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The Contribution of Morphological and Semantic Relatedness to Repetition Priming at Short and Long Lags: Evidence from Hebrew

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The effect of morphological repetition at lag 0 and at lag 15 on lexical decision was investigated in Hebrew with three types of relation between prime and target. In the semantic-plus-morphological condition (SM), the prime and the target in each pair were two semantically related derivatives of the same root. In the "pure morphological" condition (M), the prime and the target derived from the same root, but their semantic association was very low, or non-existent. In the semantic priming condition (S), primes and targets were semantically associated but were not morphologically related. The pure semantic relationship produced a significant facilitation at lag 0 that disappeared completely at lag 15. The pure morphological relation produced (smaller but) significant facilitation at lag 0 that was not attenuated at lag 15. When prime and target were semantically as well as morphologically related, the facilitation at lag 0 was similar to semantic priming, whereas at lag 15 it was similar to the pure morphological effect. Significant repetition effects at both lags were also found with non-words that shared the same (nonsensical) root and differed with respect to real derivational affixes. The differential time course for

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facilitation due to semantic and morphological relatedness suggests distinct underlying processes, although at lag 0 it is possible that semantic relatedness may augment the morphological repetition effect. Morphological repetition probably facilitates the retrieval of lexical information that, under certain circumstances, is necessary for lexical decision.

The repetition priming effect in lexical decision refers to the reduction in response time and/or the error rate when the target stimulus has been previously encountered in the list (Forbach, Stanners, & Hochhaus, 1974; Scarborough, Cortese, & Scarborough, 1977). In addition to an effect of identical repetitions of a stimulus (full repetition), facilitation has also been observed when some but not all structural or formal aspects of the stimulus were repeated (partial repetition). Specifically, significant facilitation was observed when prime and target preserved the morphological stem in different inflections or derivatives of the word, an effect known as the morphological repetition effect (Feldman & Fowler, 1987; Feldman & Moskovljevic, 1987; Fowler, Napps, & Feldman, 1985; Kempley & Morton, 1982; Monsell, 1985; Murrell & Morton, 1974; Stanners, Neiser, Hernon, & Hall, 1979; Stanners, Neiser, & Painton, 1979).

The morphological repetition effect in a lexical decision task is typically examined by presenting two morphologically related words (usually the stem and one of its affixed derivatives or inflections) in the same list. The word that is presented first in such a pair is labelled "prime" and the second "target". Primes and targets may be separated by a variable number of intervening stimuli, and this interval defines the size of the lag. In an early study Stanners et al. (1979) reported that at lag 10, "base" verbs induced repetition effects for inflection forms that were as large as identity repetition effects, whereas for irregular past tense forms and derivatives the repetition effects were significantly smaller. Emphasizing primarily an account of the repetition effect that assumed a lexical network origin, Stanners et al. (1979) concluded that "base words" and their inflections share a common lexical entry, whereas derivatives have separate but related entries.[1] These authors also suggested that the morphological repetition effect reflects the common product of semantic priming and the effect of repeated access to the same morpheme. In a more recent study, however, Fowler et al. (1985) observed that when episodic and semantic components were attenuated by increasing lags between prime and target and by using irregular morphological forms, lexical decisions for unaffixed target words (stems) were facilitated to a similar extent by morphologically related derivations, inflections, and identi-

[1] We use the term "lexical entry" to refer to the representation of the word in the lexicon; it contains abstract phonological and orthographic information, and it is usually associated to at least one meaning in semantic memory.

cal repetitions. They interpreted this outcome as evidence that both inflections and derivatives are represented lexically as related but separate lexical entries. Moreover, and in concert with other authors (e.g. Henderson, 1985; Morton, 1981), they concluded that the sources of morphological repetition cannot be reduced to simple reactivation of the lexical entry of the same morpheme.

