Journal of Experimental Psychology:
Learning, Memory, and Cognition
1997, Vol. 23, No. 4, 829–856

Copyright 1997 by the American Psychological Association, Inc.
0278-7393/97/$3.00

What Can We Learn From the Morphology of Hebrew? A Masked-Priming Investigation of Morphological Representation

Ram Frost
The Hebrew University

Kenneth I. Forster
University of Arizona

1045

Avital Deutsch
The Hebrew University

All Hebrew words are composed of 2 interwoven morphemes: a triconsonantal root and a phonological word pattern. The lexical representations of these morphemic units were examined using masked priming. When primes and targets shared an identical word pattern, neither lexical decision nor naming of targets was facilitated. In contrast, root primes facilitated both lexical decisions and naming of target words that were derived from these roots. This priming effect proved to be independent of meaning similarity because no priming effects were found when primes and targets were semantically but not morphologically related. These results suggest that Hebrew roots are lexical units whereas word patterns are not. A working model of lexical organization in Hebrew is offered on the basis of these results.

Part 1: Morphological Organization and the Mental Lexicon

All models of visual or auditory word perception assume that the dynamic processes involved in word recognition operate on a mental lexicon which contains the basic linguistic units of a language. Words, in general, have phonological, semantic, and orthographic properties. However, they cannot be fully described without reference to their morphology as well.

The role of morphological factors in determining the organization of the mental lexicon has been the focus of both old and recent controversies in word-perception research (for a review, see Marslen-Wilson, Tyler, Waksler, & Older, 1994). 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). According to this view, lexical access does not entail the decomposition of polymorphemic words into their morphemic constituents (Henderson et al., 1984; Manelis & Tharp, 1977). In contrast, other investigators have proposed that polymorphemic words are decomposed into their morphemic units prior to lexical access and that their base form is initially accessed in the process of word recognition (e.g., Taft, 1981; Taft & Forster, 1975). Between these two conflicting views are theories supporting morphological decomposition for some polymorphemic words such as inflected forms, but supporting full listing of derived forms (e.g., Stanners, Neiser, Hernon, & Hall, 1979). To complicate matters even further, in some models of word recognition that use distributed representations (e.g., Seidenberg, 1987; Seidenberg & McClelland, 1989), morphemic units are not explicitly represented at all. These investigators contend that many of the morphological effects previously reported in the literature reflect nothing but a fine tuning to the correlations that exist between the phonological, orthographic, and semantic properties of some words. According to this view, there is no level of representation that corresponds to morphology. All that can be said is that a level of hidden units picks up on the correlation between phonology and semantics that underlies morphological effects.

Obviously, this question is not language independent. Multimorphemic words are composed in different languages according to different morphological principles. For example, in Turkish, morphological elements are always appended to a base form to create inflections or derivations, and the morphemic units are always transparent to the reader. In contrast, in inflected languages such as Hebrew, morphemic boundaries are not always transparent. In some languages, like English, morphological derivations often involve some phonological variations in the base form (e.g., *steal–stealth*), whereas in languages like Serbo-Croatian they do not. All these structural contrasts could have implications for the salience of a word's components and therefore for its analysis in the recognition process.

In their recent work on English morphology, Marslen-

Ram Frost, Department of Psychology, The Hebrew University, Jerusalem, Israel; Kenneth I. Forster, Department of Psychology, University of Arizona; Avital Deutsch, School of Education, The Hebrew University.

Part of this study was conducted while Ram Frost was a Fulbright fellow at the Department of Psychology at the University of Arizona. The article was supported in part by the Binational Science Foundation and in part by National Institute of Child Health and Human Development Grant HD-01994. We thank Meirav Margolin and Michal Master for their extensive help and assistance in running the experiments.

Correspondence concerning this article should be addressed to Ram Frost, Department of Psychology, The Hebrew University, Jerusalem, 91905 Israel. Electronic mail may be sent via Internet to frost@pluto.mscc.huji.ac.il.

Wilson and his colleagues (Marslen-Wilson et al., 1994) were careful to specify that their aim was to map the English mental lexicon. Indeed, most studies of morphological processing have been conducted in English (e.g., Fowler, Napps, & Feldman, 1985; Manelis & Tharp, 1977; Stanners et al., 1979; Taft & Forster, 1975). Thus, we should consider the empirical value of a parallel mapping of the Hebrew lexicon or any other lexicon for that matter. Although we naturally assume that all lexicons have equal rights to be investigated and that no one is more important or interesting than the other, our investigation is not aimed at offering 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 process. Such a metatheory could predict systematic variations of morphological analyses given systematic variations in morphological structures. The aim of the present article is to take a step in this direction by examining morphological processing in Hebrew.

Characteristics of Hebrew Morphology

In Hebrew, as in other Semitic languages, all verbs and the vast majority of nouns and adjectives are composed of roots which usually consist of three (sometimes two or four) consonants. 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 interwined. It is this feature that makes Hebrew morphology an interesting case for investigating morphological decomposition.

Roots and word patterns are abstract structures, and only their joint combination (after the application of phonetic rules) forms specific words. Although these morphemes carry some semantic and syntactic information, their meaning is often obscure and changes for each root–pattern combination (Berman, 1978). This is because there are no unequivocal rules for combining roots and phonological patterns to produce specific word meanings. For example, the word *zimra* [singing] is a derivation of the root *zmr.* It is composed of the root and the phonological pattern *_i__a* (each underline indicates the position of a root consonant). The root *zmr* alludes to anything related to the concept of singing, whereas the phonological pattern *_i__a* is often (but not always) used to form feminine nouns that are usually the product of the action specified by the root. It is the merging of the root with the word pattern that forms the word meaning "singing." Other phonological word patterns may combine with the same root to form different words with different meanings that can be either closely or remotely related to the notion of singing. For example, the word *zamar* [a singer] is formed by combining the root *zmr* with the phonologic pattern *_a__a_* (the second consonant is doubled), which carries the syntactic information that the word is a noun that signifies a profession. Unlike *zamar,* the word *tizmoret* [an orchestra] is formed by combining the same root with a phonological pattern *ti__o_et* that includes consonants as well as vowels. This pattern carries the syntactic information that the word is a feminine noun. Note that the same phonologic pattern can be applied to other roots, resulting in various different verbs or nouns, each of which is related to its respective root action. Therefore, only the combination of both root and phonological pattern specifies the exact meaning of a word. Figure 1 represents the most common derivations of the root *zmr,* their respective word patterns, and their meanings, but note that other derivations or inflected forms of the same root exist as well.

Although Hebrew words are basically composed of two morphemes, the semantic information conveyed by each morpheme is not equally informative. The semantic information specified by the root is far more restricting than that specified by the word pattern, and it conveys the core meaning of the word. The word pattern, on the other hand, in many cases carries nothing more than word-class information (part of speech). Therefore, one might assume that the extraction of words' meanings is based primarily on the identification of their roots.

An important characteristic of Hebrew morphology is the way in which the two morphemes are combined to form words. The most common type of morphological formation in inflected languages consists of affixation of an element to a base morpheme (Matthews, 1972). In languages like English (as well as other Indo-European languages), affixation includes the processes of prefixation and suffixation, which entail the linear concatenation of elements to a base morpheme which remains intact. Hebrew, by contrast, relies on an intertwining of two independent morphemes. A word pattern, which includes vowels or consonants and vowels, is infixed to merge with a skeleton of consonants that is the root. The word pattern may consist of syllabic prefixes and suffixes in addition to the infixed vowels. When a word pattern is infixed within the root, the integrity of the root morpheme is necessarily compromised relative to concatenated combinations. English and Hebrew contrast, there-

Word	Printed Form	Word Pattern	Meaning
/zamar/	zmr	_a_a_	a male singer
/zemer/	zmr	_e_e_	a song
/zameret/	zmrt	_a_e_et	a female singer
/zimra/	zimrh	_i__a	singing
/zamir/	zmir	_a_i_	a nightingale
/tizmoret/	tzmort	ti__o_et	an orchestra
/mizmor/	mzmor	mi__o_	a psalm
/zamarut/	zmrut	_a_a_ut	singing profession

Figure 1. Most common derivations of the root *zmr,* which conveys the action of singing. The printed form can represent two words in unpointed Hebrew.

fore, in the principle by which morphological units are combined.

In a recent study, Feldman, Frost, and Pnini (1995) examined the morphological processing of Hebrew, using the segment-shifting task (see Feldman, 1991, 1994; Stolz & Feldman, 1995, for a similar manipulation in English). Participants were presented with Hebrew words that contained transparent and 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 cannot be combined with any other word pattern. Although these consonants are formally considered as roots, they do not display the characteristic productivity of Hebrew roots. The participants in Feldman et al.'s 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 containing transparent roots than from words containing opaque roots. Thus, the fact that a word was composed of an "active" root that productively created different words 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 of printed word processing in Hebrew.

One possible argument for the notion of morphological decomposition of Hebrew printed words derives from the special characteristics of the Hebrew language. Because in Hebrew (as well as in other Semitic languages) many words can be related to one source root, it is possible that the most efficient lexical organization would consist of representing roots as lexical entities. Thus, according to this hypothesis, all or most words that are derived from a specific root would be lexically linked to it. The major gain of such lexical organization is of search efficiency due to an organizing principle. Indirect support for this hypothesis can be found in studies showing that lexical decisions in Hebrew are often given on the basis of an early recognition of a phonologically ambiguous consonantal structure and are not based on the identification of a specific word that this letter string represents. In Hebrew, letters represent mostly consonants, whereas most of the vowels can optionally be superimposed on the consonants as diacritical marks (*points*). The diacritical marks, however, are omitted from most reading material and can be found only in poetry, children's literature, and religious scriptures (see Appendix A). Because different vowels may be inserted into the same string of consonants to form different words or nonwords, Hebrew unpointed print usually cannot specify a unique phonological unit. Therefore, a printed consonant string is phonologically ambiguous and often represents more than one word. Bentin and Frost (1987) have shown that lexical decisions for unpointed Hebrew ambiguous words (words that do not include vowel information in print and can thus be read in two ways) were faster than lexical decisions to *either* of the disambiguated pointed alternatives. This outcome suggests that lexical decisions in unpointed Hebrew are based on the early recognition of the orthographic structure shared by the two phonological and semantic alternatives, supporting the hypothesis that an abstract orthographic structure could serve as a lexical entry for words sharing an identical consonant string.

Bentin and Frost's (1987) study which examined lexical decisions for heterophonic homographs provides, at best, circumstantial evidence as to the exact structure of the mental lexicon of Hebrew readers (see for a review Bentin & Frost, 1995; Frost & Bentin, 1992). These studies merely suggest that words that share an identical orthographic configuration but have a different vowel pattern are probably similarly accessed. However, exactly how roots and word patterns are processed by the reader, and what their role is in lexical access require further investigation. A more direct test of the role of these morphemes in word recognition can be achieved by using a priming paradigm in which prime and target share morphological properties. Results from this paradigm not only could reveal the lexical structure involved in the accessing of Hebrew words, but could also provide a necessary contrast to languages with concatenative morphology such as English.

The fundamental aim of this research is to establish whether the lexical representation of Hebrew printed words reflects their morphological structure. In concrete terms, such a formal representation would require that the recognition of a word involve the recognition of its morphological constituents. Further, satisfactory priming evidence for such a process would need to rule out the possibility that the overlap in representation between the prime and the target was not morphological in nature but was simply orthographic, or semantic and conceptual. Hebrew presents a particularly interesting opportunity for studying this issue. Also, the question of how the input is parsed into a possible root and a possible word pattern is of particular interest, because the left-to-right parsing algorithm suggested by Taft and Forster (1975) for English (but see also Schreuder & Baayen, 1994) would be of no value in Hebrew, because of the interleaved nature of roots and word patterns.

Experimental Task

All of the experiments in the present article were conducted with the masked-priming technique developed by Forster and Davis (1984). The central features of this procedure are that a forward pattern mask is presented before the prime, and that the temporal interval between the onset of the priming stimulus and the subsequent target stimulus is very brief (50–60 ms, see Forster, 1987, for a review). The advantage of this procedure for current purposes 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 it is relatively insensitive to overlap at the level of meaning. Although masked-priming effects for associatively related pairs have been reported (e.g., Sereno, 1991), these effects are not robust, especially when the relationship is purely semantic. For example, Perea, Gotor, Rosa, and Algarabel (1995) found no effects of semantic relatedness with a stimulus onset asynchrony (SOA) of 67 ms, although clear effects were obtained with an SOA of 83 ms. This suggests that masked priming may, therefore, be well suited to our aim of detecting effects of morphological relatedness at the level of form, rather than at a semantic or conceptual level. A further advantage of the masked-priming technique is that it seems very unlikely that the participants' decisions are influenced in any way by a conscious appreciation of the relationship between the prime and target, and any priming effects are therefore more likely to be produced by automatic, unconscious processes. The experimental paradigm is illustrated as follows:

forward mask (500 ms):	########
prime (50 ms):	*nature*
target (500 ms):	*MATURE*

The participants' task is to name or classify the target as a word or not a word as rapidly as possible. 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. When forced, they can make slightly better-than-chance judgments about whether the prime was identical to the target but not about whether it was a word (e.g., Forster & Davis, 1984). The interpretation of the effect is that the priming stimulus is in fact perceptually processed, but because of the interrupting effect of the target stimulus, the properties of the prime are never encoded into episodic memory, and hence the participants are unable to subsequently report its identity (see Forster, 1987, for a review).

Thus, two general principles guide the design of the masked-priming technique. First, the very close temporal proximity of the two stimuli allows the investigator to pick up highly transient effects that may otherwise dissipate during the interval between the prime and the target. Second, the masking procedure eliminates the possibility that the observed priming effects are the products of a conscious, retrospective appreciation of the relationship between the primes and the targets. A weakness of regular priming procedures is that the primes and the targets may be consciously perceived to be related in some ways, and this may influence the way participants respond to the target stimulus, without there being any effect at all on the *perceptual* processing of the target. The procedure with forward masking of the prime and immediate presentation of the target has the advantage that the participants' responses to the target words are unlikely to be influenced by strategic processes that rely on conscious awareness. This also helps to reduce the possibility that any priming effect is due to the fact that the participants consciously recognize that the prime and the target share a common morpheme.

It is important to note that the forward-masking procedure has been mainly used to examine the effects of primes on targets that shared a similar orthographic structure (i.e., form priming). The extent of priming is measured by comparing performance in the primed condition with a baseline condition in which the prime is orthographically different from the target (e.g., *system*–NATURE). The strongest priming effects are found when the prime contains exactly the same letters as the target, that is, in *identity priming* (e.g., *nature*–NATURE). However, strong priming effects are also obtained with nonidentical primes that share all but one letter, that is, with *form priming* (e.g., *mature*–NATURE). Most important, none of these effects appear to occur reliably for nonword targets (e.g., *matune*–MAZUNE), suggesting that the priming effect depends crucially on the existence of a lexical representation (Forster, 1987; Forster & Davis, 1984; Forster et al., 1987).

Humphreys, Evett, Quinlan, and Besner (1987) demonstrated that if the SOA (i.e., prime presentation time) was increased so that participants became aware of the prime, then no form-priming effects were obtained, although clear repetition priming was obtained. That is, the identification of the target word TILE was enhanced by a prior presentation of *tile* regardless of SOA, but for a prior presentation of *file*, enhancement was produced only with a very short SOA. A similar outcome was also reported by Veres (1986) who found that the facilitatory effect of a masked word prime with an SOA of 60 ms was completely absent with an SOA of 500 ms. Taken together, these results suggest that awareness of a prime that is orthographically similar to the target, but represents a different lexical item, prevents the prime from facilitating the target and in some cases may lead to its inhibition (e.g., Grainger, 1990). It seems that the masking of the prime eliminates this late inhibitory process from operating by preventing the prime from being perceived as a separate entity from the target (Humphreys, Besner, & Quinlan, 1988). Thus, the information extracted from the prime is somehow integrated into the processing of the target, as if the masking had the effect of preventing a reset of the recognition system prior to the processing of the target. In general terms, form priming occurs because of a residual effect that is left over from the processing of the prime, which enhances the processing of the subsequently presented target. The inability to obtain any form priming for nonword targets reveals this effect to be lexical rather than prelexical. These conclusions are further reinforced by recent studies demonstrating that form-priming facilitation depends mainly on neighborhood density: Strong facilitation was obtained for word targets having few orthographic neighbors, and weak facilitation was obtained for words having many (Forster et al., 1987; Forster & Taft, 1994). That is, when the prime's orthographic structure overlaps with a target that has many neighbors (high-density neighborhood), its beneficial effect on target processing is drastically reduced, and vice versa. In addition, as mentioned earlier, target processing appears to be affected mainly by form rather than by semantic similarity to the prime.

