generated for primes and targets having similar onsets. Because in the identity condition the targets were phonologically identical to the primes, the phonological segments assembled from the primes could serve as a basis for computing the final phonological output of the targets. This form of naming facilitation in masked priming was previously reported by Forster and Davis (1991). Because it is due to the convergence of phonological assembly of primes and targets, it appears for both words and nonwords (e.g., Forster & Davis, 1991; Frost et al., 1997).

Experiment 2

Given the theoretical importance of verbal pattern priming, in Experiment 2 we tested the limits of this facilitation. As described in the introduction, most roots do not conjugate with each of the seven verbal patterns. Thus, it is easy to construct pseudowords that are composed of a nonexistent combination of a legal root and a legal verbal pattern. For example, the root *gmr* (which conveys the notion of finishing) cannot be conjugated in the *hi__i_* verbal pattern. Although entities such as *higmir* are unequivocally considered by native Hebrew speakers as nonwords, they can be easily decomposed into their constituent morphemes. (A parallel example in English would be a pseudoword like *costed*, in which the stem *cost* is wrongly combined with the *ed* past-tense morpheme.) The aim of Experiment 2 was to examine whether verbal pattern facilitation can be obtained even when such pseudowords are presented as primes. Significant facilitation of verbal pattern morphemes with pseudoword primes would strongly reinforce our conclusion concerning their status as independent lexical units.

Table 5
Examples of Stimuli Used in Experiment 2 in the Identity, Related, and Control Conditions

Stimulus type	Identity	Related	Control
Forward mask	########	########	########
Words			
Prime	/hilbish/ (*he dressed*)	/higmir/	/hitbadek/
	hlbish	*hgmir*	*htbdk*
	הלביש	הגמיר	התבדק
Target	*hlbish*	*hlbish*	*hlbish*
	הלביש	הלביש	הלביש
Nonwords			
Prime	/hilbir/	/higmin/	/hitbaxez/
	hlbir	*hgmin*	*htbxz*
	הלביר	הגמין	התבחז
Target	*hlbir*	*hlbir*	*hlbir*
	הלביר	הלביר	הלביר

Note. Primes were nonexisting combinations of roots and verbal patterns. The verbal pattern was the active *hi_ _i_* (first vowel does not appear in print). Forms in the related and control conditions had no meaning.

Method

Participants

The participants were 96 undergraduate students at the Hebrew University, all native speakers of Hebrew, who participated in the experiment for course credit or for payment. Forty-eight participants were assigned to the lexical-decision experiment and 48 to the naming experiment. None of the participants had participated in Experiment 1.

Stimuli and Design

The stimuli consisted of 48 target words that were derived from one of the base forms (past, singular, masculine) of one of the following verbal patterns (the numbers in parenthesis denote the number of items derived in each pattern): *_i__e_* (6), *hi__i_* (16), *ni__a_* (8), *hu__a_* (6), or *hit_a__e_* (12). The numbers of letters, syllables, and morphemes for each of these patterns are identical to those described for the stimuli in Experiment 1. The mean number of letters was 4.7 and the mean number of phonemes was 6.4.

Each target was paired with three primes. In the identity condition primes and targets were identical, whereas in the related condition the primes were pseudowords consisting of nonexistent combinations of legal roots with the same verbal patterns as the targets. In the control condition the primes were also pseudowords, but they were composed of a different root and a different verbal pattern than the targets, yet preserving the same orthographic overlap with the targets as the primes in the related condition. Primes and targets overlapped on the average by 2.3 letters and 3.9 phonemes in the related condition, and by 2.3 letters and 3.2 phonemes in the control condition. The position of overlapping letters and phonemes in the related and the control conditions could be initial, middle, or final, with similar distributions in the two conditions. An example of the stimuli used in the experiment is presented in Table 5.

As in Experiment 1, in order to create the nonwords from each target word and its prime, target–prime nonwords were generated. Thus, nonwords were composed of the same word patterns as the words but had nonexistent roots. Similar to the word targets, the nonwords too were divided into three experimental conditions (identity, related, control). Note that the primes in the experiments were all nonexistent words. The difference between the words and the nonword trials was that the primes for the words contained existing roots, whereas the primes for the nonwords included nonexistent roots. The procedure and apparatus were identical to those in the previous experiments.