The morphological repetition effect in word recognition has been distinguished from the effect of semantic relatedness. In semantic priming the degree of semantic overlap between prime and target clearly influences the magnitude of the facilitation (Becker, 1980, Fischler, 1977a, 1977b). In contrast, in morphological repetition, the degree of semantic relation between prime and target apparently does not affect the magnitude of the morphological repetition effect. The latter result has been found for priming among related derivatives (Feldman, in press-a) and for priming compound words by their constituents (Monsell, 1985). A second difference between semantic priming and morphological repetition effects is their respective duration. Semantic priming dissipates when the related words are separated by two or more intervening stimuli (e.g. Davelaar & Coltheart, 1975; Dannenbring & Briand, 1982; Meyer, Schvaneveldt, & Ruddy, 1972), or by time lags of more than several seconds (Henderson, Wallis, & Knight, 1984), whereas significant morphological repetition effects are found when several, or even many, stimuli intervene between the prime and target (e.g. Feldman & Moskovljevic, 1987; Fowler et al., 1985, Monsell, 1985; Murrell & Morton, 1974).

The distinction between the time courses of these two sources of facilitation in word recognition tasks and their additive rather than interactive effects on lexical decision has led some investigators to posit distinct underlying principles of lexical organization (e.g. Henderson et al., 1984; den Heyer, Goring, & Dannenbring, 1985). Although this position seems to be supported by the data, it is still possible that the two mechanisms interact, at least while semantic priming is still alive. This possibility has not been sufficiently investigated (with the possible exception of Feldman & Stotko's experiment reported by Feldman, in press-a), because in most studies the morphologically related prime and target words are also semantically related. For example, in the Henderson et al. (1984) comparison of the morphological and semantic repetition effects, the "semantic" and the "morphological" sets were matched on rated semantic similarity. The outcome of that study indicated that in contrast to semantic priming, the morphological repetition effect at a 4-sec ISI was not significantly reduced relative to that measured at 1-sec ISI. There is no direct evidence, however, that the same facilitatory mechanism was active at both lags. In the Feldman and Stotko's study, on the other hand, the lag between prime and target was too long to permit any influence of the semantic relationship, but, relative to the identity prime condition, numerically small effects were observed for all morphological primes.

In order to elucidate the relative contribution of semantic and morphological relatedness to word recognition, we examined the relative contribution of these two types of relatedness to facilitation in lexical decision. The study was conducted in Hebrew, a language whose derivational morphology is substantially different from English in ways that provide an elegant opportunity to disentangle the effects of morphological and semantic relatedness.

The Hebrew language has a very complex and unusually rich morphological structure, which is specific to Semitic languages. A synchronic analysis of modern Hebrew reveals that almost all verbs and nouns are derived from roots that are usually formed of three consonants. In contrast to the stem in English, which is (usually) a word, the Hebrew root is not a word, it is an abstract structure. Words are derived by embedding the root into one of several pre-existing "word patterns". A word pattern is also an abstract structure. It is composed of vowels with or without additional consonants and needs to be complemented by a root in order to become a lexical unit. For example, [SH], [M], [R], form a root and [G], [D], [L], a different root. By embedding each of these roots into the word pattern [__O__E__], we can form the words SHOMER (watchman) and GODEL (magnitude); using a different word pattern such as [MI____A__] we can form two different words MISHMAR (guard—as in the "Night guard") and MIGDAL (tower). Both the word pattern and the root are productive because the same pattern can be applied to different roots, and each root may be embedded in different word patterns. By adding prefixes, suffixes, and infixes, words can be inflected, but the process of derivation is usually mediated by the abstract root (as opposed to a real word). Accordingly, words usually do not derive directly from other words. This process of derivation always rends the phonemic structure and frequently changes the orthographic sequence of the root by intermixing the consonants and vowels of the word pattern with the root-consonants.

The question of whether the root and word pattern are, independently, morphological structures is debatable. The meaning of a word is determined concurrently by the root and by the word pattern, but, because the relative contribution of these two components is independent, they should probably be considered as separate morphemes. However, the meaning of the root and/or the connection between the meaning of the root and the word in which it is embedded is not always clear. Similarly, there are no clear rules for assigning meanings to word patterns or word patterns to meanings (although there are some general patterns). Thus the exact meaning of a derived word is usually not automatically predictable (see Aronoff, 1976, for similar analysis of English words). Furthermore, the same sequence of three consonants might form two different roots (distinguished on a semantic basis). Assuming that both roots and word patterns are morphemes, it follows that all verbs and nouns in Hebrew are at least bi-morphemic. Considering this complex derivational process, it is likely that in Hebrew different derivations of one root entertain separate lexical entries.