Another issue that should be discussed concerns the relative frequency of the primes and their effectiveness in opening the entry for the targets. One possible concern is that if the prime is very low in frequency relative to the target, then with very short SOAs, by the time the target has occurred, the processing of the prime might be insufficiently advanced to produce a normal priming effect. If this were the case, then the comparison of priming in different conditions would involve a confound, namely the frequency of the prime. It should be noted that very similar issues arise in the case of identity priming, where the same argument would imply that priming for low-frequency words should be weaker than for high-frequency words because it would be less likely that a low-frequency prime would have been processed by the time the target occurred. However, Forster and Davis (1984) found that masked priming was just as strong for low-frequency words as for high-frequency words. This finding has since been confirmed by Seguí and Grainger (1990) and Rajaram and Neely (1992). These results show that for masked repetition priming at least, it is irrelevant whether the prime is high or low frequency. Although there has been no systematic study of the relative frequencies of prime and target when they are different words (i.e., form priming), the available findings suggest that this cannot be an important factor, because it has been shown that form primes that differ from the target by one letter are equally effective whether they are words (e.g., *aptitude*–ATTITUDE) or nonwords (e.g., *antitude*–ATTITUDE; Forster, 1993). Thus, it seems that the relevant factor for determining facilitation in this paradigm concerns the extent of form overlap between primes and targets, and not the lexical frequency of the primes.

The following experiments used masked priming to investigate the role of roots and word patterns in lexical access in Hebrew. We examined whether a previous exposure to a word pattern or root morpheme can facilitate lexical decisions or naming of derivations composed of these morphemes. The masking of the primes allowed us to avoid conscious strategies characteristic of the unmasked primed lexical-decision and naming tasks.

Experiment 1A: Priming With Word Patterns

Experiment 1A investigated the lexical status of word-pattern morphemes and their role in lexical access. The aim of the experiment was to examine whether a word prime can facilitate lexical decision for a word target when the two words share an identical phonological word pattern. Any facilitation caused by the prime would suggest that word-pattern morphemes not only are analyzed during word recognition, but also govern lexical retrieval. This would indicate that Hebrew words having identical word patterns are interconnected or organized in a neighborhood defined by the pattern's phonological features.

The experiment comprised three experimental conditions: In the related condition, the primes and the targets were two words with the same word pattern but with different roots (e.g., ***t**a**k**l**i**t*–*t**a**r**g**i**l*, root consonants in bold). In the control condition, primes and targets were words with roughly the same number of shared letters as in the related condition, but with different word patterns and roots. The third condition was an identity condition in which the primes were identical to the targets. Facilitation in the related and identity conditions was assessed relative to that in the control condition.

Method

Participants. The participants were 48 undergraduate students at The Hebrew University, all native speakers of Hebrew, who participated in the experiment for course credit or for payment.

Stimuli and design. The stimuli consisted of 48 target words which were four to six letters long and contained two or three syllables with five to eight phonemes. The mean number of letters was 5.0, and the mean number of phonemes was 6.5. The words represented a variety of 20 common word patterns in Hebrew, having both consonants and vowels (see Appendix B). The target words were paired with 48 primes to create the three experimental conditions: identity, related, and control. Primes and targets always had the same number of letters in both the related and control conditions. The position and number of letters that overlapped with the targets was determined by the specific word patterns. On the average, primes and targets in the related condition overlapped by 2.2 letters and overlapped by 1.7 letters in the control condition. The mean overlapping phonemes of primes and targets in the related condition was 3.6, and in the control condition the mean was 2.1. Given the possible greater importance of the initial letter in the masked-priming paradigm (e.g., Forster & Davis, 1991), whenever 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 (in Hebrew script it is the rightmost letter). Examples of stimuli used in the experiment are presented in Figure 2. Forty-eight target nonwords composed of the same word patterns as above, but with pseudoroots, were introduced as fillers. Similar to the word targets, the nonwords were also divided into three experimental conditions (identity, related, and control).

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 by a Latin square design. Sixteen participants were tested in each list, allowing each participant to provide data points in each condition, yet avoiding stimulus repetition effects.

The stimuli were presented in unpointed Hebrew characters. However, all words selected for the experiments were phonologically unambiguous and could be read as a meaningful word in one way only, that is, with the intended word pattern. In general, throughout the study stimuli were unpointed. This is because adult readers read unpointed print almost exclusively. Moreover, because some of the following experiments explicitly required unpointed print (involving the presentation of root morphemes which do not have a specific vowel configuration), it ensured a uniformity in stimuli characteristics throughout the study.

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 (RTs) was the DMASTR display system developed by Forster and 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

	IDENTITY	RELATED	CONTROL
Forward mask	########	########	########
prime	/targil/ [exercise] תרגיל	/taklit/ [record] תקליט	/tadhema/ [amazement] תדהמה
target	TARGIL תרגיל	TARGIL תרגיל	TARGIL תרגיל

Word pattern: T A _ _ I _ (masculine noun, result of an action).

Figure 2. Examples of stimuli used in Experiment 1 in the identity, related, and control conditions. Stimuli were presented in unpointed Hebrew script, and therefore, not all of the word-pattern vowels were necessarily printed. For example, the vowel /a/ of the word pattern *TA_I_* does not appear in print. Note that Hebrew is read from right to left.

followed by the prime with an exposure duration of 43 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.[1] 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.

Participants were instructed to make lexical decisions about 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 the latency of the response. The accuracy of this 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 RTs 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

Correct RTs in the three experimental conditions were averaged across subjects and across items. Within each participant, RTs that were outside a range of two standard deviations from the participant's mean were curtailed. The effect of outliers was minimized by establishing cutoffs two standard-deviation units above and below the mean for each participant. Any RTs exceeding these cutoffs were replaced by the appropriate cutoff value. Trials in which an error occurred were discarded. This procedure was repeated in all of the following experiments. The results are presented in Table 1 (left). The effects of the identity and related primes were assessed relative to the control baseline.

Lexical decisions for targets were facilitated only in the identity condition (38 ms) when the primes and the targets were the same word. The previous exposure to a word having the same word pattern (i.e., the related condition) produced an effect of only 1 ms.

Table 1
Reaction Times (RTs) and Percent Errors for Lexical Decision (Experiment 1A) and RTs for Naming (Experiment 1B) for Target Words and Nonwords in All Conditions

Target and condition	Lexical decision RT (ms)	Lexical decision Error (%)	Naming RT (ms)
Words			
Identity	541	5.2	543
Related	578	9.1	571
Control	579	8.2	574
Nonwords			
Identity	617	8.4	603
Related	627	8.8	632
Control	624	9.6	631

Note. Related targets had the same word patterns as primes.

The results were subjected to a two-way analysis of variance (ANOVA) in which the prime condition was one variable, and word list was the other. This procedure was used in all of the following experiments, but we report only the main effect of the prime because the list variable was introduced merely to extract any variance due to counterbalancing. The prime variable was significant both by subjects (F_1) and by items (F_2), $F_1(2, 90) = 46.6$, $MSE = 444$, $p < .001$; $F_2(2, 90) = 14.0$, $MSE = 1,641$, $p < .001$, and this effect was due to the difference between the identity and the control condition (38 ms). Planned comparisons revealed that the difference between the related and the control conditions (1 ms) was not significant (Fs < 1.0). The error analysis revealed a significant effect of the prime, $F_1(2, 90) = 5.2$, $MSE = 39$, $p < .01$; $F_2(2, 90) = 3.2$, $MSE = 62$, $p < .05$. This effect was again due to a smaller percentage of errors in the identity condition. The nonword analysis showed no significant effect of the prime for RTs, $F_1(2, 90) = 2.8$, $MSE = 556$, $p < .07$; $F_2(2, 90) = 1.6$, $MSE = 911$, $p < .2$, or for errors (Fs < 1.0).

Discussion

The results of Experiment 1A are straightforward: A strong facilitation effect was observed in the identity-priming condition, but not in the related condition. The priming effect obtained in the identity condition supports our preliminary assumptions concerning the masked-priming procedure. First, it is fairly clear that the primes were indeed processed, exerting their influence on the targets in spite of their exposure parameters. Thus, lexical retrieval of the targets was speeded if they were previously presented as primes, even though participants were not aware of their presentation. In contrast to the words, lexical decisions for nonwords were not facilitated in the identity condition. This outcome was consistently found in each of the lexical-decision experiments in the present study and conforms with previous results in masked priming (e.g., Forster & Davis, 1984). It merely confirms that facilitation in this paradigm is indeed related to lexical processes. Because nonwords are not lexically represented, there is nothing for the priming stimulus to prime, and hence responses to the targets are not facilitated.

In contrast to the identity condition, a previous presentation of word primes having the same word patterns as the targets did not facilitate lexical decision for the targets. It could be argued that priming effects were not obtained because the vowels defining a specific word pattern were not explicitly conveyed in print. Note, however, that the word patterns we used also included vowels that appeared within

[1] 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 display procedure is equivalent to measuring latencies to the targets from prime on sets rather than from target onsets. In English, the separation of primes and targets has often been 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 therefore we adopted the manipulation of size rather than form.

the word as letters. Moreover, all of the word patterns included consonants as well, so that the overall orthographic cluster represented the intended word pattern unequivocally. Thus, it seems unlikely that the lack of priming could be attributed simply to orthographic invisibility. We conclude, therefore, that although word patterns are considered morphemes, they do not play a critical role in the lexical-retrieval process.

Experiment 1B: Priming With Word Patterns

Whereas Experiment 1A found no benefit of a shared word pattern for lexical decision, it is possible that a naming task would be more sensitive to phonological overlap. Two Hebrew words having the same word pattern are phonologically identical except for the three consonants of the root. Experiment 1B investigated whether word patterns that appear in primes can help in generating a phonological representation for target words that have identical patterns but are embedded in different roots. If the processing of Hebrew words entails the separation of roots and word patterns (see, e.g., Feldman et al., 1995), a previous exposure to a specific word-pattern morpheme could facilitate naming of a target word, if it contains the identical morpheme.

Previous studies with masked priming have shown that facilitation in naming could occur if primes and targets share an identical initial segment (e.g., Forster & Davis, 1991). The source of this facilitation is the similar pronunciation routine that is generated for primes and targets having similar onsets. Consequently, the overlap of prime and target in the initial syllable was controlled across experimental conditions. That is, if the related prime had the same onset as the target, then so did the control prime. If they had different onsets, then so did the control prime.

Method

Participants. The participants were 48 undergraduate students at The Hebrew University, all native speakers of Hebrew, who participated in the experiment for course credit or for payment. None of the participants took part in Experiment 1A.

Stimuli and design. The stimuli, design, and apparatus were identical to those of Experiment 1A, except that participants were instructed to name the stimuli as fast as possible, and their responses were monitored through a voice key.

Results

RTs in the three experimental conditions were averaged across subjects and across items. The results are presented in Table 1 (right). Similar to Experiment 1A, naming was facilitated only if the primes and the targets were the same word. A previous exposure to a word having the same word pattern did not facilitate naming.

The results were subjected to a two-way ANOVA with the variables prime conditions and word lists. The effect of prime condition was significant in both subject and item analyses, $F_1(2, 90) = 33.1$, $MSE = 430$, $p < .001$; $F_2(2, 90) = 12.2$, $MSE = 1,152$, $p < .001$, and was due to the fast RTs in the identity condition (31 ms). Planned comparisons revealed that the difference between the related and the control conditions (3 ms) was not significant (Fs < 1.0).

In contrast to the lexical-decision data, naming times for nonwords were faster in the identity condition than in the control condition, $F_1(2, 90) = 18.5$, $MSE = 691$, $p < .001$; $F_2(2, 90) = 6.1$, $MSE = 2,126$, $p < .003$. The small number of errors (in some conditions less that 1%) did not permit a reliable statistical analysis.

Discussion

The results of Experiment 1B suggest that the process of computing the target's phonological representation from print cannot be facilitated by a previous exposure to a word with an identical phonological word pattern. One possible conclusion from this outcome is that the primary morphological analysis in Hebrew entails the extraction of the root and not of the word pattern. Because in our experiment primes and targets had different roots, no facilitation was obtained.

The facilitation observed for naming nonword targets in the identity condition suggests that a prelexical computation of the prime's phonological structure was launched even though the primes were not consciously perceived. 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 appeared for both words and nonwords.

Experiment 2: Priming With Roots

The aim of Experiment 2 was to examine whether a masked prime that is a root can facilitate lexical decisions and naming for a word target that is a derivation of that root and contains other letters besides the root's three consonants (e.g., ***zmr***–*ti**zm**o**r**et*, root consonants in bold). In Hebrew, all inflections and derivations contain the root phonemes. However, because the root phonemes can be combined with a large set of word patterns, their positions within the words vary, and they are often separated by other vowels or consonants. Thus, the morphological analysis of a given printed word entails the classification of its phonemes (and therefore of its letters) into those belonging to the root and those belonging to the word pattern. Experiment 2 investigated whether previous exposure to the root letters speeds lexical access and naming of the letters' derivations, relative to any other letter sequence appearing within the root derivations.

Participants were presented with target words (all root derivations) which were paired with three different primes: In the related condition, the primes were the three letters of the roots. In the control condition, the primes for the same targets were three letters contained in the targets, but not in the root letters. Finally, in the identity condition, the primes were identical to the targets. Thus, facilitation in the related condition was assessed relative to an orthographic control condition in which an orthographic but not a morphological relationship existed between primes and targets. Greater facilitation for root letters would reflect the special effect they exert as primes on the processing of the targets, relative to the other letters. However, facilitation in the related condition was also assessed relative to an identity condition in which there was complete repetition of the targets. The purpose of the identity condition was to obtain a baseline for the maximal priming effect when the targets were primed by themselves.

We used both the lexical-decision and naming tasks because both tasks have been shown to tap lexical processes in Hebrew and therefore might provide converging evidence (e.g., Frost, Katz, & Bentin, 1987). Several studies in Hebrew have suggested that the process of generating a complete and detailed phonological representation involves both prelexical computation and lexical information (Frost, 1994, 1995). The prelexical computation consists of launching letter-to-phoneme conversion rules, which produces a partial phonological representation. In unpointed Hebrew, this representation contains mainly the consonantal phonemes, as well as the few vowels that are presented as letters. This incomplete prelexical representation is filled by top-down lexical information that provides those vowels that were missing in the orthographic structure (Frost, 1995). Thus, the aim of the naming experiment was to examine how lexical information affects this process, by investigating the role of roots in generating a complete phonological representation from print. If root primes can facilitate lexical access, they should contribute to the activation of the various lexical candidates that contain the root. This activation would, therefore, enhance the top-down lexical shaping that is necessary for correct pronunciation. Thus, if roots are lexical entities in Hebrew, the presentation of roots as primes should result in faster naming of target words that are derivations of the prime roots. Root priming in the naming task would, therefore, provide strong evidence for the lexical status of the root.

Method

Participants. A total of 96 undergraduate students at The Hebrew University, all native speakers of Hebrew, participated in the experiment for course credit or for payment. Forty-eight were tested in the lexical-decision task, and 48 were tested in the naming task. None of the participants took part in the previous experiments.

Stimuli and design. Forty-eight target words that were four to seven letters long, and contained two or three syllables with five to seven phonemes were used (see Appendix C). Their mean number of letters was 5.1, and their mean number of phonemes was 6.4. The words were derivations of productive roots that were combined with a variety of common word patterns in Hebrew. The target words were paired with 48 primes to create three experimental conditions: In the identity condition, primes and targets were the same word. In the related condition, the primes consisted of the three letters that formed a root, and the targets were the root derivations. In the control condition, the primes consisted of a sequence of three letters contained in the targets, which were *not* the root letters but could, nevertheless, be read as meaningful words. The position of overlapping letters in the related and the control conditions could be initial, middle, or final, with similar distributions in the related and the control conditions. However, 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. Another overlap control concerns the number of times that the three letters of the primes appeared as nondisrupted three-letter sequences within the targets. In both the related and the control conditions, half of the trials involved the disruption of the prime's letter sequence within the target, and half of the trials did not. An example of the stimuli used in the experiment is presented in Figure 3. Forty-eight target nonwords composed of the same word patterns as above, but with pseudoroots, were introduced as fillers. Similar to the word targets, the nonwords were also divided into three experimental conditions. Thus, the primes for the nonwords could have been the pseudoroots that were the basis for constructing the nonwords (the related condition), another meaningless sequence of letters (the control condition), or the nonword itself (the identity condition). The procedure and apparatus were identical to those in the previous experiments.

Results

RTs in the three experimental conditions in the two tasks were averaged across subjects and across items. The results are presented in Table 2. We first report the results in the lexical-decision task and subsequently report those obtained in the naming task.

Lexical decision. The effect of prime condition was significant in both the subject and the item analyses, $F_1(2, 90) = 7.3$, $MSE = 881$, $p < .001$; $F_2(2, 90) = 10.5$, $MSE = 667$, $p < .001$. This was due to faster responses in both the identity (25 ms) and related conditions (14 ms) relative to the control baseline. Planned comparisons revealed that the difference between the related and the control conditions was significant for both subjects and items, $F_1(1, 45) = 4.2$, $MSE = 826$, $p < .04$; $F_2(1, 45) = 6.8$, $MSE = 543$, $p < .01$. No effects of prime conditions were found in the error analysis ($Fs < 1.0$). Prime condition had no effect on nonwords in RTs or error measures ($Fs < 1.0$).