Results

RTs in the three experimental conditions for the two tasks were averaged across subjects and across items and are presented in Table 6. The pattern of results was very similar to Experiment 1 with word primes. We report first the results of the lexical-decision task and subsequently those obtained in the naming task.

Lexical Decision

As in the previous experiment, lexical decisions to targets were facilitated in both the identity condition (51 ms) and the morphologically related condition (13 ms), in comparison with the control condition. The results were subjected to a two-way ANOVA. The prime condition variable was significant in both subject and item analyses, $F_1(2, 90) = 51.2$, $MSE = 671$, $p < .001$; $F_2(2, 90) = 44.7$, $MSE = 790$,

Table 6
Reaction Times (RTs) and Percentage of Errors for Lexical Decision and Naming of Target Words and Target Nonwords in the Identity, Related, and Control Conditions of Experiment 2

	Words			Nonwords		
	Identity	Related	Control	Identity	Related	Control
			Lexical decision			
RT	550	588	601	639	648	648
% error	5.2	7.7	8.1	7.4	7.7	7.1
			Naming			
RT	555	574	585	584	606	611

Note. Related targets shared the same verbal pattern with the primes; primes were pseudowords.

$p < .001$. Planned comparisons revealed that the difference between the related and the control conditions was significant for subjects and for items, $F_1(1, 45) = 5.0$, $MSE = 769$, $p < .03$; $F_2(1, 45) = 3.6$, $MSE = 899$, $p < .06$. The error analysis revealed a marginally significant prime condition effect in the subject analysis, $F_1(2, 90) = 2.8$, $MSE = 41$, $p < .07$, and a nonsignificant effect in the item analysis, $F_2(2, 90) = 2.2$, $MSE = 52$, $p < .1$. This was mainly due to fewer errors in the identity condition. The number of errors in the related and the control condition did not differ significantly ($F_1, F_2 < 1.0$). The prime condition had no significant effect on nonwords for RTs, $F_1(2, 90) = 1.3$, $MSE = 922$; $F_2(2, 90) = 1.8$, $MSE = 860$, or for errors ($F_1, F_2 < 1.0$).

Naming

As with the results in the lexical-decision task, naming of targets was facilitated in both the identity condition (30 ms) and the morphologically related condition (11 ms). ANOVA revealed a significant effect of prime condition in the subject and item analyses, $F_1(2, 90) = 17.3$, $MSE = 645$, $p < .001$; $F_2(2, 90) = 20.8$, $MSE = 538$, $p < .001$. Planned comparisons revealed that the difference between the related and the control condition was significant for subjects and for items, $F_1(1, 45) = 4.3$, $MSE = 672$, $p < .04$; $F_2(1, 45) = 5.3$, $MSE = 576$, $p < .03$.

As in Experiment 1, the results for nonwords show a facilitation of 27 ms in the identity condition compared with the control condition. The prime condition was significant by subjects and by items, $F_1(2, 90) = 14.6$, $MSE = 651$, $p < .001$; $F_2(2, 90) = 11.7$, $MSE = 793$, $p < .001$. The difference between the related and control conditions (5 ms) was not significant ($F_1, F_2 < 1.0$). The errors in the naming task were too few to allow a reliable analysis.

Discussion

The results of Experiment 2 provide strong support for the role of verbal patterns in lexical access. As in Experiment 1, primes constructed of the same verbal pattern as the targets facilitated both lexical decision and naming of targets. This outcome suggests that morphological decomposition of verbal forms occurs even when the printed word consists of a nonexistent combination of a root and a verbal pattern. The extracted verbal patterns thus facilitate lexical retrieval of verbal forms conjugated with them, thereby demonstrating that the process of verbal pattern extraction is independent of accessing a whole word unit. This has important implications for modeling morphological decomposition in Hebrew, and we discuss it in detail in the General Discussion.

Before concluding, we would like to refer to the absence of priming effect for nonwords. Because the nonwords in Experiment 2 and Experiment 1 were constructed similarly, this outcome strengthens the conclusion that the facilitation obtained for nonwords in the identity condition of Experiment 1 was indeed a Type I error.