Words that are derived from the same root are by definition morphologically related. However, because they are constructed from a common root but not one from another, the semantic relations between derivations can be very remote. Consider, for example, the close semantic relationship between *letter* and *address* and compare it with the distant semantic relationship between *letter* and (journal) *article*. The Hebrew translations of "letter", "address", and "article" are MIKTAV, KTOVET, and KATAVA, respectively. Note that all three words are formed from the root K–T–V (which semantically alludes to anything related to "writing").

The critical comparisons in the present study were between semantically associated pairs that were and were not morphologically related (e.g. *letter–address* vs *letter–stamp*, respectively), and between morphological related pairs that were and were not semantically related (e.g. *letter–address* vs. *letter–article*, respectively). Those comparisons were made at lag 0, at which pure semantic priming is effective, and at lag 15, at which it is not. Thus, this design permitted an independent assessment of repetition effects stemming from a "pure morphological (viz., derivational) relation", from a "pure semantic relation", and from a combination of the two.

Method

Subjects. The subjects were 96 undergraduate students, who participated in the experiment for course credit or for payment. They were all native speakers of Hebrew, with normal or corrected-to-normal vision.

Stimulus Materials. The stimuli were 120 Hebrew words (all nouns) and 72 non-words. The experimental word set included 24 targets. Each target was paired with three related primes. One of the primes was semantically related to the target but had a different root (S). A second prime was derived from the same root as the target but was not (or was remotely) semantically associated to it. We defined this type of relation "pure morphologic" (M). The third prime type was morphologically related, as well as semantically associated to the target (SM). Due to the characteristics of Hebrew morphology that were described above, morphologically related primes and targets shared the three root-consonants but differed with respect to "word pattern" defined by vowels and additional consonants (see example in Figure 1 and Appendix A).

Semantic association was determined empirically in a pilot study in the

EXAMPLES OF PRIME TYPES

	TARGET	PRIMES		
		Sem.	Morph.	Sem + Morph.
Hebrew	ספריה	קריאה	מספר	ספרן
Phonetic transcription	sifria	kria	mispar	safran
English translation	library	reading	number	librarian

FIG. 1. Examples of three prime types and their relationship to target.

following manner. Each of 56 target words was paired with two primes that shared the same root. One prime was assumed to be highly related to the target, and the other prime was not. Each root was used in only one triad. In addition, each target was paired with a semantically associated prime taken from a different morphologic family. The resulting 168 pairs were randomized and presented to 50 randomly selected undergraduate students to judge. They were instructed to rate the strength of the semantic relationship within each pair on a scale from 1 (no relationship) to 7 (very close semantic association). It was emphasized that the rating should be based on meanings, not on the presence of a common root, and that the full scale should be used.

The 24 target words used in the present study were selected on the basis of those ratings, such that the judged semantic relationship for morphologically related primes was low for one prime (M) and high for the other (SM). The rating for the high-association pairs ranged from 3.9 to 6.6, with an average of 5.7 (on a 7-point scale). For the low-association pairs, the rating ranged from 1.4 to 3.6, with an average of 2.4. In no case was the difference between the rating of the low and high associates to one target less than 2.5 points. The rated semantic association strength for the 24 targets and their (morphologically unrelated) semantic associates (S) ranged from 4.0 to 6.1, with an average of 5.3. In this way, sets consisting of a target, a morphological relative, a semantic relative, and a morphological and semantic relative were formed.

In addition to target words and the three types of primes, 24 filler words were used. The fillers were the remaining 18 target words that were presented for rating and six additional nouns, arbitrarily taken from the other morphological families. The fillers were not related to any of the other stimuli in the list and were included to maintain lags between experimental primes and targets.