Naming. The effect of prime condition was significant in both subject and item analyses, $F_1(2, 90) = 15.0$, $MSE = 473$, $p < .001$; $F_2(2, 90) = 11.8$, $MSE = 612$, $p < .001$. This was due to faster naming latencies in both the identity (24 ms) and related (13 ms) conditions relative to the control baseline. Similar to the results obtained in the lexical-decision task, planned comparisons revealed that the difference between the related and the control conditions was

	IDENTITY	RELATED	CONTROL
Forward mask	########	########	########
prime	tizmoret תזמורת	zmr זמר	tmr תמר
target	TIZMORET תזמורת	TIZMORET תזמורת	TIZMORET תזמורת

ROOT: Z M R- זמר (anything to do with singing)

tizmoret [orchestra]

Tmr [date]

Figure 3. Examples of stimuli used in Experiment 2 in the identity and control conditions.

significant both by subjects and by items, $F_1(1, 45) = 9.4$, $MSE = 445, p < .003$; $F_2(1,45) = 7.0, MSE = 601, p < .01$. There was no effect of prime condition for nonwords, $Fs < 1.0$. The number of errors was too small to allow any meaningful statistical analysis.

Discussion

The results of Experiment 2 suggest that a previous masked exposure to the root letters facilitated lexical access and naming of targets that were derivations of the root. This effect was not due to simple orthographic overlap. Other letters of the targets, regardless of their position within the word, were not as effective as primes. Note that facilitation in the related condition was measured relative to facilitation in a control condition in which the primes had some letter overlap with the targets and was not measured 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 for the targets are somewhat *facilitated* even if the letters are not the root letters. Thus, assessing the priming effect in the related condition relative to a pure neutral control would necessarily confound simple orthographic form priming with morphologically related priming. Our aim in setting the control baseline in Experiment 2 was to measure the *additive* contribution of the morphological factor to simple orthographic overlap.

The overlap in number of letters between primes and targets is of special interest in the present context. Previous studies with masked priming in English have suggested that form priming typically occurs when the primes and targets differ only by one letter (e.g., Forster et al., 1987). In the present experiment, however, targets were sometimes six or seven letters long, thereby differing from the three-letter primes by as many as four letters. Nevertheless, a reliable facilitation in lexical decisions and naming of targets was obtained, if the three letters were the root letters. For example, the size of the priming effect for targets that were five to seven letters long was 14 ms in the lexical-decision task and 11 ms in the naming task, suggesting that the priming obtained in Experiment 2 was not due to the large letter overlap between the primes and the targets which had only four letters. This outcome supports the hypothesis that the roots serve as lexical entities in the Hebrew lexicon and probably facilitate lexical access of their derivations.

Note that the facilitation in the related condition was about half the size of the facilitation in the identity condition. If roots serve as lexical entities that connect to all of the root derivations, their beneficial effect on accessing the targets should indeed be limited relative to the presentation of the target words themselves as primes.

Priming was not obtained in any experimental condition for nonwords. This result supports the claim that the masked-priming paradigm taps processing occurring at the lexical level. As nonwords do not have a lexical entry, any previous exposure to some or all the letters they contain could only facilitate performance if priming occurred at the prelexical level.

Table 2
Reaction Times (RTs) and Percent Errors for Lexical Decisions and RTs for Naming of Target Words and Nonwords in All Conditions in Experiment 2

Target and condition	Lexical decision RT (ms)	Lexical decision Error (%)	Naming RT (ms)
Words			
Identity	566	6.2	583
Related	578	6.7	594
Control	591	6.4	607
Nonwords			
Identity	640	8.9	653
Related	642	9.8	663
Control	639	8.3	661

Note. Related targets had the same roots as primes.

Although priming effects are typically weaker in naming than in lexical decision (e.g., Lupker, 1984), the naming results were almost identical in size to those obtained in the lexical-decision task. One possible conclusion from this outcome is that the source and mechanism of facilitation in the naming and lexical-decision tasks were similar in nature and reflected purely lexical processes rather than postlexical-decision effects.[2] Note also that letters that were not the three root letters, were not as effective in facilitating target naming. Because letter position within the target words was controlled, a facilitation caused by simple prelexical phonological computation of the prime letters into phonemes would not have differentiated between root letters and other letters. Thus, the gain in naming latencies in the related condition relative to the control condition was not due to the partial computation of the target's phonological structure but was due to its lexical location given the previous presentation of the root. The results of the naming task, therefore, provide additional support for the lexical role of roots in Hebrew.

Experiment 3: Priming With Nonword Legal Roots

The purpose of Experiment 2 was to provide evidence concerning the role of roots in lexical access. However, firm conclusions concerning the structure of the mental lexicon in Hebrew can be reached only by assessing the relative contribution of both semantic and morphological similarity in masked priming. Specifically, it should be established that

[2] It is worth noting that the entry opening model of masked priming proposed by Forster and Davis (1984) actually predicts similar sized effects. In this model, lexical entries have to be "opened" before any information can be retrieved from them, and this opening process is assumed to take an appreciable time. The priming effect occurs as a result of the fact that the prime opens the entry for the target word (and other words that are closely related to the prime), which leads to a savings effect, because when the target word occurs, its entry will be opened. Thus, it is entirely possible that the naming task could show as large an effect as the lexical-decision task, because the saving would be the same for both tasks.

the priming effects obtained with root primes were not due to simple word-to-word activation within the semantic lexicon but were due to the morphological overlap between roots and derivations.

Most roots printed in unpointed Hebrew can be read as a noun or as a verb inflected in the simple past tense,[3] third person singular. Therefore, there is always some semantic similarity between their readings as nouns or inflected verbs and the following target word which contains the same root. Taking the example provided in Figure 3, the three letters *zmr* can be read as */zamar/* [a singer], or */zemer/* [a song], which are both semantically related to the target *TIZMORET* [an orchestra]. It could be argued that part of the obtained root facilitation was due to pure semantic priming from one word to its semantic associate, and not to morphological effects. Note that most studies that have used masked priming have shown that facilitation in this paradigm results from similarity in *form* rather than from pure semantic meaning. Thus, when primes and targets were two words that did not overlap in their orthographic structures, but merely consisted of semantic associates (e.g., *doctor–nurse*), priming effects were very small (e.g., Perea et al., 1995). However, some other studies have shown reliable semantic facilitation with masked presentation (e.g., Lukatela & Turvey, 1994; Sereno, 1991). Thus, it should be established that root priming cannot be explained merely in terms of semantic activation.

To address this theoretical distinction we used roots that could not be inflected in the simple past tense or could not be read as a noun form. Thus, their printed forms were nonwords. For example, the root *rdm* (conveying the notion of sleeping) can be productively inflected in many words by being combined with word patterns that include prefixed and suffixed consonants (e.g., its combination with the word pattern *ta__e_ah* creates the word *tardemah* [deep sleep]). However, the three letters *RDM* by themselves never appear as an independent sequence and, therefore, cannot be read as a meaningful word with any vowel combination. The aim of the experiment was to examine whether root letters that cannot be read as words can nevertheless facilitate lexical decision and naming of targets sharing the same root. Similar root facilitation, if obtained, would strongly support our conclusions concerning the lexical status of root morphemes in Hebrew.

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 tested in the lexical-decision task, and 48 were tested in the naming task. None of the participants took part in the previous Experiments.

Stimuli and design. The design of the experiment was identical to that of the previous one, and the target words had the same characteristics as those in Experiment 2 (see Appendix D). Their mean number of letters was 4.9, and their mean number of phonemes was 6.2. However, 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. Similarly, the primes in the control condition were three letters that appeared in the targets, but could not be read as a meaningful word. The position of overlapping letters in the related and the control conditions could be initial, middle, or final, with similar distributions in the related and the control conditions. The procedure and apparatus were identical to those in the previous experiments.

Table 3
Reaction Times (RTs) and Percent Errors for Lexical Decisions and RTs for Naming of Target Words and Nonwords in All Conditions of Experiment 3

Target and condition	Lexical decision		Naming
	RT (ms)	Error (%)	RT (ms)
Words			
Identity	558	5.1	550
Related	565	5.1	565
Control	579	5.5	576
Nonwords			
Identity	643	6.8	598
Related	652	6.9	616
Control	648	7.1	621

Note. Related targets had the same roots as primes, but roots are nonwords.

Results

RTs in the three experimental conditions for the two tasks were averaged across subjects and across items and are presented in Table 3. The pattern of results was very similar to that in Experiment 2 with word roots. We first report the results in the lexical-decision task and subsequently report those obtained in the naming task.

Lexical decision. The effect of prime condition was significant in both subject and item analyses, $F_1(2, 90) = 7.2$, $MSE = 699$, $p < .001$; $F_2(2, 90) = 6.8$, $MSE = 787$, $p < .002$, and was due to faster decision latencies in both the identity (21 ms) and related (14 ms) conditions relative to the control baseline. Planned comparisons revealed that the difference between the related and the control conditions was significant both by subjects and by items, $F_1(1, 45) = 4.3$, $MSE = 947$, $p < .04$; $F_2(1, 45) = 6.5$, $MSE = 703$, $p < .01$. No effects of prime conditions were found in the error analysis or for nonwords ($F\text{s} < 1.0$, for both).

Naming. The results with naming were almost identical to the lexical-decision results. Naming was faster in both the identity (26 ms) and related (11 ms) conditions relative to the control baseline. The effect of prime condition was significant in both subject and item analyses, $F_1(2, 90) = 13.5$, $MSE = 570$, $p < .001$; $F_2(2, 90) = 13.9$, $MSE = 592$, $p < .001$. Planned comparisons revealed that the difference between the related and the control conditions was significant both by subjects and by items, $F_1(1, 45) = 5.2$, $MSE = 503$, $p < .03$; $F_2(1, 45) = 4.9$, $MSE = 603$, $p < .03$. There was a significant effect of prime conditions for nonwords which was due to faster responses in the identity condition, $F_1(2, 90) = 10.8$, $MSE = 727$, $p < .001$; $F_2(2, 90) = 11.4$, $MSE = 660$, $p < .001$. Errors were too few to allow a reliable analysis.

[3] *Simple past tense* relates to one form of past inflection in Hebrew labeled as *binyan Kal*.

Discussion

The facilitation obtained in the related condition with nonword roots reinforces the conclusions concerning the morphological characteristics of the priming effects in the previous experiments. The results contravene a simplistic account of word-to-word semantic priming. The roots in the present experiment consisted of abstract morphemes but did not represent spoken or printed words. Thus, they were sequences of consonants that never appear independently as word units in the Hebrew language. Nevertheless, they facilitated lexical access and naming for their respective root derivations. This result clearly establishes that the prime does not need to be an actual word form to produce a morphological priming effect. This rules out a simple linkage model between actual words and strongly favors the notion that abstract root morphemes can serve as lexical units. The implication is that the priming stimulus activates the representation of the root morpheme, which is subsequently involved in the recognition of the target, but this would be so only if recognition of the target involved recognition of the root. Thus, the results suggest that root morphemes are indeed lexically represented and can facilitate lexical decision or naming of their respective derivations.

Experiment 4: Priming With Semantic Associates

The aim of Experiment 4 was to provide additional evidence for the morphological and nonsemantic aspects of priming obtained with masked presentation. Participants were presented with the same targets as in Experiment 2. The primes, rather than being the targets' roots, consisted of words that were semantically but not morphologically associated with the targets. For example, the target TIZMORET [orchestra] was primed by *ngn* (the root *ngn* conveys the notion of instrument playing, and the printed form can be read as the word *nagan* [instrument player]) rather than by *zmr*, which conveys the notion of singing. The relations of *ngn* and TIZMORET are purely semantic, whereas *zmr* and TIZMORET are related both semantically and morphologically. Note that if we disregard morphological relations, the semantic meaning of *ngn* is even closer to TIZMORET than *zmr* is. This design allowed us to disentangle the effects of semantic and morphological relatedness in masked priming.

Method

The stimuli and design of the experiment were identical to those of Experiment 2, but all the prime roots in the related condition were replaced by semantic associates of the targets (see Appendix E). The words in the related conditions were two to five letters long (mean number of letters was 3.9), which did not overlap with the targets aside from a few random one-letter overlaps. Primes in the control conditions were words with the same orthographic characteristics as the primes in the related condition, but they were not semantically related to the targets (mean number of letters was 3.8). Note that in this experiment orthographic overlap between primes and targets was quite small. To control for the semantic similarity of the primes and the targets in the present and the previous experiments, 50 judges evaluated their semantic relatedness on a 7-point scale, from *unrelated* (1) to *highly related* (7). Mean semantic similarity of the semantic associates and the root primes to the targets was found to be almost identical (4.7 and 4.8, respectively, $SD = 1.0$). The mean semantic similarity of primes and targets in the control condition was 1.5.

Results

RTs in the three experimental conditions were averaged across subjects and across items and are presented in Table 4. In contrast to the results obtained with primes consisting of roots, targets were not facilitated by semantically related primes. In fact, lexical-decision latencies in the related condition were slightly slower than in the control condition (−3 ms). The effect of prime condition was significant in both subject and item analyses because of a strong facilitation (32 ms) in the identity condition, $F_1(2, 90) = 40.1$, $MSE = 447, p < .001$; $F_2(2, 90) = 34.8, MSE = 530, p < .001$. The effect of prime condition on error rate was significant, $F_1(2, 90) = 6.2, MSE = 45, p < .01$; $F_2(2, 90) = 7.6, MSE = 37, p < .01$. This was due to a larger error rate in the control condition relative to the identity condition, $F_1(1, 45) = 11.9, MSE = 42, p < .001$; $F_2(1, 45) = 14.1$, $MSE = 35, p < .001$, and relative to the related condition, $F_1(1, 45) = 5.9$, $MSE = 54$, $p < .02$; $F_2(1, 45) = 6.7$, $MSE = 47, p < .01$. There was a significant effect of prime condition for nonwords, $F_1(2, 90) = 5.7, MSE = 504, p < .004$; $F_2(2, 90) = 5.4$, $MSE = 499$, $p < .006$. However, because the nonwords were assigned to each condition randomly, this effect cannot be explained and was probably due to some stimulus specificities. No effect was found in the error analysis for nonwords ($Fs < 1.0$).

Discussion

The results of Experiment 4 demonstrate that root derivations were not facilitated by semantically related primes. This reinforces our belief that semantic overlap plays a small role in masked priming and strengthens the argument that the priming effects observed in the previous experiments were due to factors operating at the level of form, not at the level of meaning. This is not to deny that semantic-priming effects might be observable under different conditions (e.g., with an SOA longer than 43 ms or with primes that were also associatively linked with the targets). All that we can claim is that under the conditions used in the current series of experiments, primes that were judged to be as closely related to the targets as the root primes had no discernible effect. Thus, Experiment 4 supports the interpretation that root priming is not semantic in nature, suggesting that a morpho-

Table 4
Reaction Times (RTs) and Percent Errors for Lexical Decisions to Target Words in All Conditions in Experiment 4

	Identity	Related	Control
RT (ms)	532	567	564
Error (%)	5.3	6.2	9.8

Note. Targets are semantically but not morphologically related to the primes.

logical relation between primes and targets is necessary to obtain facilitation effects.

Part 2: Morphological and Semantic Processing: Which Comes First?

Although pure semantic relations do not seem to play a strong role in masked priming, the role of semantic factors in driving morphological priming is a question of great interest. In general, it is not easy to disentangle semantic from morphological relations; words that are morphologically related are usually semantically related as well. Studies conducted in English suggest that morphological relations do not lead to priming if they are not reflected by meaning similarity. For example, Marslen-Wilson et al. (1994) have shown that in a cross-modal priming paradigm, priming effects were obtained for derived forms only when the two words were clearly related semantically (e.g., *govern–governor*). No priming at all was obtained for pairs that were marked in a dictionary as being related, but which had no apparent semantic relationship (e.g., *apart–apartment, casualty–casual, successful–successor*).[4] Marslen-Wilson et al. have therefore concluded that morphologically related but semantically opaque pairs are represented in the lexicon as distinct entries without morphological links. However, because, for the native speaker of English, the main clue for determining morphological relations is semantic overlap, this finding merely suggests that dictionary definitions of morphological relations do not necessarily have psychological reality.

This characteristic of the English language might derive in part from its specific morphological structure. In English, the morphemes of morphologically complex words are linearly appended one to the other, but identical letter clusters could represent a morpheme in one word and a nonmorphemic unit in another. Because there are no a priori rules about how to parse a word into its morphemic constituents, words that share form can be judged as morphologically related mainly by applying semantic criteria. For example, *need–needy* and *fort–forty* have similar form overlap, but which one of the two pairs is morphologically related? The correct conclusion can be drawn by considering semantic factors. Whereas there is clear semantic overlap between *need* and *needy*, there is none between *fort* and *forty*. Thus, semantic considerations serve as the main clue for assessing and representing morphological relations in English.

Hebrew, on the other hand, has a different derivational system. Because in Hebrew all words are morphologically complex and many derivations can be formed by combining the same root with different word patterns, Hebrew speakers are finely tuned to the root contained within the word (see, e.g., Ben-Dror, Bentin, & Frost, 1995; Berman, 1982). Some studies in Hebrew suggest that this morphological tuning does not necessarily depend on semantic overlap. For example, Bentin and Feldman (1990) showed that repetition effects for words sharing the same root but having different semantic meanings were evident even at long lags, whereas effects of simple semantic association were evident only at short lags. Words that shared the same root and were also semantically related showed the most robust repetition-priming effects. This outcome suggests that different mechanisms may underlie morphological processing and the appreciation of semantic association, even though both rely on the analysis of the root. The following experiments were designed to determine whether a similar state of affairs applies in masked priming. It is possible that the influence of semantic factors is dissipated with long intervals between prime and target, but with very short intervals, the absence of any semantic relation may interfere somehow with the morphological priming effect.