Experiment 3

The finding that word pattern morphemes facilitate lexical access for conjugated verbs does not contravene the possibility that roots have a facilitatory effect as well. The aim of Experiment 3 was to establish whether the root morpheme is also a mediating unit of lexical access in the verbal system, as it is in the nominal system. Our previous investigation of the nominal system of Hebrew revealed robust priming effects induced by root morphemes. These effects were obtained regardless of whether the root letters could be read as a meaningful word, or whether the prime consisted of the root morpheme itself, or whether it was derived from the same root as the target (Frost et al., 1997). The present experiment was designed to extend these findings to the verbal system and examine whether a derived verbal form can prime another verbal form containing the same root.

The experiment included three conditions. In the related condition, the primes and targets were verbal derivations of the same root, that is, two conjugated verbal forms consisting of two different verbal patterns, but with the same root (i.e., ***hitlabesh–hilbish***; verbal pattern in bold). In the orthographic control condition, primes and targets were words with the same number of shared letters as in the related condition, but with different verbal patterns and different roots. The third condition was an identity condition in which the primes were identical to the targets. On the basis of our previous findings in the nominal system, which showed that Hebrew roots are lexical units that mediate lexical access, we predicted that verbal targets would be facilitated by verbal forms derived from the same root.

Method

Participants

The participants were 96 undergraduate students at the Hebrew University, all native speakers of Hebrew, who participated in the experiment for course credit or for payment. Forty-eight participants were assigned to the lexical-decision experiment and 48 to the naming experiment. None of the participants had participated in the previous experiments.

Stimuli and Design

The stimuli consisted of 48 target words that were derived from one of the base forms (past, singular, masculine) of one of the following verbal patterns (the numbers in parenthesis denote the number of items derived in each pattern): *_i__e_* (3), *hi__i_* (7), *ni__a_* (8), *hu__a_* (1), or *hit_a__e_* (29). The numbers of letters, syllables, and morphemes for each of these patterns are identical to those described for the stimuli in Experiment 1. The mean number of letters was 4.8 and the mean number of phonemes was 7.2. The target words were paired with 48 verbal forms, to create the three experimental conditions: identity, related, and control. An example of the stimuli used in the experiment is presented in Table 7.

Primes and targets always had the same number of letters in both the related and control conditions. The position and number of letters shared with the target were determined by the specific word patterns. On the average, primes and targets in both the related and the control conditions shared 3.7 letters. The mean number of shared phonemes of the primes and the targets in the related

Table 7
Examples of Stimuli Used in Experiment 3 in the Identity, Related, and Control Conditions

Stimulus type	Identity	Related	Control
Forward mask	########	########	########
Words			
Prime	/hilbish/ (*he dressed*) *hlbish* הלביש	/hitlabesh/ (*he got dressed*) *htlbsh* התלבש	/hitbayesh/ (*got shy*) *htbysh* התביש
Target	*hlbish* הלביש	*hlbish* הלביש	*hlbish* הלביש
Nonwords			
Prime	/hilnish/ *hlnish* הלניש	/hitlanesh/ *htlnsh* התלנש	/hitnayesh/ *htnysh* התניש
Target	*hlnish* הלניש	*hlnish* הלניש	*hlnish* הלניש

Note. Primes and targets in the related condition were conjugations with the same root but different verbal patterns. The root *lbsh* conveys the action of dressing.

condition was 4.8, and in the control condition 4.4. The position of overlapping letters in the related and the control conditions could be initial, middle, or final, given the specific verbal pattern, with similar distributions in the related and the control conditions. Given the probable greater importance of the initial letter in masked priming paradigm (Forster & Davis, 1991), in almost all cases (92%) in which the prime in the related condition had the same initial letter as the target, the prime in the control condition also had the same initial letter, and vice versa. Each target word and its prime were paired with target and prime nonwords. As in Experiments 1 and 2, the nonwords were composed of the same word pattern as above, but with pseudoroots. As with the word targets, the nonwords too were divided into three experimental conditions (identity, related, control). The procedure and apparatus were identical to those used in the previous experiments.

Results

RTs in the three experimental conditions for the two tasks were averaged across subjects and across items and are presented in Table 8. We report first the results in the lexical-decision task and subsequently those obtained in the naming task.

Lexical Decision

Lexical decisions to targets were facilitated in the identity condition (29 ms) when the primes and the targets were the same word. In addition, lexical decisions to target words in the morphologically related condition were faster than in the control condition (13 ms).