Experiment 5: Priming With Root Derivations

In this experiment, participants were presented with prime and target pairs that were derivations of the same root but which varied in the degree of semantic overlap. The aim of the experiment was twofold: first, to examine whether a derived word can prime another derivation in the masked-priming paradigm and, second, to investigate whether such potential facilitation depends on semantic relatedness. These questions are of significant importance in light of recent results obtained in English. For example, Marslen-Wilson et al. (1994) have shown no facilitation between two derived forms in cross-modal priming (e.g., *governor–government*). Facilitation was obtained only between stems and derivations (e.g., *govern–government*), but only when they were semantically related. However, if in the Hebrew lexicon all derivations are connected to the abstract root unit, and the root extraction is a mandatory phase of word processing, facilitation between two derivations could very well be obtained. This is because the root extracted from the prime should facilitate lexical access to the target derivation if it contains an identical root. Moreover, we would predict that such facilitation should occur regardless of semantic relatedness.

Method

Participants. The participants were 60 undergraduate students at The Hebrew University, all native speakers of Hebrew, who participated in the experiment for course credit or for payment. None of the participants took part in the previous Experiments.

Stimuli and design. The stimuli consisted of 60 target root derivations that were four to seven letters long and contained two or three syllables with five to eight phonemes (see Appendix F). Their mean number of letters was 5.0, and their mean number of phonemes was 6.5. The target words were paired with 60 primes to create four experimental conditions: In the identity condition, primes and targets were identical. In the morphologically related but semantically unrelated condition (M+S−), primes were derivations of the same root as the targets, but their meaning was unrelated to the targets. For example, both *MERAGEL* [a spy] and *TARGIL* [an exercise] are derivations of the root *rgl*, which conveys the meaning of a foot action. Whereas it is possible to trace the historical evolution of these derivations from the root, their semantic overlap in modern Hebrew is entirely opaque. In the morphologically and semantically related condition (M+S+), the

[4] It could of course be argued that these words are related only in a historical sense, and that for current speakers they are completely unrelated and should be treated as pseudorelated items.

primes not only contained the same root as the targets, but also had a similar meaning. Finally, in the control condition, the primes shared with the targets, on average, the same number of letters as in the related conditions, but consisted of a derivation of a different root. As in the previous experiments, the position of overlapping letters in the related and the control conditions could be initial, middle, or final, with a similar distribution in the two conditions. On average, primes and targets overlapped by 3.4 letters in the M+S+ and M+S− conditions and overlapped by 3.3 letters in the control condition. Thus, pure orthographic similarity was preserved in all experimental conditions, which differed one from the other only in semantic and morphological factors. Examples of stimuli used in the experiment are presented in Figure 4, and stimuli are presented in Appendix E. Sixty target nonwords composed of the same word patterns as above, but with pseudoroots, were introduced as fillers. Similar to the word targets, the nonwords were also divided into four experimental conditions.

The stimuli were divided into four lists, each containing 15 words and 15 nonwords in each of the four experimental conditions. The stimuli were rotated within the four conditions in each list by a Latin square design, and 15 participants were tested on each list. The procedure and apparatus were identical to those used in the previous experiments.

Results

RTs in the four experimental conditions were averaged across subjects and across items and are presented in Table 5. The effect of prime condition was significant in both subject and item analyses, $F_1(3, 180) = 28.2$, $MSE = 567$, $p < .001$; $F_2(3, 168) = 20.1$, $MSE = 860$, $p < .001$. This was due to faster responses in the identity condition and in *both* morphologically related conditions, relative to the control baseline. Planned comparisons revealed that the difference between the M+S− and the control conditions (11 ms) was significant for both subjects and items, $F_1(1, 60) = 6.3$, $MSE = 614$, $p < .01$; $F_2(1, 56) = 4.7$, $MSE = 889$, $p < .03$. In contrast, the difference (4 ms) between the semantically related and unrelated primes (M+S+ and M+S−) was not significant ($Fs < 1.0$). Significant priming effects were also found in the error analysis for both subjects and items, $F_1(3, 180) = 7.0$, $MSE = 31$, $p <$ .002; $F_2(3, 168) = 5.8$, $MSE = 35$, $p < .008$. This was mainly because there were fewer errors in the identity condition. No effects were found for nonwords.

	IDENTITY	M+S+	M+S-	CONTROL
Forward mask	########	########	########	########
Prime	taklit [a record] תקליט	haklata [a recording] הקלטה	klita [absorption) קליטה	takala [malfunction] תקלה
Target	TAKLIT תקליט	TAKLIT תקליט	TAKLIT תקליט	TAKLIT תקליט

ROOT: KLT - קלט (anything to do with receiving).

Figure 4. Examples of stimuli used in Experiment 5. Stimuli were presented in unpointed Hebrew script, and therefore, not all of the word vowels were printed. For example, the middle vowel /a/ does not appear in print. M+S+ = morphologically and semantically related; M+S− = morphologically related and semantically unrelated.

Table 5
Reaction Times (RTs) and Percent Errors for Lexical Decisions to Target Words in All Conditions in Experiment 5

	Identity	M+S+	M+S−	Control
RT (ms)	546	568	572	583
Error (%)	3.1	6.3	6.6	7.3
Priming (ms)	37	15	11	

Note. Priming times were calculated by subtracting the RT for each condition from the RT for the control condition. M+S+ = morphologically and semantically related; M+S− = morphologically related and semantically unrelated.

Discussion

The results of Experiment 5 demonstrate that in Hebrew, root derivations can prime other derivations and that morphological priming occurs irrespective of semantic relatedness. These results are consistent with the previous findings of Bentin and Feldman (1990), who showed repetition-priming effects for derivations that are semantically unrelated. Two possible lexical structures and processes could account for the findings of Experiment 5. The first supports the hypothesis that mandatory morphological decomposition occurs in Hebrew and that roots are extracted as a default process by the reader. If roots indeed serve as lexical entities connecting to all their inflections or derivations, morphological priming is indeed expected to occur regardless of the semantic overlap between any two derivations. According to this hypothesis, the brief exposure to the primes would result in detecting the lexical entries of the relevant derivations, and the subsequent mandatory process of root extraction would allow faster lexical access to all targets containing it. Another possible interpretation of the results would simply suggest that all derivations are lexically linked and that access to one allows faster access to another regardless of semantic overlap. Note, however, that both interpretations of the data suggest that words in Hebrew are organized in the lexicon in clusters that are morphologically defined.

The finding that priming occurs between derived words is inconsistent with the findings of Marslen-Wilson et al. (1994), as is the finding that priming occurs independently of semantic overlap. Two possible explanations should be considered. One is that we have uncovered a genuine difference between languages. It may be, for example, that morphological processes in English are not sufficiently productive to require the language learner to use morphological structure to store and retrieve lexical items, whereas in Hebrew this is an essential requirement. Another possibility is that the differences are due to differences in experimental techniques, because Marslen-Wilson et al.'s findings were based on a cross-modal technique in which an auditory prime is followed by a visual target. Apart from the obvious difference in modalities, there is the factor of awareness of the prime to consider, and also the very short temporal interval between prime and target used in the current experiments. It is possible that the masked-priming paradigm picks up very transient effects that are missed in the cross-modal paradigm.

Experiment 6: Priming With Pseudoroot Derivations

In this experiment, we examined whether root extraction occurs only for words or whether it could occur also for pseudoderivations. Because in Hebrew each root may be combined only with a predetermined set of word patterns, pseudowords may be created by using an illegal combination of root and word pattern. There are no specific rules that predict what word patterns specifically combine with what roots. Part of the language skills of the native Hebrew speaker reflects this acquired knowledge. In fact, in the process of language acquisition, many errors made by young children consist of illegal combinations of roots and word patterns (e.g., Berman, 1982). This presents an interesting theoretical question. Does the facilitation caused by root morphemes in the previous experiments depend on the existence of a lexical representation for the prime? If the process of morphological decomposition depends on locating an existing lexical entry for the prime, then no priming should occur when pseudoword primes are used.

In Experiment 6, participants were presented with pseudoderivation primes consisting of an illegal combination of legal roots and legal word patterns (e.g., *tazmera,* which illegally combines the legal root *zmr* with the legal word pattern *ta__e_a*). Thus, primes in the related condition were illegal derivations of the roots.

Method

Participants. The participants were 48 undergraduate students at The Hebrew University, all native speakers of Hebrew, who participated in the experiment for course credit or for payment.

Stimuli and design. The stimuli consisted of the 48 targets used in Experiment 2 but paired with pseudoword primes rather than with roots (see Appendix G). The pseudowords in the related condition were constructed by embedding the targets' roots with word patterns that do not legally combine with those specific roots. These primes were four to seven letters long. Their mean number of letters was 5.1, and their mean number of phonemes was 6.7. The primes overlapped with the targets, in most cases, only by the three root letters, but sometimes by an additional letter. Thus, on average, primes and targets in the related condition overlapped by 3.7 letters and by 3.9 phonemes. In the control condition, the primes were pseudowords sharing on average a similar number of letters with the targets, but not sharing the entire root letter unit. The mean number of overlapping letters of primes and targets in the control condition was 3.1, and the mean number of overlapping phonemes was 3.4. As in the previous experiments, the position of overlapping letters in the related and the control conditions could be initial, middle, or final, with a similar distribution in the two conditions. Thus, pure orthographic similarity was preserved in the two conditions, which differed one from the other only by morphological factors. The procedure and apparatus were identical to those used in the previous experiments.

Results and Discussion

RTs in the identity, related, and control conditions are presented in Table 6. The effect of prime condition was significant in both subject and item analyses, $F_1(2, 90) = 30.7$, $MSE = 385$, $p < .001$; $F_2(2, 90) = 21.0$, $MSE = 636$, $p < .001$, and was mainly due a 30-ms facilitation in the identity relative to the control condition. Planned comparisons revealed that the difference between the related and the control conditions (4 ms) was not significant ($Fs < 1.0$). The error analyses showed a significant effect of prime condition as well, $F_1(2, 90) = 4.4$, $MSE = 41$, $p < .01$; $F_2(2, 90) = 5.6$, $MSE = 33$, $p < .005$. This was due to fewer errors in the identity condition than in the control condition. No significant effects were found for nonword targets, $F_1(2, 90) = 1.2$, $MSE = 422$; $F_2(2, 90) = 1.9$, $MSE = 585$.

Table 6
Reaction Times (RTs) and Percent Errors for Lexical Decisions to Target Words in All Conditions of Experiment 6

	Identity	Related	Control
RT (ms)	530	555	559
Error (%)	4.5	6.6	8.4

Note. Primes are nonwords composed of illegal combinations of legal roots and word patterns.

The results of Experiment 6 suggest that a masked presentation of a root pseudoderivation does not facilitate lexical access to a target that is a legal derivation of that root. This outcome poses some important constraints on the process of morphological decomposition. We discuss this in length in the General Discussion.

General Discussion

The present study examined the morphological structure of the Hebrew mental lexicon. Because in Hebrew all words are composed of two abstract morphemic units, roots and word patterns, we investigated their role in governing lexical organization and lexical processing. The two classes of morphemic units in semitic languages present an interesting taxonomy. Word patterns organize words into clusters that are phonologically defined. Thus, they are morphophonemic units that convey vague syntactic or semantic information, but represent, first of all, a distinguishable phonological form. Roots, on the other hand, organize words into clusters that are semantically defined. Admittedly, all root derivations share a phonological pattern (i.e., the three-consonantal skeleton). However, they represent *primarily* families of words that explicitly or implicitly share features of meaning.

Although the native speaker of Hebrew has knowledge of both roots and word patterns, their role in lexical access should not necessarily be equivalent. Our hypothesis was that roots serve as lexical entities that can facilitate lexical access to a large cluster of words that are derived from them. In contrast, we hypothesized that at least for nominal forms, word patterns are lexically represented but may have a relatively minor role in accessing all the words that are formed with them.

Our results confirm the different roles of roots and word patterns in lexical retrieval. We did not obtain any significant facilitation in lexical decision or naming of target words that shared the same word pattern with the primes. Although the overlap between primes and targets was sometimes even smaller when roots served as primes, a previous presentation of the root letters did produce consistent priming effects in both lexical decisions and naming. These effects were measured relative to an orthographic control, thereby emphasizing the specific morphological status of the root letters. More important, root primes did not have to consist of legal words to exert their facilitatory influence. This outcome emphasizes the abstract nature of roots as morphemic units.

Our working hypothesis is that masked priming reflects a transfer effect. That is, the results of processing carried out on the prime are transferred across to the target. This transfer is made possible when the prime and target have overlapping representations. This assumption was based on several studies showing that the brief exposure of the prime and its unconscious perception result in a facilitation of target identification that is due to form 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. Therefore, additional representations that are shared between the prime and target should be assumed, and these representations must be activated whenever the prime or the target is recognized. We suggest that these shared representations are the roots. Further, we would assume that a semantically related prime that did not share a root with its target would not involve any of the structures required for the target, and hence no priming would be observed. The results of Experiment 4 support this assumption. When primes and targets were semantically and not morphologically associated, no priming at all was obtained.

The effects we obtained for roots seem very stable. In four independent experiments, facilitation of about 13–14 ms was repeatedly obtained in the related condition relative to an orthographic control. This stability was probably due to the specific features of the masked-priming paradigm. Because participants were not aware of the primes, they did not have any conscious appreciation of their relations with the targets, thereby minimizing strategic response biases. The masked-priming paradigm has characteristic footprints, which were revealed in all of the present experiments: Large effects emerged in an identity condition for words, thus setting a baseline for maximal facilitation. Facilitation in the related condition was about half as large. No facilitation was obtained in the identity condition for nonwords in lexical decision, emphasizing the lexical source of this facilitation.

The contrasting results of Experiments 1A and 1B involving word-pattern morphemes and the results of the following experiments involving root morphemes therefore provide important insight concerning the exact morphological structure that facilitates lexical retrieval. Lexical retrieval of target words was not speeded by the previous processing of words with identical phonological word patterns. Thus, in contrast to the root morpheme, even if the word pattern morpheme was indeed processed and recognized, it did not facilitate access to other words containing it. This conclusion should be constrained, however, to the processing of words in the visual modality; it is possible that word patterns might be found to have a more significant role in auditory word perception. Indeed, Marslen-Wilson and his colleagues (Marslen-Wilson et al., 1994) have shown different results with visual and auditory presentations of morphologically related words. Furthermore, at this stage of our research, the present conclusion should be limited to the noun derivational system on which all the current findings are based. It is possible that the role of word patterns in lexical access is more central for the verbal system in which the number of word patterns is much more limited and in which their semantic characteristics are more transparent.

The main finding of the present study concerns, however, the role of root morphemes in lexical access. Our results demonstrate that access for word targets was always speeded if they were primed by the root letters. The results of Experiment 3 revealed that these root letters need not be a legal, meaningful word. The three consonants of a root are recognized because they are the common morpheme that appears in all of its inflections and derivations, and not because they appear as a word unit in print. Once the root morpheme is located, lexical access to a derivational target is facilitated. Furthermore, Experiment 5 revealed that access to targets was facilitated not only by primes consisting of roots, but also by primes consisting of words that share the same root with the targets. This outcome suggests that all words that contain the same root morpheme are linked to the shared morphological unit of the root.

A possible model of morphological processing in the Hebrew lexicon is presented in Figure 5. According to this model, the lexical structure of the Hebrew lexicon consists of two levels of representations: a level of lexical units (i.e., words) and a level of subword units of root morphemes. These two levels are interconnected so that the root morpheme can be accessed at the lexical level from words containing that root (right side of Figure 5) or, alternatively, by directly following a process of morphologically decomposing the orthographic structure (left side of Figure 5). As for printed words, they can be identified directly from the orthographic structure, but this process can also be aided by access to their respective roots. Thus, according to this model, the processing of printed words consists of *both* lexical retrieval and morphological decomposition, which may take place simultaneously. This duality allows for

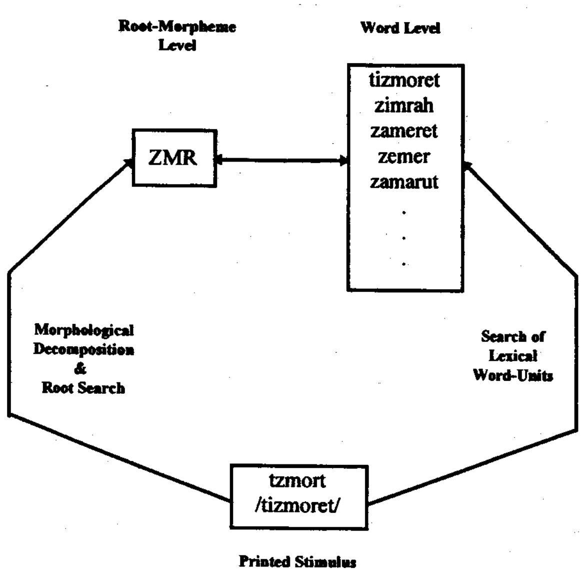

Figure 5. The internal structure of the Hebrew lexicon and the processes involved in printed word recognition.

efficient reading in Hebrew because morphological analysis in general and the extraction of root morphemes in particular provide essential information that may integrate the printed word into the semantic context. Evidence in support of subword units of root morphemes that are independent of word representations is apparent in the results of Experiment 3. In this experiment, we found that lexical decision and naming of targets were facilitated by a previous presentation of a legal root that did not represent a word.