The results were subjected to a two-way ANOVA in which the prime condition was one variable and the word list was the other. The prime condition variable was significant in both subject and item analyses, $F_1(2, 90) = 9.8$, $MSE = 1{,}030$, $p < .001$; $F_2(2, 90) = 9.3$, $MSE = 964$, $p < .001$. Planned comparisons revealed that the difference between the related and the control conditions was significant for subjects and marginal for items, $F_1(1, 45) = 5.0$, $MSE = 775$, $p < .05$; $F_2(1, 45) = 3.4$, $MSE = 899$, $p = .07$. No effects of prime conditions were found in the error analysis, $F_1(2, 90) = 1.1$, MSE $= 40$, $p < .3$; $F_2(2, 90) = 2.3$, MSE $= 108$, $p < .1$. The prime condition had no effect on nonwords in either the RT, $F_1(2, 90) = 1.2$, $MSE = 1054$, $p < .3$; $F_2 < 1.0$, or the error measure (F_1, $F_2 < 1.0$).

Naming

Naming of targets was facilitated in the identity condition (16 ms) and in the morphologically related condition (9 ms). The prime condition variable was significant in both subject and item analyses, $F_1(2, 90) = 9.6$, $MSE = 345$, $p < .001$; $F_1(2, 90) = 6.9$, $MSE = 477$, $p < .001$. Although the priming effect was relatively small, planned comparisons revealed that the difference between the related and the control conditions was significant both for subjects and for items, $F_1(1, 45) = 5.3$, $MSE = 357$, $p < .03$; $F_2(1, 45) = 4.0$, $MSE = 471$, $p < .05$. The prime condition was significant for nonwords, $F_1(2, 90) = 8.3$, $MSE = 565$, $p < .005$; $F_2(2, 90) = 5.2$, $MSE = 840$, $p < .007$. This was mainly due to faster naming latencies in the identity condition (20 ms). Planned comparisons revealed that the difference between the related and the control condition for nonwords was not significant either by subjects or by items, $F_1(1, 45) = 2.4$, $MSE = 594$, $p < .12$; $F_2(1, 45) = 1.5$, $MSE = 808$, $p < .23$. Errors were too few to allow a reliable analysis.

Table 8
Reaction Times (RTs) and Percentage of Errors for Lexical Decision and Naming of Target Words and Target Nonwords in the Identity, Related, and Control Conditions of Experiment 3

	Words			Nonwords		
	Identity	Related	Control	Identity	Related	Control
Lexical decision						
RT	581	597	610	659	667	658
% error	6.2	7.9	7.7	11.8	11.9	12.9
Naming						
RT	548	555	564	579	591	599

Note. Related targets shared the same root with the primes.

Discussion

The results of Experiment 3 suggest that the perception of verbal forms is facilitated by the root morpheme. The facilitation effect was reflected by a shorter RT for lexical-decision and naming tasks in which the target and prime shared the same consonantal root (the related condition), as compared to a control condition in which the target and prime shared three letters that did not constitute a root morpheme.

In contrast to the different role of word patterns in the nominal and verbal system (Frost et al., 1997), the current results for the verbal system replicate our results for the nominal system, where nominal forms were facilitated by primes derived from the same root as the target. This accordance in findings may indicate that when the root morpheme is processed, similar lexical processes occur for nominal and for verbal forms. Accordingly, lexical access for nouns, as well as for verbal forms, includes a process of morphological decomposition in which the root morpheme is extracted.

General Discussion

The present study examined the role of root and verbal pattern morphemes in governing lexical organization and lexical access of conjugated verbs. This investigation was designed to provide a comparison between the results obtained with verbs and previous findings obtained with nouns. Our hypothesis concerned particularly the different lexical status of the nominal and the verbal word-pattern morphemes. Experiments within the nominal system revealed that nominal word patterns had no influence on lexical access of nouns (Frost et al., 1997). In contrast to these findings, we hypothesized that verbal patterns should have an important role in the processing of verbal forms because of the properties of verbal patterns that distinguish them from nominal patterns, namely, semantic transparency and frequency of appearance. The results confirmed our hypothesis. A similar facilitation effect was obtained in the lexical-decision and the naming tasks when the targets and the primes were conjugated with an identical verbal pattern. Moreover, verbal pattern facilitation was revealed even when the primes were pseudoverbs consisting of nonexistent combinations of roots and verbal patterns. In addition, a similar facilitation was obtained when the primes and the targets contained the same root.

Our working hypothesis using masked priming is that facilitation in this paradigm reflects a transfer effect; that is, the result of processing carried out on the prime is transferred across to the target. This transfer is made possible when the prime and targets have overlapping representations. This assumption is based on several studies showing that the brief exposure of the prime, in which it is unconsciously perceived, results in a facilitation of target identification that is due to orthographic overlap (see Forster, 1987, for a review). However, in the case of morphological priming this account has to be extended, because the priming effect cannot be explained merely in terms of orthographic similarity. It is, therefore, necessary to assume that there are additional units that are shared between the prime and target, and that these units are activated whenever the prime or the target is recognized. We suggest that these lexical units are morphemic in nature.

Under this assumption, we have recently proposed a model for the lexical organization and morphological processing of nominal forms (Frost et al., 1997). According to this model the Hebrew lexicon consists of two levels of representation: a level of lexical units (words) and a level of subword morphological units (root morphemes). The processing of printed words thus consists of both a lexical retrieval process in which a lexical unit is located at the word level, and a morphological decomposition process in which the root morpheme is extracted and located on the subword, morphological level. These two processes may occur simultaneously, and may aid each other through bidirectional connections between the two levels (for a detailed description of the empirical findings constraining this architecture, see Frost et al., 1997). According to this model, all words derived from the same root are clustered via a shared representation of the root morpheme. This organization is independent of semantic factors, because the facilitation effect induced by the root morpheme was found to be insensitive to semantic relatedness between the basic meaning of the root and the meaning of the target.

On the basis of the present results from the verbal system, we propose an extension of this model to incorporate the representation and processing of verbal forms as well (see Figure 1). In light of the findings of Experiment 3, which demonstrated significant priming effects when primes and targets were conjugated with the same root, our extended model proposes first, that all words, whether nouns or verbs, which are derived from the same root, are linked to a shared morphological unit corresponding to the root. This unity in the principle of organization of both nouns and verbs is further supported by a recent study conducted in our laboratory that revealed a similar facilitation for target verbal forms when the primes consisted of nominal forms providing that they share the root morpheme. Thus, it seems that the facilitation effect induced by root morphemes crosses the word-class boundary. The claim that the root morpheme forms the basis of a similar principle of organization for verbs as well as nouns, seems to be reasonable on theoretical grounds too, in light of the fact that there is only one root system in the language, which forms the basis of the nominal and the verbal systems by the same principles of derivational morphology.

However, the most striking result of the present study is the consistent facilitation induced by verbal patterns. This outcome contrasts with previous findings within the nominal system, and apparently derives from the specific morphological properties of the Hebrew verbal system. Our model in Figure 1 suggests that, for conjugated verbs, the verbal pattern morphemes as well as the roots are represented on the subword morphological level, in addition to the roots, and all verbal forms derived from the same verbal pattern morpheme are linked to that shared morphological unit. Thus, according to this extended model, there is a multiple