The results of Experiment 6 provide important constraints concerning the search process. In this experiment, we found that nonword primes that were nonexisting combinations of real roots and real word patterns did not facilitate lexical decisions for target words that were derived from the same roots. Thus, it seems that any facilitation obtained by root morphemes is constrained by the lexical representation of the prime. Considering the model presented in Figure 5, exposure to a printed word entails both a retrieval of a root unit and a parallel access to the lexical-units level. Thus, if the root is embedded in a nonword, the morphological decomposition of the orthographic structure would indeed result in access to the subword root level, but the retrieval process at the lexical level would be unsuccessful. In this case, the activation produced by the root extracted from the nonword prime would have to be inhibited in some way.

Note that although the primes in Experiments 3 and 6 were nonwords, there is an inherent difference between them. Whereas in Experiment 3 we presented participants with existing subword morphological units (real roots) that did not represent a spoken or written word, the primes in Experiment 6 did not represent any independent unit, either in the lexical level or in the subword morphological level. Thus, the three letters of the root morpheme had to be extracted from a longer sequence of letters, allowing for other alternative letter combinations to be considered as root candidates. In contrast to meaningful word primes (as in Experiment 5), this process could not be aided by access to a lexical unit containing this root and was, therefore, ineffective. This clarifies why priming was obtained in Experiment 3 but not in Experiment 6. Thus, our results suggest that identification of targets can be aided by the location of the morphological subword units from which they are derived, but it seems that this facilitation is not apparent if the primes do not have any lexical representation.

It should be noted that the majority of orthographic sequences of the three-consonant roots did indeed have a lexical status because they could be read as real words in Hebrew. It is possible, however, that the organization of the lexicon according to the morphological principle of root morphemes also develops on the basis of recognizing basic words that contain only the root morpheme combined with a word pattern of consonants (C) and vowels (V) consisting of two vowels (CVCVC words like *zemer*). These words might have a similar function as the stem in languages with concatenated morphology. However, considering the derivational properties of the language, which are heavily anchored in the root and word-pattern morphemes, the basic root morpheme would gain, according to this view, a lexical status that allows access to all root derivations. Thus, this developmental process might be further formalized and applied for any consonantal root sequence regardless of its lexical status as a real word in the language.

A question of considerable interest is the nature of the parsing routine that analyzes a derived word into its morphological constituents. Taft and Forster (1975) postulated a left-to-right incremental parsing routine, in which increasingly larger chunks of the input were tested for lexical status. Thus, accessing the word *postman* would involve searching for entries for *po-*, *pos-*, *post-*, and so forth. A left-to-right processing of derivations was recently demonstrated in Dutch as well (e.g., Hudson & Buijs, 1995). Alternatively, Schreuder and Baayen (1994) have suggested that the principle of early stripping is based on the metric structure of the word, so that initial syllables and not letters are more likely to be the basic units of this process (see also Cutler & Norris, 1988). Although there is evidence for prefix stripping in Hebrew, it mainly concerns initial letters that serve as functors and are appended to the word (Koriat & Greenberg, 1993). Simple linear stripping procedures work well for concatenated systems but would be less effective for the interleaved nature of Hebrew morphemes. For example, how is the root *zmr* recovered from *tizmoret*? The *ti*, for example, is represented in Hebrew as a single character, but it could be a character of the root as well as the word pattern. Thus, an interesting question concerns the effectiveness of priming when the root sequence appears as a nondisrupted unit within the target or when it is orthographically dispersed. If the root consonants are not extracted in a linear fashion from the word, priming effectiveness should not depend on the integrity of the morphemic sequence. This can be easily tested in our study by examining the stimuli in Experiment 2. For half of the stimuli, the root morphemes appeared as nondisrupted units within the targets, and for the other half the sequence of root letters was disrupted by letters belonging to the word-pattern morpheme. If it is more difficult to extract a distributed root, then we might expect less priming. However, a post hoc analysis of the data from Experiment 2 showed virtually identical priming in the related condition for distributed targets and nondistributed targets. The model in Figure 5 provides a possible description of the dynamics involved in recovering the root from the orthographic structure. Although several roots could theoretically be extracted from a given letter string (left path of Figure 5), only one would fit the possible candidates searched in the word-unit level (right path of the figure).

Note that our results and conclusions can also be described in a connectionist framework. Such a model would consist of two levels of nodes, one corresponding to the words (lexical-units level) and one corresponding to the morphological structure of the root. These two levels are interconnected so that every node in the lexical-units level is connected to the root node from which it is derived. Although nodes in the lexical-units level may also be connected to other root nodes that share some similarity with them, these connections are assumed to be weaker than the connections between a specific root node and its derived words. Activation of nodes in both of these levels may rise directly from exposure to the printed word as well as from positive feedback from the mutual excitatory connections between the two levels. In our study, exposure to the prime may have initiated some activation at the root level (as in Experiments 2 and 3) and at the lexical-units level (as in Experiments 2 and 5). Thus, when the target following the prime was presented, its lexical-unit node may have been already partially activated. This partial activation of the target was due to the activation of its corresponding root, given the prime presentation. Note that in Experiment 6, activation of nodes at the root level could not have been supported by the corresponding activation at the lexical-unit level because the primes were nonwords. This explains the different results in Experiments 5 and 6.

A model consisting of both a subword morphological level and a lexical word level was recently offered by Drews and Zwitserlood (1995) for the shallow Dutch and German orthographies. Similar to our results in Experiment 6, Drews and Zwitserlood found no morphological facilitation when the prime was a pseudoword composed of an illegal combination of a legal stem and a legal suffix, in both masked and unmasked priming. Drews and Zwitserlood suggested, therefore, that the morphological level is activated *following* activation in the lexical level (the "form" level, in their terms). However, the results of Experiment 3 in our study where the primes were nonword legal roots suggest that in Hebrew, activation of the subword morphological root morphemes is not necessarily postlexical.

Whether our results are described in activation terms or using the classical entry-opening account is not of major relevance to the central issue concerning the role of morphology in lexical representation. What is indeed crucial is our assumption regarding the existence of localized representations of words and roots (see Besner, in press, for a discussion). Thus, the main conclusion from our investigation of Hebrew morphology is that abstract morphological units have, indeed, a strong lexical reality. Not only are they units that can be recognized and manipulated by the native speaker, but they seem to govern the organization of the words in the lexicon. However, one qualification regarding this interpretation needs to be acknowledged. It concerns the statistical properties of the letter used in the related and control conditions in our experiments. Recent models assuming distributed representations (e.g., Seidenberg, 1987) have argued for the critical role played by these properties in printed word recognition. These models would, therefore, argue that the consistent morphological effects obtained in our study could have emerged from different correlations between orthography, phonology, and semantics, in the different experimental conditions. From this point of view, to obtain unambiguous evidence for morphological representations per se, these correlations should be controlled and matched.

Our results cannot unequivocally resolve the differences between localized and distributed modeling of morphological structure, because normative measures of trigram frequencies are not available in Hebrew, and the contribution of the relative frequency of letter primes in the related and unrelated conditions to the priming effects could not be assessed. Moreover, in the absence of a detailed computational model in Hebrew, it is not clear what specific correlations need to be controlled. Nevertheless, our experiments in Hebrew could provide interesting insights into this debate. As we chose our stimuli on the basis of morphological structure alone, it is not very likely that simply by chance the prime letters in the related condition had consistently higher trigram frequencies than the prime letters in the control condition, in each of our experiments. Thus, a proponent of distributed representations would have to concede that such consistency is due, not to random sampling, but to the specific characteristics of Hebrew morphological structure. In this case, the different statistical characteristics of letters in the related and control conditions would necessarily reflect a consistent statistical property of the root letters versus other letters. This, however, is what the psychological learning of morphological structure is all about. Another argument concerns the clear awareness of root morphemes. Root morphemes are not explicitly taught to children, and they are probably extracted by the native speakers given the correlation between phonological forms and semantic meaning. Both localized and distributed representation models would be happy with this account. Note, however, that the native speaker of Hebrew has a clear metaknowledge of the root morpheme that composes every root derivation, regardless of the semantic meanings that each derivation carries. Thus, although models of distributed representations could explain morphological priming by referring to different correlations of letters in primes and targets, their explanatory adequacy is much less compelling in accounting for the explicit morphological knowledge of the native speaker. Therefore, these models would need to offer two different accounts for explicit knowledge and implicit performance.

Not all morphological units in Hebrew have an identical status. The different results we obtained for roots and word patterns suggest that morphemic units should have an optimal level of specification to have a role in lexical access. Note that both morphemic units in Hebrew are phonologically defined. Roots are phonological units as word patterns are, by virtue of being composed of three consonants. The main difference between roots and word patterns concerns their level of semantic specification. The family resemblance of words sharing a root is more coherent than the family resemblance of words sharing a word pattern. This is probably the source of their differential role in lexical organization.

The results from Hebrew emphasize the relatively minor role of semantic overlap in morphological processing. They suggest that semantic relatedness does not necessarily drive morphological priming. Note that in their account of morphological organization of English, Marslen-Wilson et al. (1994) showed that priming does not occur for semantically opaque items, and consequently they argued that semantically opaque but morphologically complex words are represented as morphologically simple at the level of lexical entries. However, it should be noted that the average speaker of English is unaware of the diachronic history of some morphologically complex words (e.g., *depart, department*). Therefore, these words could not have been considered by participants as morphologically related and were probably treated as words having simple orthographic overlap. Thus, the results of Marslen-Wilson et al.'s study cannot provide clear evidence for the role of semantic relatedness in *morphological* processing. In Hebrew, on the other hand, the appearance of the same consonant cluster in many derivations is the main clue for correct morphological decomposition. Thus, the appreciation of morphological relations between derivations arises mainly from the productivity of the roots, and therefore, the role of semantic relatedness in driving morphological priming can be more easily tested.

Our results from Hebrew thus suggest that in general, lexical structure should be regarded as an *optimal* system for organizing the meaningful units of language. This optimization principle would necessarily reflect the idiosyncratic features of the language's morphological, orthographic, and phonological structures. If the morphological structure of a language allows a lexical organization defined by morphophonological principles, then pure semantic features may become a secondary organizing principle.

References

Ben-Dror, I., Bentin, S., & Frost, R. (1995). Semantic, phonological, and morphological skills in children with reading disabilities and normally achieving readers: Evidence from perception and production of spoken Hebrew words. *Reading Research Quarterly, 30,* 876–893.

Bentin, S., & Feldman, L. B. (1990). The contribution of morphological and semantic relatedness to the repetition effect at long and short lags: Evidence from Hebrew. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 42(A),* 693–711.

Bentin, S., & Frost, R. (1987). Processing lexical ambiguity and visual word recognition in a deep orthography. *Memory & Cognition, 15,* 13–23.

Bentin, S., & Frost, R. (1995). Morphological factors in visual word identification in Hebrew. In L. Feldman (Ed.), *Morphological aspects of language processing* (pp. 271–292). Hillsdale, NJ: Erlbaum.

Berman, R. A. (1978). *Modern Hebrew structure.* Tel Aviv, Israel: University Publishing Projects.

Berman, R. A. (1982). Verb pattern alternation: The interface of morphology, syntax, and semantics in Hebrew child language. *Journal of Child Language, 9,* 169–191.

Besner, D. (in press). Basic processes in reading: Multiple routines in localist and connectionist models. In P. A. McMullen & R. M. Klein (Eds.), *Converging methods for understanding reading and dyslexia.* Cambridge, MA: MIT Press.

Butterworth, B. (1983). Lexical representation. In B. Butterworth (Ed.), *Language production* (Vol. 2, pp. 257–294). San Diego, CA: Academic Press.

Cutler, A., & Norris, D. G. (1988). The role of strong syllables in segmentation for lexical access. *Journal of Experimental Psychology: Human Perception and Performance, 14,* 113–121.

Drews, E., & Zwitserlood, P. (1995). Morphological and orthographic similarity in visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 1098–1116.

Feldman, L. B. (1991). The contribution of morphology to word recognition. *Psychological Research, 53,* 33–41.

Feldman, L. B. (1994). Beyond orthography and phonology: Differences between inflections and derivations. *Journal of Memory and Language, 33,* 442–470.

Feldman, L. B., Frost, R., & Pnini, T. (1995). Decomposing words into their constituent morphemes: Evidence from English and Hebrew. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 947–960.

Forster, K. I. (1987). Form-priming with masked primes: The best-match hypothesis. In M. Coltheart (Ed.), *Attention and performance XII* (pp. 127–146). Hillsdale, NJ: Erlbaum.

Forster, K. I. (1993). Form priming and temporal integration in word recognition. In G. Altmann & R. Shillcock (Eds.), *Cognitive models of speech processing: The Second Sperlonga Meeting* (pp. 467–495). Hillsdale, NJ: Erlbaum.

Forster, K. I., & Davis, C. (1984). Repetition priming and frequency attenuation in lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10,* 680–698.

Forster, K. I., & Davis, C. (1991). The density constraint on form priming in the naming task: Interference effects from a masked prime. *Journal of Memory and Language, 33,* 442–470.

Forster, K. I., Davis, C., Schoknecht, C., & Carter, R. (1987). Masked priming with graphemically related forms: Repetition or partial activation? *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 39(A),* 211–251.

Forster, K. I., & Taft, M. (1994). Bodies, antibodies, and neighborhood-density effects in masked form priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 844–863.

Fowler, C. A., Napps, S. E., & Feldman, L. B. (1985). Relations among regular and irregular morphologically related words in the lexicon as revealed by repetition priming. *Memory & Cognition, 13,* 241–255.

Frost, R. (1994). Prelexical and postlexical strategies in reading: Evidence from a deep and a shallow orthography. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 116–129.

Frost, R. (1995). Phonological computation and missing vowels: Mapping lexical involvement in reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 398–408.

Frost, R., & Bentin, S. (1992). Reading consonants and guessing vowels: Visual word recognition in Hebrew orthography. In R. Frost & L. Katz (Eds.), *Advances in psychology: Vol. 94. Orthography, phonology, morphology, and meaning* (pp. 27–44). Amsterdam: North-Holland.

Frost, R., Katz, L., & Bentin, S. (1987). Strategies for visual word recognition and orthographical depth: A multilingual comparison. *Journal of Experimental Psychology: Human Perception and Performance, 13,* 104–115.

Grainger, J. (1990). Word frequency and neighborhood frequency effects in lexical decision and naming. *Journal of Memory and Language, 29,* 228–244.

Henderson, L., Wallis, J., & Knight, K. (1984). Morphemic structure and lexical access. In H. Bouma & D. Bouwhuis (Eds.), *Attention and performance X: Control of language processes* (pp. 211–226). Hillsdale, NJ: Erlbaum.

Hudson, P. T. W., & Buijs, D. (1995). Left-to-right processing of derivational morphology. In L. Feldman (Ed.), *Morphological aspects of language processing* (pp. 383–395). Hillsdale, NJ: Erlbaum.

Humphreys, G. W., Besner, D., & Quinlan, P. T. (1988). Even perception and the word repetition effect. *Journal of Experimental Psychology: General, 117,* 51–67.

Humphreys, G. W., Evett, L. J., Quinlan, P. T., & Besner, D. (1987). Orthographic priming: Qualitative differences between priming from identified and unidentified primes. In M. Coltheart (Ed.), *Attention and performance XII* (pp. 105–125). Hillsdale, NJ: Erlbaum.

Koriat, A., & Greenberg, S. N. (1993). Prominence of leading functors in function morpheme sequence as evidenced by letter detection. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19,* 51–70.

Lukatela, G., & Turvey, M. T. (1994). Visual lexical access is initially phonological: Evidence of associative priming by words, homophones, and pseudohomophones. *Journal of Experimental Psychology: General, 123,* 107–128.

Lupker, S. (1984). Semantic priming without association: A second look. *Journal of Verbal Learning and Verbal Behavior, 23,* 709–733.

Manelis, L., & Tharp, D. (1977). The processing of affixed words. *Memory & Cognition, 5,* 690–695.

Marslen-Wilson, W. D., Tyler, L. K., Waksler, R., & Older, L. (1994). Morphology and meaning in the English mental lexicon. *Psychological Review, 101,* 3–33.

Matthews, P. H. (1972). *Inflectional morphology: A theoretical study based on Latin verb conjugation.* Cambridge, England: Cambridge University Press.

Perea, M., Gotor, A., Rosa, E., & Algarabel, S. (1995, November). *Time course of semantic activation for different prime–target relationships in the lexical decision task.* Poster presented at the 36th annual meeting of the Psychonomic Society, Los Angeles, CA.

Rajaram, S., & Neely, J. H. (1992). Dissociative masked repetition priming and word frequency effects in lexical decision and episodic recognition tasks. *Journal of Memory and Language, 31,* 152–182.

Schreuder, R., & Baayen, R. H. (1994). Prefix stripping rerevised. *Journal of Memory and Language, 33,* 357–375.

Seguí, J., & Grainger, J. (1990). Masquage et effet de repetition du mot: Sa nature et sa localisation fonctionelle. [Masking and repetition of words: Their nature and functional localization.] *L'Annee Psychologique, 90,* 345–357.

Seidenberg, M. S. (1987). Sublexical structures in visual word recognition: Access units or orthographic redundancy? In M. Coltheart (Ed.), *Attention and performance XII* (pp. 245–263). Hillsdale, NJ: Erlbaum.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed developmental model of word recognition and naming. *Psychological Review, 96,* 523–568.

Sereno, J. A. (1991). Graphemic, associative, and syntactic priming effects at brief stimulus onset asynchrony in lexical decision and naming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 459–477.

Stanners, R. F., Neiser, J. J., Hernon, W. P., & Hall, R. (1979). Memory representation for morphologically related words. *Journal of Verbal Learning and Verbal Behavior, 18,* 399–412.

Stolz, J. A., & Feldman, L. B. (1995). The role of orthographic and semantic transparency of the base morpheme in morphological processing. In L. Feldman (Ed.), *Morphological aspects of language processing* (pp. 109–129). Hillsdale, NJ: Erlbaum.

Taft, M. (1981). Prefixed stripping revisited. *Journal of Verbal Learning and Verbal Behavior, 20,* 289–297.

Taft, M., & Forster, K. I. (1975). Lexical storage and retrieval of prefixed words. *Journal of Verbal Learning and Verbal Behavior, 14,* 638–647.

Veres, C. (1986). *Factors affecting word selection in the masked prime paradigm.* Unpublished honors thesis, Monash University, Melbourne, Australia.

Appendix A

The Hebrew Alphabet

Hebrew print	Orthographic transcription	Phonetic transcription
א	ʔ	ʔ
ב	b	b, v
ג	g	g
ד	d	d
ה	h	h
ו	w	o, u, v
ז	z	z
ח	x	x
ט	θ	t
י	y	I, y
כ	k	q, x
ך[a]	K	x
ל	l	l
מ	m	m
ם[a]	M	m
נ	n	n
ן[a]	N	n
ס	s	s
ע	ʕ	ʕ
פ	p	p, f
ף[a]	P	f
צ	c	ts
ץ[a]	C	ts
ק	q	k
ר	r	r
ש	S	sh
ת	t	t

[a]The letters k, m, n, p, and c have different orthographic forms when they appear at the end of the word.

(*Appendixes continue*)

Appendix B

Stimuli Used in Experiments 1A and 1B

Target				Related				Control			
Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning	Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning	Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning
מצלמה	mclmh	/matslema/	a camera	מקדחה	mqdxh	/makdexa/	a drill	מבריח	mbrIx	/mavrIax/	a smuggler
מחצבה	mxcbh	/maxtseva/	a quarry	ממטרה	mmθrh	/mamtera/	a sprinkler	מדריך	mdrIk	/madrIx/	a guide
מסרגה	msrgh	/masrega/	knitting needle	מטחנה	nθxnh	/matxena/	a mill	מחסום	mxswm	/maxsom/	a barrier
מקהלה	mqhlh	/makhela/	a choir	מזמרה	mzmrh	/mazmera/	secateur	מטמון	/matmon/	mθmwn	a treasure
מקפצה	mqpch	/makpetsa/	a springboard	מחרשה	mxrSh	/maxreSa/	a plough	מלשין	mlSIn	/malSIn/	a denouncer
מגרפה	mgrph	/magrefa/	a rake	מבחנה	mbxnh	/mavxena/	a test tube	מנהיג	mnhIg	/manhIg/	a leader
משאבה	mSʔbh	/maSʔeva/	a pump	מרגמה	mrgmh	/margema/	a mortar	מחסור	mxswr	/maxsor/	a shortage
מחלקה	nxkqh	/maxlaka/	department	ממלכה	mmlkh	/mamlaxa/	a kingdom	מצביא	mcbyʔ	/matsbI/	commander
מדרשה	mdrSh	/mIdraSa/	an academy	מפלגה	mplgh	/mIflaga/	a party	מכלול	mklwl	/mIxlol/	entity
מלחמה	mlxmh	/mIlxama/	a war	מגבלה	mgblh	/mIgbala/	a limitation	משמרת	mSmrt	/mISmeret/	a shift
מסעדה	msʕdh	/mIsʕada/	a restaurant	מנהלה	mnhlh	/mInhala/	directorate	מסגרת	msgrt	/mIsgeret/	a frame
מפקדה	mpqdh	/mIfkada/	headquarters	מקדמה	mqdmh	/mIkdama/	an advance	מצנפת	mcnpt	/mItsnefet/	a turban
משטרה	mSθrh	/mIStara/	police	משאלה	mSʔlh	/mISʔla/	a wish	מקלדת	mqldt	/mIkledet/	a keyboard
משמעת	mSmʕt	/mISmaʕat/	discipline	מגרעת	mgrʕt	/mIgraʕat/	a defect	מתנדב	mtndb	/mItnadev/	a volunteer
תחלופה	txlwph	/taxlufa/	substitution	תחזוקה	txzwqh	/taxzuka/	maintenance	תחמושת	txmwSt	/taxmoSet/	ammunition
תרדמה	trdmh	/tardema/	deep sleep	תבערה	tbʕrh	/tavʕera/	fire	תבשיל	tbSyl	/tavSIl/	a cooked dish
תקליט	tqlyθ	/taklIt/	a record	תרגיל	trgyl	/targIl/	exercise	תדהמה	tdhmh	/tadhema/	shock
מכללה	mkllh	/mIxlala/	a college	מנהרה	mnhrh	/mInhara/	a tunnel	מזחלת	mzxlt	/mIzxelet/	a sled
מזמור	mzmwr	/mIzmor/	a song	מסתור	mstwr	/mIstor/	a hideaway	מפלצת	mplct	/mIfletset/	a monster
תרשים	trSym	/tarSIm/	a sketch	תלמיד	tlmyd	/talmId/	a pupil	תרעלה	trʕlh	/tarʕela/	poison
תחקיר	txqyr	/taxkIr/	debriefing	תסביך	tsbyK	/tasbIx/	a complex	תאווה	tʔwwh	/taʔava/	lust
מעבדה	mʕbdh	/maʕabada/	a laboratory	מעצמה	mʕcmh	/maʕatsma/	a power	מערכת	mʕrkt	/maʕarexet/	a system
מצבר	mcbr	/matsber/	a battery	מסמר	msmr	/masmer/	a nail	מזגן	mzgN	/mazgan/	air condition
הגדרה	hgdrh	/hagdara/	a definition	אכזבה	ʔxzbh	/axzava/	disappointment	סתימה	stymh	/stIma/	a filling
שקרן	SqrN	/Sakran/	a liar	חלבן	xlbN	/xalban/	a milkman	מעבר	mʕbr	/maʕavar/	a passage
בדרן	bdrN	/badran/	entertainer	פשרן	pSrN	/paSran/	compromiser	משרד	msrd	/mIsrad/	an office
חסכן	xskN	/xasxan/	thrifty	עקשן	ʕqSN	/ʕakSan/	obstinate	מקלט	mqlθ	/mIklat/	a refuge
בגרות	bgrwt	/bagrut/	maturity	עצלות	ʕclwt	/ʕatslut/	laziness	תזונה	tzwnh	/tzuna/	nutrition
בטלנות	bθlnwt	/batlanut/	idleness	חשדנות	xSdnwt	/xaSdanut/	suspicion	תקשורת	tqSwrt	/tIkSoret/	communication
שמרנות	Smrnwt	/Samranut/	conservatism	סחטנות	sxθnwt	/saxtanut/	extortion	תסבוכת	tsbwkt	/tIsboxet/	complication
חנפנות	xnpnwt	/xanfanut/	flattery	בלשנות	blSnwt	/balSanut/	linguistics	תרגולת	trgwlt	/tIrgolet/	a drill
בדידות	bdydwt	/bdIdut/	loneliness	גמישות	gmySwt	/gmISut/	elasticity	ילדונת	yldwnt	/yaldonet/	a girl
פצצה	pcch	/ptsatsa/	a bomb	קטטה	qθθh	/ktatah/	a quarrel	מחזה	mxzh	/maxaze/	a play

Appendix B (*continued*)

Target				Related				Control			
Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning	Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning	Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning
אורגת	ʔwrgt	/ʔoreget/	a weaver	חותמת	xwtmt	/xotemet/	a seal	תורשה	twrSh	/toraSa/	heredity
שופטת	Swpθt	/Sofetet/	a judge	מוכרת	mwkrt	/moxeret/	saleswoman	תחושה	txwSh	/txuSa/	sensation
פועלת	pwʕlt	/poʕelet/	a worker	שודדת	Swddt	/Sodedet/	a robber	תוצאה	twcʔh	/totsaʔa/	a result
תבנית	tbnyt	/tavnIt/	a form	תשדיר	tSdyr	/taSdIr/	a commercial	תחתון	txtwN	/taxton/	lower
שוטרת	Swθrt	/Soteret/	policewoman	צוברת	cwbrt	/tsoveret/	accumulates	תרומה	trwmh	/truma/	contribution
חובש	xwbS	/xoveS/	a paramedic	סוהר	swhr	/soher/	a jailer	כתום	ktwM	/katom/	orange
מושבה	mwSbh	/moSava/	a colony	הוצאה	hwcʔh	/hotsaʔa/	an expense	מוצלח	mwclx	mutslax	successful
פרוצה	prwch	/prutsa/	a prostitute	גרושה	grwSh	/gruSa/	divorcée	שומרת	Swmrt	/Someret/	a keeper
קבוצה	qbwch	/kvutsa/	a group	מכונה	mkwnh	/mexona/	a machine	רווחה	rwwxh	/revaxa/	welfare
שמועה	Smwʕh	/Smuʕa/	a rumor	פרוטה	prwθh	/pruta/	a penny	מודעה	mwdʕh	/modaʕa/	an ad
זריחה	zryxh	/zrIxa/	sunrise	גלישה	glySh	/glISa/	sliding	יהדות	yhdwt	/yahadut/	Judaism
עצבות	ʕcbwt	/ʕatsvut/	sadness	יתמות	ytmwt	/yatmut/	orphanhood	שעמום	SʕmwM	/SIʕamum/	boredom
חוצפה	xwcph	/xutspa/	insolence	דוגמא	dwgmʔ	/dugma/	an example	תופרת	twprt	/toferet/	a seamstress
חולשה	xwlSh	/xulSa/	weakness	טומאה	θwmʔh	/tumʔa/	impurity	הוספה	hwsph	/hosafa/	addition
תמימות	tmymwt	/tmImut/	innocence	פרישות	prySwt	/prISut/	abstinence	תצרוכת	tcrwkt	/tItsroxet/	consumption

Note. The following phonological word patterns were used in Experiments 1A and 1B: maXXeXa, maXXaXa, miXXaXa, miXXaXat, taXXuXa, taXXeXa, taXXiX, miXXoX, maXXeX, AXXaXa, XaXXan, XaXXut, XaXXanut, XXiXut, XXaXa, XoXeXet, XoXeX, XXuXa, XXiXa, and XuXXa. Orth. = orthographic; trans. = transliteration.

(*Appendixes continue*)

Appendix C

Stimuli Used in Experiment 2

Target				Related			Control			
Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning	Hebrew	Orth. trans.	Semantic meaning	Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning
מפלט	mplθ	/mIflat/	escape	פלט	plθ	emitting	מפל	mpl	/mapal/	a waterfall
קציר	qcyr	/katsIr/	harvest	קצר	qcr	harvesting	ציר	cyr	/tsIr/	axis
מזרק	mzrq	/mazrek/	syringe	זרק	zrq	throwing	מרק	mrq	/marak/	soup
שקרן	SqrN	/Sakran/	a liar	שקר	Sqr	lying	קרן	qrN	/keren/	a ray
מפגש	mpgS	/mIfgaS/	a meeting	פגש	pgS	meeting	מגש	mgS	/magaS/	a tray
מראה	mrʔh	/marʔa/	a mirror	ראה	rʔh	seeing	מאה	mʔh	/meʔa/	a century
כפיל	kpyl	/kfIl/	a double	כפל	kpl	multiplying	פיל	pyl	/pIl/	an elephant
מרחק	mrxq	/merxak/	distance	רחק	rxq	removing	מרח	mrx		smearing
צלול	clwl	/tsalul/	clear	צלל	cll	diving	לול	lwl	/lul/	a hen house
משקל	mSql	/mISkal/	weight	שקל	Sql	weighting	משק	mSq	/meSek/	a farm
מצעד	mcʕd	/mItsʕad/	a march	צעד	cʕd	marching	מעד	mʕd		stumbling
רעשן	rʕSN	/raʕaSan/	noisemaker	רעש	rʕS	making noise	עשן	ʕSN		smoking
מרדף	mrdP	/mIrdaf/	a chase	רדף	rdP	pursuing	מדף	mdP	/madaf/	a shelf
ספוג	spwg	/sfog/	a sponge	ספג	spg	absorbing	סוג	swg	/sug/	a type
מחקר	mxqr	/mexkar/	research	חקר	xqr	examining	מחק	mxq		erasing
משתלה	mStlh	/mIStala/	a nursery	שתל	Stl	planting	משל	mSl	/maSal/	a fable
חותמת	xwtmt	/xotemet/	a stamp	חתם	xtm	signing	חום	xwm	/xum/	brown
הכתבה	hktbh	/haxtava/	a dictation	כתב	ktb	writing	כבה	kbh		extinguishing
מרפאה	mrpʔh	/mIrpaʔa/	a clinic	רפא	rpʔ	healing	פאה	pʔh	/peʔa/	a wig
בריחה	bryxh	/brIxa/	an escape	ברח	brx	escaping	ריח	ryx	/reax/	a smell
מאפה	mʔph	/maʔafe/	baked goods	אפה	ʔph	baking	מפה	mph	/mapa/	a map
מזבלה	mzblh	/mIzbala/	a dump	זבל	zbl	trashing	מזל	mzl	/mazal/	luck
פריחה	pryxh	/prIxa/	blossoming	פרח	prx	blooming	פרי	pry	/prI/	a fruit
גרושה	grwSh	/gruSa/	a divorcée	גרש	grS	driving away	גוש	gwS	/guS/	a block
מסעדה	msʕdh	/mIsʕada/	a restaurant	סעד	sʕd	dining	מסע	msʕ	/masa/	a journey
זחילה	zxylh	/zxIla/	crawling	זחל	zxl	crawling	חול	xwl	/xol/	sand
צפירה	cpyrh	/tsfIra/	a siren	צפר	cpr	honking	ירה	yrh		shooting
קישור	qySwr	/kISur/	liason	קשר	qSr	tying	שור	Swr	/Sor/	a bull
חקירה	xqyrh	/xakIra/	an inquiry	חקר	xqr	examining	קיר	qyr	/kIr/	a wall
טריקה	θryqh	/trIka/	a slam	טרק	θrq	slamming	טרי	θry	/tarI/	fresh
זריעה	zryʕh	/zrIʕa/	sowing	זרע	zrʕ	sowing	רעה	rʕh		herding
התגמדות	htgmdwt	/hItgamdut/	dwarfing	גמד	gmd	dwarfing	תות	twt	/tut/	a strawberry
מלכודת	mlkwdt	/malkodet/	a trap	לכד	lkd	capturing	מלך	mlK	/melex/	a king
התכנסות	htknswt	/hItkansut/	assembly	כנס	kns	assembling	כסת	kst	/keset/	a featherbed
בדידות	bdydwt	/bdIdut/	loneliness	בדד	bdd	being alone	בית	byt	/bayIt/	home
תגבורת	tgbwrt	/tIgboret/	reinforcement	גבר	gbr	overcoming	בור	bwr	/bor/	a hole
צרכנות	crknwt	/tsarxanut/	consumption	צרך	crK	consuming	רכן	rkN		bending
מחרוזת	mxrwzt	/maxrozet/	a necklace	חרז	xrz	rhyming	מחר	mxr	/maxar/	tomorrow
נפיחות	npyxwt	/neflxut/	swelling	נפח	npx	blowing	פיח	pyx	/plyax/	soot
משקולת	mSqwlt	/mISkolet/	a weight	שקל	Sql	weighting	מקל	mql	/makel/	a stick
מגרפה	mgrph	/magrefa/	a rake	גרף	grP	sweeping away	מגף	mgP	/magaf/	a boot
צביעות	cbyʕwt	/tsvIʕut/	hypocrisy	צבע	cbʕ	painting	צבי	cby	/tsvI/	a gazelle
תזמורת	tzmwrt	/tIzmoret/	an orchestra	זמר	zmr	singing	תמר	tmr	/tamar/	a palm tree
נוכחות	nwkexwt	/noxexut/	presence	נכח	nkx	being present	נוח	nwx	/noax/	convenient
התרגזות	htrgzwt	/hItragzut/	irritation	רגז	rgz	being agitated	הרג	hrg	/harag/	killed
תחזוקה	txzwqh	/taxzuka/	maintenance	חזק	xzq	being strong	חוק	xwq	/xok/	law
התרגשות	htrgSwt	/hItragSut/	excitement	רגש	rgS	feeling	רשת	rSt	/reSet/	a net
תהלוכה	thlwkh	/tahaluxa/	procession	הלך	hlk	walking	תהה	thh		wondering

Note. Although the roots in the related condition can be read as words that have an exact phonetic transliteration, the roots themselves are considered to have only a consonantal structure. In these cases, the phonetic transliteration is not included. Orth. = orthographic; trans. = transliteration.