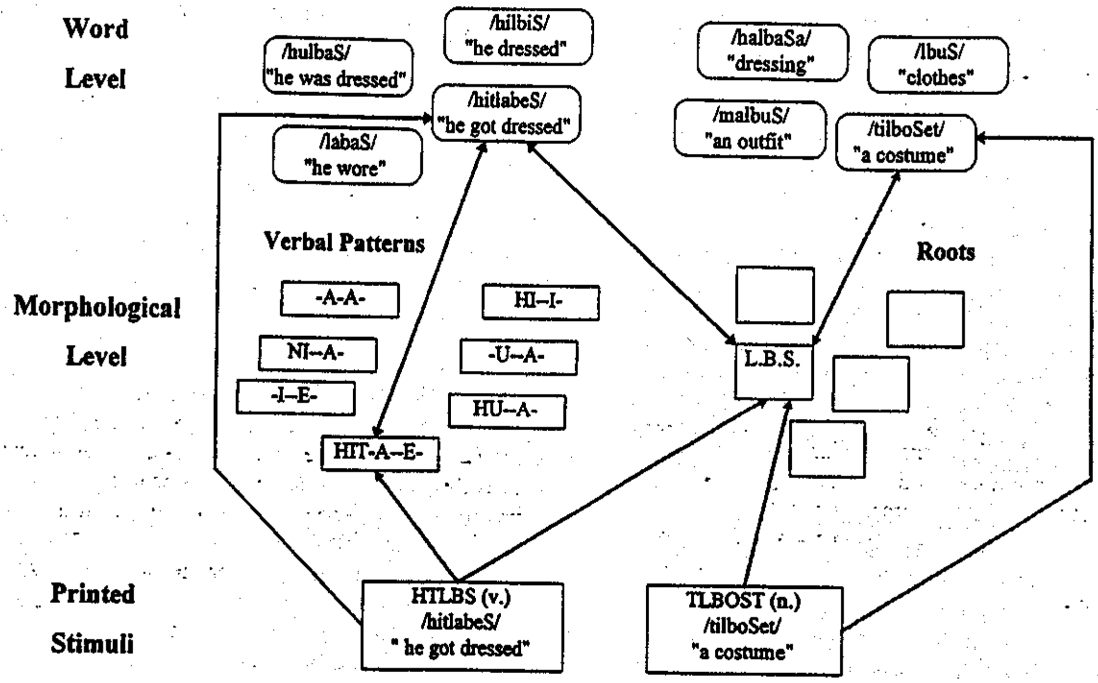

Figure 1. A model of the internal organization of the Hebrew lexicon and the process involved in the recognition of nominal (n.) and verbal (v.) printed forms.

system of connections between the word level and the subword morphological level. One set of links connects word units with root units, and another set connects word units with word-pattern units. As with nominal forms, the processing of verbal forms has two parts: morphological decomposition and whole-word search. However, whereas the essence of morphological decomposition for nominal forms entails only the extraction of the root morpheme, this process for verbs entails the extraction and identification of their two fundamental morphemes, the root and the verbal pattern.

Evidence in support of a morphological decomposition process that is not based on a postlexical analysis of the whole word can be found in the results of Experiment 2. In this experiment verbal targets were facilitated by the previous presentation of nonword primes that were nonexistent combinations of real roots and real verbal patterns. Thus, although the prime could not be located as a lexical unit in the word level, its morphological components affected the lexical processing of the target. This suggests that the decomposition of verbal forms into roots and patterns is a relatively simple computational process that can be easily performed by the native speaker, probably because of the small number of verbal patterns in Hebrew and their phonological transparency.

This finding diverges from the previous findings in the nominal system. Although a robust facilitation was revealed with root primes, priming was not obtained for root plus nominal-pattern combinations that did not represent existing words in Hebrew (Frost et al., 1997, Experiment 6). The contrasting findings in the nominal and the verbal systems can be accounted for by considering the nature of the morphemic unit that has to be extracted from the nonword prime. In our previous study of nominal forms, we suggested that roots cannot be easily extracted from a long sequence of letters because there is often more than one alternative combination of consonants that could, in principle, be the root. If the prime is a nonword, the extraction process cannot be aided by a parallel access to a lexical unit in the word level, which provides confirmatory information concerning the embedded root. For example, the nonword *mslxh* could, in principle, be analyzed as containing the roots *msl* (*governing*) or *slx* (*sending*). However, in contrast to the huge number of root morphemes that are considered as possible candidates in the root extraction process, there is only a very limited number of verbal patterns, and each one of them has very distinct characteristics. Thus, the recognition of a specific word pattern from a limited number of candidates is probably a simpler computational process.

The different roles observed for the nominal and the verbal patterns may provide insight into the factors that determine whether a specific morpheme would gain the status of a lexical unit, thereby governing lexical access. The current results from the verbal system present the roots and the verbal patterns as having a parallel lexical status, whereas in the nominal system only the roots were found to govern lexical organization. But although the semantic characteristics of the verbal patterns are more specific than those of the various nominal patterns, they are still rather general, and usually much less consistent than the semantic characteristics of the roots. Thus, in addition to semantic considerations, the distributional properties of verbal patterns probably account for their lexical role as well; verbal patterns consist of a very small closed class system and consequently the native speaker is repeatedly exposed to their phonological structure. Consequently, it seems that the factors that may determine whether a morphological unit has a role in lexical organization entail a fine balance between semantic factors and distributional properties. The differential role of the nominal and the verbal patterns suggests how this tuning can result in a different lexical status for a similar morphological unit within a language—in the present case, the word pattern. Similar conclusions were recently suggested by Laudanna and Burani (1995), who investigated derivational morphology in Italian. In their study, they showed that processes of morphological decomposition are determined by the interrelation between orthographic transparency and the distributional properties of the morphemic constituents.

The observed difference between the verbal and the nominal patterns may be regarded as analogous to the difference found between productive and nonproductive roots using the segment shifting task (see above, Feldman et al., 1995). In that study the ease by which participants could segment a word pattern from a root was found to be related to the root productivity (i.e., its distributional characteristics). It was easier to segment a word pattern from a word consisting of a root that appears with many word patterns in the language (i.e., a productive root) than from a root that combines with only one word pattern in the language. The same principle of distributional properties can be applied to our present investigation: When a morpheme is common to more words in the language, its impact on processes of morphological decomposition is more prominent. (For a similar conclusion, see the combinability effect on the recognition of Chinese characters, as was observed by Feldman & Siok, 1997. Combinability is defined as the tendency of a morphemic unit to enter into few or many combinations to form phonetic compounds.)

All of these differences between the nominal and the verbal patterns treat verbs and nouns as isolated words. However, words are usually accessed in a sentential context and not in isolation. Nouns and verbs differ in the syntactic function they usually have in the language, with verbs usually serving as the predicate of a sentence. However, the morphological structure of the verbal form, that is, its verbal pattern, constrains the syntactic analysis of the sentence by determining the transitivity of the verb, and consequently influences the sentential voice as passive or active. Thus, whereas the distinction between various nominal patterns is less essential for the basic syntactic analysis of the linguistic input, the identification of the exact verbal pattern in the main verb may often be crucial for the initial stages of syntactic analysis. Hence, although the extraction of the root morpheme is important for the process of integrating the semantic context of the word, the extraction of the verbal-pattern morpheme is important for integrating the syntactic structure of the sentence in which it appears. This may explain why both roots and verbal patterns develop to be organizing components for verbs in the mental lexicon (for a similar suggestion regarding the effects of semantic transparency and syntactic function of morphological units on their lexical status as independent units, see Schreuder & Baayen, 1995).

The role ascribed to the semantic factor in determining the lexical status of a morphological unit may seem to contradict our previous claim stating that the lexical organization via shared root morphemes is independent of semantic relations between the roots and their derivations (Frost et al., 1997). This claim was based on empirical findings showing similar morphological priming effects for root derivations regardless of semantic relation (Frost et al., 1997, Experiment 5). Note however, that for the majority of words in Hebrew, the semantic relation between the root and its derivations is transparent. The opaque cases are the irregular cases. Thus, the perception of semantic relations between derived forms that contain identical phonological structures is in fact the essence of acquiring a lexicon organized according to morphological principle, for root as well as for verbal pattern morphemes. However, once this organization becomes fully developed for the mature native speaker, it is possible that this principle of lexical organization becomes formalized and applied to all morphological units regardless of the semantic relation between them. Because Frost et al. (1997) examined mature readers, their results reflect the lexical organization of an adult, native speaker, which is no longer based on purely semantic considerations.

Further support for the notion of the lexical representation of verbal patterns comes from the domain of language development, and particularly the acquisition of predicate transitivity by children. Research on the development of transitivity marking in Hebrew has revealed that at an early stage children cannot decompose verbal forms into their morphemic constituents, as no productive process of embedding roots in various verbal patterns is apparent (Berman, 1982, 1994). Children seem to express different verb-argument configurations before they can express these meaning variations through the appropriate use of verbal patterns (see Berman, 1994, for a detailed discussion). However, at about the age of six, children master the derivational features of the verbs, suggesting that verbal-pattern representations are established in the lexicon. This stage is preceded by frequent "creative" errors of speech production, in which children produce nonexisting combinations of legal roots and legal word patterns, similar to the stimuli we composed in Experiment 2. Only later do these errors disappear, suggesting that the word-pattern representations are interconnected with the whole-word representations acquired previously. Our proposal that semantic and distributional factors determine the lexical status of a morphological unit is in accordance with Berman's suggestion that the order of acquisition of the various verbal patterns by children is determined by the relative semantic and syntactic transparency of the verbal patterns, as well as their distributional properties. (See also Schreuder & Baayen's, 1995, discussion on the acquisition of morphological representations.)