Appendix D

Stimuli Used in Experiment 3

Target				Related			Control	
Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning	Hebrew	Orth. trans.	Semantic meaning	Hebrew	Orth. trans.
חנופה	xnwph	/xanupa/	flattery	חנף	xnP	flattering	חפה	xph
התלבטות	htlbθwt	/hItlabtut/	floundering	לבט	lbθ	struggling	בטת	bθt
חפזון	xpzwN	/xIpazon/	hurry	חפז	xpz	hurrying	חון	xwN
בדיחה	bdyxh	/bdIxa/	a joke	בדח	bdx	joking	דיח	dyx
חצוף	xcwP	/xatsuf/	insolent	חצף	xcP	being insolent	ציף	cyP
בהיר	bhyr	/bahIr/	bright	בהר	bhr	brightening	ביר	byr
תדהמה	tdhmh	/tadhema/	a shock	דהם	dhM	being astounded	תדם	tdM
מחבוא	mxbwʔ	/maxbo/	hiding place	חבא	xbʔ	hiding	חוא	xwʔ
בהלה	bhlh	/behala/	panic	בהל	bhl	being afraid	בלה	blh
הכרזה	hkrzh	/haxraza/	declaration	כרז	krz	declaring	הרז	hrz
חיתול	xytwl	/xItul/	a diaper	חתל	xtl	diapering	חתו	xtw
עדיפות	ʕdypwt	/ʕadIfut/	preference	עדף	ʕdP	prefering	עדת	ʕdt
עלפון	ʕlpwN	/ʕIlafon/	fainting	עלף	ʕlP	fainting	עפן	ʕpn
הברגה	hbrgh	/havraga/	screwing	ברג	brg	screwing	ברה	brh
עיטוש	ʕyθwS	/ʕItuS/	sneeze	עטש	ʕθS	sneezing	עוש	ʕwS
נחוץ	nxwC	/naxuts/	necessary	נחץ	nxC	being necessary	נוץ	nwC
השגחה	hSgxh	/haSgaxa/	supervision	שגח	Sgx	watching	הגח	hgx
דלקת	dlqt	/daleket/	inflammation	דלק	dlq	burning	דקת	dqt
הצלחה	hclxh	/hatslaxa/	success	צלח	clx	succeeding	צחה	cxh
משוגע	mSwgʕ	/meSuga/	mad	שגע	Sgʕ	being crazy	שוג	Swg
הפסד	hpsd	/hefsed/	a loss	פסד	psd	losing	הפס	hps
שיזוף	SyzwP	/SIzuf/	suntan	שזף	SzP	tanning	שוף	SwP
תרדמה	trdmh	/tardema/	a deep sleep	רדם	rdM	sleeping	תדם	tdM
מושחז	mwSxz	/muSxaz/	sharpened	שחז	Sxz	sharpening	משז	mSz
מברשת	mbrSt	/mIvreSet/	a brush	ברש	brS	brushing	ברת	brt
כניעה	knyʕh	/knIʕa/	surrender	כנע	knʕ	surrendering	כעה	kʕh
קשוח	qSwx	/kaSuax/	hard	קשח	qSx	being hard	קוח	qwx
מכוער	mkwʕr	/mexoʕar/	ugly	כער	kʕr	being ugly	כוע	kwʕ
המלצה	hmlch	/hamlatsa/	recommendation	מלץ	mlC	recommending	המץ	hmC
מעליב	mʕlyb	/maʕalIv/	insulting	עלב	ʕlb	insulting	מלב	mlb
צפיפות	cpypwt	/tsfIfut/	density	צפף	cpP	crowding	צפת	cpt
מרפאה	mrpʔh	/mIrpaʔa/	a clinic	רפא	rpʔ	healing	מרא	mrʔ
יאוש	yʔwS	/yeʔuS/	despair	יאש	yʔS	despairing	אוש	ʔwS
צימוק	cymwq	/tsImuk/	a raisin	צמק	cmq	shrinking	ימק	ymq
מכשפה	mkSph	/maxSefa/	a witch	כשף	kSP	bewitching	מכף	mkP
דפוס	dpws	/dfus/	print	דפס	dps	printing	דפו	dpw
התמדה	htmdh	/hatmada/	persistence	תמד	tmd	persisting	המד	hmd
סבון	sbwN	/sabon/	a soap	סבן	sbN	soaping	סון	swN
נבואה	nbwʔh	/nevuʔa/	a prediction	נבא	nbʔ	predicting	נוא	nwʔ
עמימות	ʕmymwt	/ʕamImut/	ambiguity	עמם	ʕmm	dimming	מית	myt
החלטה	hxlθh	/haxlata/	a decision	חלט	xlθ	deciding	לטה	lθh
רשלנות	rSlnwt	/raSlanut/	sloppiness	רשל	rSl	being sloppy	שלן	SlN
פיצול	pycwl	/pItsul/	splitting	פצל	pcl	splitting	יצל	ycl
צרוד	crwd	/tsarud/	hoarse	צרד	crd	being hoarse	רוד	rwd
עתודה	ʕtwdh	/ʕatuda/	a reserve	עתד	ʕtd	intending	תדה	tdh
נמוך	nmwK	/namux/	short	נמך	nmwK	lowering	נוך	nwK
ידידות	ydydwt	/yedIdut/	friendship	ידד	ydd	being friendly	ידת	ydt
גמישות	gmySwt	/gmISut/	flexible	גמש	gmS	being flexible	משת	mSt

Note. Semantic meanings are the meanings of the roots. The three letters by themselves do not represent a meaningful word. Orth. = orthographic; trans. = transliteration.

(*Appendixes continue*)

Appendix E

Stimuli Used in Experiment 4

Target				Related–semantic				Control			
Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning	Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning	Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning
מפלט	mplθ	/mIflat/	escape	מחבוא	mxbwʔ	/maxavo/	hiding place	רחמים	rxmyM	/raxamIm/	compassion
קציר	qcyr	/katsIr/	harvest	חיטה	xyθh	/xIθa/	wheat	שיפוע	Sypwʕ	/SIpuʕ/	a slope
מזרק	mzrq	/mazrck/	syringe	רופא	rwpʔ	/rofe/	a doctor	לכלך	lklK	/lIxlex/	soiled
שקרן	SqrN	/Sakran/	a liar	רמאי	rmʔy	/ramay/	a charlatan	מלמד	mlmd	/melamed/	instructor
מפגש	mpgS	/mIfgaS/	meeting place	צומת	cwmt	/tsomet/	crossroads	קבלה	qblh	/kabala/	a receipt
מראה	mrʔh	/marʔa/	a mirror	דמות	dmwt	/dmut/	a figure	קלמר	qlmr	/kalmar/	a pen case
כפיל	kpyl	/kfIl/	a double	תאום	tʔwM	/teʔom/	a twin	לוקח	lwqx	/lokeax/	taking
מרחק	mrxq	/merxak/	distance	דרך	drK	/derex/	a way	שפט	Spθ	/Safat/	judged
צלול	clwl	/tsalul/	clear	שקוף	SqwP	/Sakuf/	transparent	מנבא	mnbʔ	/menabe/	predicting
משקל	mSql	/mISkal/	weight	קילו	qylw	/kIlo/	kilogram	בונה	bwnh	/bone/	a builder
רעשן	rʕSN	/raʕaSan/	noisemaker	פורים	pwryM	/purIm/	Purim	מחוזק	mxwzq	/mexuzak/	strengthened
מאפה	phʔm	/maʔafe/	baked goods	עוגה	ʕwgh	/ʕuga/	a cake	קנקן	qnqN	/kankan/	a pot
מרדף	mrdP	/mIrdaf/	a chase	ריצה	rych	/rItsa/	a run	מפותח	mpwtx	/mfutax/	developed
ספוג	spwg	/sfog/	a sponge	מים	myM	/mayIm/	water	שלף	SlP	/Salaf/	pulled out
מחקר	mxqr	/mexkar/	research	מדע	mdʕ	/madaʕ/	science	תות	twt	/tut/	a strawberry
משתלה	mStlh	/mIStala/	a nursery	צמח	cmx	/tsemax/	a plant	זהב	zhb	/zahav/	gold
חותמת	xwtmt	/xotemet/	a stamp	בול	bwl	/bul/	a stamp	רשע	rSʕ	/raSaʕ/	wicked
הכתבה	hktbh	/haxtava/	a dictation	בוחן	bwxN	/boxan/	a quiz	שוקת	Swqt	/Soket/	a trough
מצעד	mcʕd	/mItsʕad/	a march	צבא	cbʔ	/tsava/	an army	פועל	pwʕl	/poʕel/	a worker
מרפאה	hʔmrp	/mIrpaʔa/	a clinic	חולה	xwlh	/xole/	a patient	הסכם	hskM	/heskem/	an agreement
בריחה	bryxh	/brIxa/	an escape	משסה	mSsh	/meSase/	setting on	סרעפת	srʕpt	/sarʕefet/	a midriff
מזבלה	mzblh	/mIzbala/	a dump	אשפה	ʔSph	/ʔaSpa/	trash	יתרה	ytrh	/yItra/	balance
פריחה	pryxh	/prIxa/	blossoming	לבלוב	lblwb	/lIvluv/	blooming	מכשול	mkSwl	/mIxSol/	an obstacle
מסעדה	msʕdh	/mIsʕada/	a restaurant	ארוחה	ʔrwxh	/ʔaruxa/	a meal	נשפט	nSpθ	/nISpat/	adjudged
זחילה	zxylh	/zxIla/	crawling	תינוק	tynwq	/tInok/	a baby	רבעון	rbʕwN	/rIvʕon/	quarterly
מגרפה	mgrph	/magrefa/	a rake	מעדר	mʕdr	/maʕader/	a hoe	הבטחה	hbθxh	/havtaxa/	a promise
צפירה	cpyrh	/tsfIra/	a siren	רכבת	rkbt	/rakevet/	a train	שרוע	Srwʕ	/saruʕa/	streched out
קישור	qySwr	/kISur/	liason	קצין	qcyN	/katsIn/	an officer	נצפה	ncph	/nItspe/	be observed
חקירה	xqyrh	/xakIra/	an inquiry	משטרה	mSθrh	/mIStara/	police	מלמדת	mlmdt	/melamedet/	teacher
טריקה	θryqh	/trIka/	a slam	דלת	dlt	/delet/	a door	שבע	Sbʕ	/saveʕa/	satiated
זריעה	zryʕh	/zrIʕa/	sowing	חריש	xryS	/xarIS/	plowing	שחפת	Sxpt	/Saxefet/	tuberculosis
התגמדות	htgmdwt	/hItgamdut/	dwarfing	ננס	nns	/nanas/	a dwarf	שחט	Sxθ	/Saxat/	slaughtered

Appendix E (*continued*)

Target				Related–semantic				Control			
Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning	Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning	Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning
מלכודת	mlkwdt	/malkodet/	a trap	פח	px	/pax/	a trap	שב	Sb	/Sev/	sit
התכנסות	htknswt	/hItkansut/	assembly	אסיפה	ʔsyph	/ʔasefa/	a meeting	מקרה	mqrh	/mIkre/	an event
בדידות	bdydwt	/bdIdut/	loneliness	עצב	ʕcb	/ʕet̲s̲ev/	sadness	הסכם	hskm	/heskem/	an agreement
תגבורת	tgbwrt	/tIgboret/	reinforcement	עזרה	ʕzrh	/ʕezra/	help	געיה	gʕyh	/geʕIya/	mooing
גרושה	grwSh	/gruSa/	a divorcée	אשה	ʔSh	/ʔISa/	a woman	נמען	nmʕN	/nImʕan/	addressee
צרכנות	crknwt	/t̲s̲arxanut/	consuming	קניה	qnyh	/knIya/	buying	גביה	gbyh	/gvIya/	collection
מחרוזת	mxrwzt	/maxrozet/	a necklace	תכשיט	tkSyθ	/taxSIt/	jewelry	תרגיל	trgyl	/targIl/	an exercise
נפיחות	npyxwt	/nefIxut/	swelling	מכה	mkh	/maka/	a blow	שגרה	Sgrh	/SIgra/	a routine
משקולת	mSqwlt	/mISkolet/	weight	כובד	kwbd	/koved/	heaviness	נברא	nbrʔ	/nIvra/	was created
צביעות	cbyʕwt	/t̲s̲vIʕut/	hypocrisy	יוהרה	ywhrh	/yohara/	arrogance	בישול	bySwl	/bISul/	cooking
תזמורת	tzmwrt	/tI̅zmoret/	an orchestra	נגן	ngN	/nagan/	a player	מדף	mdP	/madaf/	a shelf
נוכחות	nwkxwt	/noxexut/	presence	קיום	qywM	/kIyum/	existence	קידש	qydS	/kIdeS/	sanctified
התרגזות	htrgzwt	/hItragzut/	irritation	זעם	zʕM	/zaʕam/	anger	תקע	tqʕ	/tekaʕ/	a plug
תחזוקה	txzwqh	/taxzuka/	maintenance	טכנאי	tknʔy	/texnay/	a technician	משפיע	mSpyʕ	/maSpIʕa/	influencing
התרגשות	htrgSwt	/hItragSut/	excitement	שמחה	Smxh	/sImxa/	joy	קפצן	qpcN	/kaft̲s̲an/	springer
תהלוכה	thlwkh	/tahaluxa/	procession	חג	xg	/xag/	a holiday	שם	SM	/Sem/	a name

Note. Orth. = orthographic; trans. = transliteration.

(*Appendixes continue*)

Appendix F

Stimuli Used in Experiment 5

Target				M+S+			
Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning	Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning
הדרכה	hdrkh	/hadraxa/	guidance	מדריך	mdryK	/madrIx/	a guide
מחזור	mxzwr	/maxzor/	cycle	חזרה	xzrh	/xazara/	rehearsal
הלשנה	hlSnh	/halSana/	informing	מלשין	mlSyN	/malSIn/	informer
עצבות	ʕcbwt	/ʕatsvut/	sadness	עצוב	ʕcwb	/ʕatsuv/	sad
מאהל	mʔhl	/maʔahal/	a tented camp	אוהל	ʔohl	/ʔohel/	a tent
נצחון	ncxwN	/nItsaxon/	victory	מנצח	mncx	/menatseax/	a winner
הפרעה	hprʕh	/hfraʕa/	disturbance	פרוע	prwʕ	/paruʕa/	wild
משקפת	mSqpt	/mISkefet/	binoculars	משקפים	mSqpyM	/mISkafayIm/	glasses
הקרבה	hqrbh	/hakrava/	sacrificing	קורבן	qwrbN	/korban/	a sacrifice
מכובד	mkwbd	/mexubad/	respectable	כבוד	kbwd	/kavod/	honor
תחליף	txlyP	/taxlIf/	substitute	החלפה	hxlph	/haxlafa/	an exchange
סמכות	smkwt	/samxut/	authority	הסמכה	hsmkh	/hasmaxa/	authorization
מפלגה	mplgh	/mIflaga/	a political party	פילוג	pylwg	/pIlug/	a political split
רצפה	rcph	/rItspa/	a floor	ריצוף	rycwP	/rItsuf/	paving
מבריק	mbryq	/mavrIk/	shining	הברקה	hbrqh	/havraka/	polishing
סגירה	sgyrh	/sgIra/	closing	מסגרת	msgrt	/mIsgeret/	a frame
התיישבות	htyySbwt	/hItyaSvut/	settlement	ישוב	ySwb	/ySuv/	settlement
מעבר	mʕbr	/maʕavar/	a passage	עביר	ʕbyr	/ʕavIr/	passable
חלוקה	xlwqh	/xaluka/	division	חילוק	xylwq	/xIluk/	division
כניסה	knysh	/knIsa/	an entry	נכנס	nkns	/nIxnas/	entered
מרגל	mrgl	/meragel/	a spy	ריגול	rygwl	/rIgul/	spying
פשרה	pSrh	/pSara/	compromise	פשרן	pSrN	/paSran/	compromiser
מחברת	mxbrt	/maxberet/	a notebook	חוברת	xwbrt	/xoveret/	a booklet
שמירה	Smyrh	/SmIra/	guarding	שומר	Swmr	/Somer/	a watchman
תפרחת	tprxt	/tIfraxat/	inflorescence	פריחה	pryxh	/prIxa/	flowering
פיקוד	pyqwd	/pIkud/	command	פקודה	pqwdh	/pkuda/	an order
חובש	xwbS	/xoveS/	paramedic	תחבושת	txbwSt	/taxboSet/	a bandage
מלקחיים	mlqxyyM	/melkaxaym/	tongs	לקיחה	lqyxh	/lekIxa/	taking
התפטרות	htpθrwt	/hItpatrut/	resignation	פיטורין	pyθwryN	/pIturIn/	dismissal
מסירות	msyrwt	/mesIrut/	devotion	מסור	mswr	/masor/	devoted
אספן	ʔspN	/ʔasfan/	collector	אוסף	ʔwsP	/ʔosef/	collection
תסרוקת	tsrwqt	/tIsroket/	hair style	מסרק	msrq	/masrek/	a comb
מיותר	mywtr	/meyutar/	redundant	יתרה	ytrh	/ytra/	the remaining balance
הטענה	hθʕnh	/hatʕana/	loading	מטען	mθʕN	/mItʕan/	cargo
מצבור	mcbwr	/mItsbor/	a stack	צבירה	cbyrh	/tsvIra/	stacking
כשרון	kSrwN	/kISaron/	talent	מוכשר	mwkSr	/muxSar/	talented
עריכה	ʕrykh	/ʕarIxa/	editing	מערכת	mʕrkt	/maʕarexet/	editorial desk
שלהבת	Slhbt	/Salhevet/	a flame	להבה	lhbh	/lehava/	a flame
חשבון	xSbwN	/xeSbon/	calculus	חישוב	xySwb	/xISuv/	calculation
פרשן	prSN	/parSan/	commentator	פרשנות	prSnwt	/parSanut/	commentary
כתובת	ktwbt	/ktovet/	an address	מכתב	mktb	/mIxtav/	a letter
פתוח	ptwx	/patuax/	open	מפתח	mptx	/mafteax/	a key
תקליט	tqlyθ	/taklIt/	a record	הקלטה	hqlθh	/haklata/	recording
פסקנות	psqnwt	/paskanut/	decisiveness	פסיקה	psyqh	/psIka/	ruling
מפורט	mpwrθ	/meforat/	detailed	פירוט	pyrwθ	/perut/	specification
פעולה	pʕwlh	/peʕula/	an action	הפעלה	hpʕlh	/hafʕala/	operation
מעצור	mʕcwr	/maʕatsor/	brake	עצירה	ʕcyrh	/ʕatsIra/	stopping
תבשיל	tbSyl	/tavSIl/	a cooked dish	בישול	bySwl	/bISul/	cooking
קדושה	qdwSh	/kduSa/	holiness	קידוש	qydwS	/kIduS/	sanctification
מקדחה	mqdxh	/makdexa/	a drill	קידוח	qydwx	/kIduax/	drilling
ביטחון	byθxwN	/bItaxon/	confidence	הבטחה	hbθxh	/havtaxa/	a promise
מגבר	mgbr	/magber/	amplifier	הגברה	hgbrh	/hagbara/	amplifying
פריצה	prych	/prytsa/	burglary	פורץ	pwrC	/porets/	a burglar
מטורף	mθwrP	/metoraf/	crazy	טירוף	θyrwP	/teruf/	craziness
תרכובת	trkwbt	/tIrkovet/	compound	הרכבה	hrkbh	/harkava/	assembling
מושפל	mwSpl	/muSpal/	humiliated	השפלה	hSplh	/haSpala/	humiliation
מעגל	mʕgl	/maʕagal/	a circle	עיגול	ʕygwl	/ʕIgul/	a circle
שמיעה	Smyʕh	/SmIʕa/	hearing	השמעה	hSmʕh	/haSmaʕa/	back play
נהיגה	nhygh	/nehIga/	driving	נהגת	nhgt	/naheget/	a woman driver
שחיתות	Sxytwt	/SxItut/	corruption	מושחת	mwSxt	/muSxat/	corrupted