Our model of morphological decomposition and the terms we use in our description of lexical structure are compatible with a localist view of the mental lexicon. Our discussion cannot be complete without describing the possible connections to a family of recent models that posit a nonlocalist approach to lexical representation. In general, these models describe a lexical structure in which word units are not explicitly represented, and the process of word recognition entails the setting of mutually consistent patterns of activation over processing units that correspond to the orthographic, phonological, and semantic features of the word. The establishment of such activation patterns results from a dynamic resonance between the different sublinguistic processing units that interact with each other until they achieve a resonant state. The learning process of this system consists of attuning the reader to the statistical regularity that emerges between these various sublexical features (see, e.g., Plaut & Shallice, 1993; Seidenberg & McClelland, 1989; Stone & Van Orden, 1993; Van Orden, Pennington, & Stone, 1990). When morphological processing is discussed, nonlocalist models contend that many (if not all) of the morphological effects previously reported in the literature reflect a fine tuning of the reader or speaker to the correlation that exist between the phonological, orthographic, and semantic properties of words. Thus, according to this approach there is no level of explicit representation that corresponds to morphological units. All that can be said is that a level of hidden units picks up the correlation between phonology and semantics or orthography and semantics, and these underlie the morphological effects (e.g., Rueckl et al., 1997; Seidenberg, 1987; Seidenberg & McClelland, 1989).

Although localist and distributed approaches to lexical structure are opposing paradigms (see Besner, in press; Forster, 1994, for a discussion), distinguishing between them on the basis of pure empirical evidence is not a simple matter. When morphological processing is concerned, the localist view and the parallel-distributed processing (PDP) approach often yield similar predictions. For example, both views predict similar effects of morphological repetition priming. The PDP paradigm will regard it as a learning process in which weight changes occur in the connections within the semantic layer and between the semantic, orthographic, and the phonological layers. This would result from the exposure of the speaker to words such as regular inflections and derivations, having similar forms and similar meaning (see Rueckl et al., 1997, for a detailed discussion). In contrast, localist approaches assume that morphologically related words are interconnected in the lexicon directly, or indirectly through their shared morpheme. Thus, when two morphologically related words are sequentially presented, priming occurs due to the partial activation of morphologically related words via these interconnections. More relevant to the present discussion, the connectionist distributed approach could easily account for morphological effects in masked priming by focusing on the distributional properties of morphemic units, suggesting that roots or word patterns are orthographic and phonological clusters that tend to be repeatedly associated with the same or similar semantic correlates. By this view the results we obtained with masked priming reflect the higher correlation between primes and targets in the related condition relative to the control condition, given the frequent exposure of readers to the root and the word-pattern's letters or phonological forms, and given their systematic correlation with semantic features. Thus, both localist and PDP approaches can account for the empirical evidence suggesting morphological decomposition. A possible critical test of these paradigms would consist of contrasting priming effects obtained by letter clusters that have low or high orthographic frequency, but nevertheless constitute morphological units. This, however, is beyond the scope of our present investigation and requires further research. Parenthetically, it should be noted that the statistical view predicts that morphological priming effects should be basically reduced if there is no semantic overlap associated with the form overlap. However, Frost et al. (1997) found no discernible effect of semantic overlap. They found that the amount of priming between words sharing a common root was the same for words that were closely related semantically as it was for words that were quite unrelated.

In conclusion, the present results indicate that a verbal form is decomposed into a root morpheme and a verbal-pattern morpheme in the course of word recognition. These two morphemes are probably represented in the lexicon and form lexical units that determine lexical organization and govern lexical access. The factors that may determine the lexical status of a morphological unit reflect a fine tuning between distributional properties of the morphemes, together with the semantic and/or syntactic transparency of the information they convey. This information is necessary for the semantic and syntactic integration of the message. Although the present results point to the complete morphological decomposition of verbal forms into their two fundamental derivational morphemes, the root and the verbal pattern, further research is needed to clarify the interrelation between these two processes.

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