Appendix F (*continued*)

M+S−				Control			
Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning	Hebrew	Orth. trans.	Phonetic trans.	Semantic meaning
דריכה	drykh	/drIxa/	stepping	מהודר	mhwdr	/mehudar/	elegant
חיזור	xyzwr	/xIzur/	courting	מחזה	mxzh	/maxaze/	a play
לשון	lSwN	/laSon/	tongue	גלשן	glSN	/galSan/	a glider
עצבים	ʕcbyM	/ʕatsabIm/	nerves	צבים	cbyM	/tsabIm/	turtles
אהיל	ʔhyl	/ʔahIl/	a lampshade	מהילה	mhylh	/mehIla/	mixing
הנצחה	hncxh	/hantsaxa/	commemoration	צחנה	cxnh	/tsaxana/	stench
פרעון	prʕwN	/peraʕon/	payment	פרוצה	prwch	/prutsa/	a prostitute
שקוף	SqwP	/Sakuf/	clear	משפט	mSpθ	/mIS̄pat/	a trial
קרוב	qrwb	/karov/	near	הקבצה	hqbch	/hakbatsa/	grouping
כבדות	kbdwt	/kvedut/	heaviness	מעבדה	mʕbdh	/maʕabada/	a laboratory
חליפה	xlyph	/xalIfa/	a suit	התחלה	htxlh	/hatxala/	a beginning
מסמך	msmK	/mIsmax/	a document	מכתב	mktb	/mIxtav/	a letter
הפלגה	hplgh	/haflaga/	sailing	מלגה	mlgh	/mIlga/	a scholarship
רציפות	rcypwt	/retsIfut/	continuity	צופה	cwph	/tsofe/	an observer
מיברק	mybrq	/mĪvrak/	a telegram	בריחה	bryxh	/brIxa/	escape
מסגר	msgr	/masger/	locksmith	גרוי	grwy	/geruy/	stimulus
ישבן	ySbN	/yaSvan/	bottom	השתלבות	hStlbwt	/hIStalvut/	integration
עבריין	ʕbryyN	/ʕavaryan/	a criminal	מבריק	mbryq	/mavrIk/	shining
החלקה	hxlqh	/haxlaka/	sliding	חישוק	xySwq	/xISuk/	a rim
כינוס	kynws	/kInus/	assembly	נסיון	nsywN	/nIsayon/	an attempt
תרגיל	trgyl	/targIl/	exercise	מגלשה	mglSh	/magleSa/	a slide
פושר	pwSr	/poSer/	tepid	הפשטה	hpSθh	/hafSata/	abstraction
חברות	xbrwt	/xaverut/	friendship	חביתה	xbyth	/xavIta/	an omelet
שמרן	SmrN	/Samran/	conservative	שיגרה	Sygrh	/SIgra/	a routine
אפרוח	ʔprwx	/ʔefroax/	a chicken	מתפרה	mtprh	/matpera/	a sewing workshop
פיקדון	pyqdwN	/pIkadon/	a deposit	שיקוף	SyqwP	/SIkuf/	a reflection
מחבוש	mxbwS	/maxboS/	confinement	לבוש	lbwS	/levuS/	garment
לקוח	lqwx	/lakoax/	a client	לחימה	lxymh	/lexIma/	fighting
פטירה	pθyrh	/ptIra/	passing away	תופרת	twprt	/toferet/	seamstress
מסורת	mswrt	/masoret/	tradition	סיירת	syyrt	/sayeret/	cruiser
אסיפה	ʔsyph	/ʔasefa/	a meeting	ספנות	spnwt	/sapanut/	shipping
סריקה	sryqh	/srIka/	screening	ספקנות	spqnwt	/safkanut/	skepticism
יתרון	ytrwN	/ytaron/	an advantage	מיתה	myth	/mIta/	dying
טיעון	θyʕwN	/tIʕun/	an argument	לענה	lʕnh	/laʕana/	wormwood
ציבור	cybwr	/tsIbur/	public	מצבה	mcbh	/matseva/	tombstone
מכשיר	mkSyr	/maxSIr/	a tool	שריון	SrywN	/SIryon/	armor
ערכים	ʕrkyM	/ʕaraxIm/	values	עריק	ʕryq	/ʕarIk/	deserter
נלהב	nlhb	/nIlhav/	enthusiastic	שלבים	SlbyM	/SlavIm/	stages
מחשבה	mxSbh	/maxSava/	a thought	שבועות	Sbwʕwt	/Ssvuʕot/	pentecost
פרישה	prySh	/prISa/	retirement	רשלן	rSlN	/raSlan/	sloven
הכתבה	hxtbh	/haxtava/	a dictation	תרבות	trbwt	/tarbut/	culture
מפותח	mpwtx	/mefutax/	developed	תוחלת	twxlt	/toxelet/	hope
קליטה	qlyθh	/kIlta/	absorption	תקלה	tqlh	/takala/	a failure
פסיק	psyq	/psIk/	a comma	סקרנות	sqrnwt	/sakranut/	curiosity
תפריט	tpryθ	/tafrIt/	a menu	משפט	mSpθ	/mISpat/	a trial
מפעל	mpʕl	/mIfʕal/	a factory	פעימה	pʕymh	/peʕIma/	pulsation
עצרת	ʕcrt	/ʕatseret/	assembly	צרור	crwr	/tsror/	a bundle
בשלות	bSlwt	/baSlut/	maturity	שילוב	Sylwb	/SIluv/	joining
הקדשה	hqdSh	/hakdaSa/	dedication	קידום	qydwm	/kIdum/	advancing
קדחת	qdxt	/kadaxat/	a fever	מיקוד	myqwd	/mIkud/	a zip code
אבטיח	ʔbθyx	/ʔavatyax/	a watermelon	טחינה	θxynh	/txyna/	grinding
גיבור	gybor	/gybor/	a hero	גזבר	gzbr	/gizbar/	a treasurer
מפרץ	mprC	/myfrats/	a gulf	עריצות	ʕrycwt	/ʕarItsut/	tyranny
טורף	θwrP	/toref/	a predator	ממטר	mmθr	/mImtar/	a shower
מרכבה	mrkbh	/merkava/	a carriage	תרבית	trbyt	/tarbIt/	breeding
שפלה	Splh	/Sfela/	a plain	נמשל	nmSl	/nImSal/	moral
עגלה	ʕglh	/ʕagala/	a carriage	מעילה	mʕylh	/meʕIla/	embezzlement
משמעות	mSmʕwt	/maSmaʕut/	meaning	כניעה	knyʕh	/knIʕa/	surrender
מנהג	mnhg	/mInhag/	a custom	נגיעה	ngyʕh	/negIʕa/	touching
משחתת	mSxtt	/maSxetet/	a destroyer	חיתול	xytwl	/xItul/	a diaper

Note. M+S+ = morphologically and semantically related; Orth. = orthographic; trans. = transliteration; M+S− = morphologically related and semantically unrelated.

(*Appendixes continue*)

Appendix G

Stimuli Used in Experiment 6

Target				Related			Control		
Hebrew	Orth. trans.	Phonetic trans.	Semantic	Hebrew	Orth. trans.	Phonetic trans.	Hebrew	Orth. trans.	Phonetic trans.
מפלט	mplθ	/mIflat/	escape	פלטן	plθN	/paltan/	מיפול	mypwl	/mIpul/
קציר	qcyr	/katsIr/	harvest	מקצרה	mqcrh	/maktsera/	צירון	cyrwN	/tsIron/
מזרק	mzrq	/mazrek/	syringe	מזרוק	mzrwq	/mazruk/	מרקן	mrqN	/markan/
שקרן	SqrN	/Sakran/	a liar	משקרה	mSqrh	/maSkera/	קרונה	qrwnh	/kruna/
מפגש	mpgS	/mIfgaS/	meeting	פגשן	pgSN	/pagSan/	מגוש	mgwS	/magoS/
מחקר	mxqr	/mexkar/	research	חקיר	xqyr	/xakIr/	ממחקת	mmxqt	/mamxeket/
כפיל	kpyl	/kapIl/	stuntman	כפלנות	kplnwt	/kaflanut/	פילונות	pylwnwt	/pIlonut/
מחבט	mxbθ	/maxbet/	a racket	החבטה	hxbθh	/haxbata/	מחיבה	mxybh	/mexIva/
צלול	clwl	/tsalul/	clear	מצללה	mcllh	/matslela/	מלולה	mlwlh	/melula/
משקל	mSql	/mISkal/	weight	תשקיל	tSqyl	/taSkIl/	משקן	mSqN	/maSkan/
מצעד	mcʕd	/mItsʕad/	a march	צעיד	cʕyd	/tsaʕId/	מיעוד	myʕwd	/mIʕud/
ספוג	spwg	/sfog/	a sponge	ספגן	spgN	/safgan/	סוגן	swgN	/sugan/
רעשן	rʕSN	/raʕaSan/	noisemaker	רעישות	rʕySwt	/reʕISut/	עשונה	ʕSwnh	/ʕaSunh/
קשירה	qSyrh	/kSIra/	binding	קשרנות	qSrnwt	/kaSranut/	קשינת	qSynt	/kSInat/
משתלה	mStlh	/mIStala/	a nursery	משתול	mStwl	/mIStol/	תמשול	tmSwl	/tamSol/
חותמת	xwtmt	/xotemet/	a seal	חתמות	xtmut	/xatamwt/	חממות	xmmwt	/xamamut/
מרדף	mrdF	/mIrdaf/	a chase	מרדפה	mrdph	/mardefa/	תמדיף	tmdyF	/tamdIf/
מרפאה	mrpʔh	/mIrpaʔa/	a clinic	רפאות	rpʔwt	/rafaʔut/	פיאוי	pyʔwy	/pIʔuy/
בריחה	bryxh	/brIxa/	an escape	מברחה	mbrxh	/mavrexa/	ריחון	ryxwN	/rIxun/
מזבלה	mzblh	/mIzbala/	a garbage dump	זובלת	zwblt	/zovelet/	תזלנות	tzlnwt	/tazlanut/
פריחה	pryxh	/prIxa/	flowering	מפרחה	mprxh	/mafrexa/	פריאות	pry wt	/prIʔut/
גרושה	grwS	/gruSa/	a divorcée	מגרשה	mgrSh	/mIgraSa/	גושיש	gwSyS	/guSIS/
זחילה	zxylh	/zxIla/	creeping	תזחיל	tzxyl	/tazxIl/	חילנת	xylnt	/xIlenet/
מגרפה	mgrph	/magrefa/	a rake	מגריף	mgryF	/magrIf/	מרפיק	mrpyq	/marpIk/
קישור	qySwr	/kISur/	binding	מקשרה	mqSrh	/makSera/	שורנות	Swrnwt	/Sornut/
חקירה	xqyrh	/xakIra/	an inquiry	חוקרה	xwqrh	/xokra/	מקירן	mqyrN	/mekIran/
טריקה	θryqh	/trIka/	a slam	מטרקת	mθrqt	/matreket/	מטרינה	mθrynh	/matrIna/
סגירה	sgyrh	/sgIra/	closing	סגרות	sgrwt	/sagarut/	סירלה	syrlh	/sIrla/
מסעדה	msʕdh	/mIsʕada/	a restaurant	סעידה	sʕydh	/seʕIda/	ממסעה	mmsʕh	/mamseʕa/
הכתבה	hktbh	/haxtava/	a dictation	כתבון	ktbwN	/kItavon/	כביות	kbywt	/kvIyut/
מסחטה	msxθh	/masxeta/	a juicer	תסחיט	tsxyθ	/tasxIt/	מסוחה	mswxh	/mesuxa/
חיפוש	xypwS	/xIpus/	a search	מחפשה	mxpS	/maxpesa/	מחפול	mxpwl	/maxpol/
מצלמה	mclmh	/matslema/	a camera	צלמנות	clmnwt	/tsalmanut/	תמציל	tmcyl	/tamtsIl/
פתרון	ptrwN	/pItron/	a solution	מפתרה	mptrh	/maftera/	מתרנה	mtrnh	/matrena/
מרכבה	mrkbh	/merkava/	a carriage	רכבנות	rkbnwt	/raxvanut/	מורכת	mwrkt	/morexet/
חיזוק	xyzwq	/xIzuk/	strengthening	חזוקה	xzwqh	/xazuka/	בזוקת	bzwqt	/bazoket/
משמרת	mSmrt	/mISmeret/	a shift	משמרה	mSmrh	/maSmera/	מישום	mySwM	/mIsum/
השקטה	hSqθh	/haSkata/	calming	שקיטות	Sqyθwt	/SkItut/	הוקטרה	hwqθrh	/okatra/
הטבלה	hηθblh	/hatbala/	dipping	מטבלה	mθblh	/matbelh/	בליה	blyh	/blIya/
מלכודת	mlkwdt	/malkodet/	a trap	מלכדה	mlkdh	/malkeda/	מליכת	mlykt	/melIxat/
תגבורת	tgbwrt	/tIgboret/	reinforcement	מגברה	mgbrh	/magbera/	מברתה	mbrth	/mavreta/
משקולת	mSqwlt	/mISkolet/	weight	שקלות	Sqlwt	/Sakalut/	מקלנת	mqlnt	/mIklenet/
קטילה	qθylh	/ktIlh/	killing	מקטלה	mqθlh	/maktela/	קטיתה	qθyta	/ktIta/
תזמורת	tzmwrt	/tIzmoret/	an orchestra	תזמירה	tzmyrh	/tazmIra/	מתמרת	mtmrt	/matmeret/
רגישות	rgySwt	/regISut/	sensitivity	תרגושת	trgwSt	/tIrgoSet/	תרשית	trSyt	/tarSIt/
שליחות	Slyxwt	/SlIxut/	mission	משלחה	mSlxh	/maSlexa/	תלחית	tlxyt	/talxIt/
חריזה	xryzh	/xarIza/	rhyming	תחריזות	txryzwt	/taxrIzut/	ריזנות	ryznwt	/rIznut/
צפירה	cpyrh	/tsfIra/	a siren	מצפרת	mcprt	/mItsperet/	פירון	pyrwN	/pIron/

Note. Orth. = orthographic; trans. = transliterations.

Received November 3, 1995
Revision received June 12, 1996
Accepted December 3, 1996 ■