The 72 non-words were constructed from regular but meaningless three-letter roots that were embedded on regular word patterns in order to form pseudo-words. There were 24 nonsensical roots that recurred in two different non-words, and these formed 24 pairs of "pseudo-morphologically" related non-words. In addition, 24 nonsensical roots were presented only once, as filler non-words. Of the 24 pseudo-morphologically related non-word targets in each list, 12 were presented immediately after their respective primes (lag 0), and the other 12 were presented at a lag 15 after their primes. The non-word targets presented at each lag were counterbalanced across subjects so that each non-word target was tested an equal number of times at each lag, and each subject was tested with a different set of 12 non-word targets at each lag.

All stimuli were presented with the diacritical marks that symbolize vowels in Hebrew. Previous studies suggested that although the adult reader usually reads Hebrew printed in the unvoweled format, when the diacritical marks are present readers do not ignore them. In particular, it was demonstrated that lexical decisions are influenced by the full phonological form (consonants and vowel), even if the consonantal pattern alone is sufficient for the word/non-word distinction (Bentin, 1989; Bentin & Frost, 1987). The stimuli were exposed in the centre of a CRT screen, subtending a horizontal visual angle of about 3°.

Design. Three prime types and two lags were combined to form six conditions in a factorial design. The levels of the Prime factor were semantic (S), morphological (M), and semantic + morphological (SM), and the lags were 0 and 15. To anticipate, because no semantic priming is expected at lag 15, this condition will be considered as a baseline against which repetition effects in individual conditions can be compared.

Six stimulus lists of 72 words and 72 non-words were prepared. In each list, a different group of four target words was assigned to each of the six conditions defined by prime and lag (S-0, M-0, SM-0, S-15, M-15, SM-15). The lists were identical with respect to the serial position of target words fillers and non-words but differed with respect to the nature and the serial position of the primes. Sixteen different subjects were assigned to each stimulus list. In summary, across subjects, each target appeared with each type of prime at both lags and each subject viewed targets from each condition. This design enabled us to analyse the effects of prime and lag both within stimulus and within subject.

Procedure. The subjects were tested in a dimly lit room. They were instructed to make a word/non-word decision by pressing one of two buttons as quickly as possible. The dominant hand was always used for the WORD responses and the other hand for the NON-WORD responses. Following the instructions, 32 practice trials were presented. The practice list included 16 words and 16 non-words. The morphological structure of the practice stimuli was similar to that of the test stimuli. During the practice, subjects were exposed to two morphological repetitions at lag 0 and one at lag 15. Following the practice items, the 144 (72 words and 72 non-words) test trials were presented in one block.

The stimuli in each list were presented to subjects in an identical pseudo-random order. The constraint on the randomization was that the prime and target pairs were evenly distributed along the list. The same randomization was used in all six stimulus lists.

Each stimulus was exposed for 1000 msec and the ISI was 2500 msec. An entire session lasted about 20 minutes.

Results

Words and non-words were analysed separately. The RTs to correct responses in each prime condition were averaged across stimuli for each subject, and across subjects for each target word. RTs that were outside plus or minus 2 *SD*s from the subject or from the stimulus mean in each condition were considered outliers and excluded from the analysis. Less than 1.5% of the responses were outliers.

Word Analysis. The average RTs and percentage of errors to target words in each prime condition are summarized in Table 1.

A Lag (0,15) × Prime condition (S, M, SM) ANOVA with repeated measures revealed a significant interaction between the two factors: $F(2, 190) = 13.02$, $MSe = 2285$, $p < 0.0001$ for the subject analysis, and $F(2,$

TABLE 1
RTs in Msec (SEM) and Percentage of Errors to Targets

	Repetition Condition		
	S	*M*	*SM*
Lag 0	563 (7) 2.1%	589 (8) 1.8%	559 (6) 1.0%
Lag 15	611 (8) 1.1%	587 (8) 1.0%	583 (7) 2.6%

46) = 5.20, $MSe = 1275$, $p < 0.01$, for the stimulus analysis. The RTs to semantically prime targets at lag 15 (Table 1) were compared to the RTs to filler words (mean 606 msec; 1.2% of errors). A t-test showed that the RTs in these two conditions were not significantly different, $t(42) = 0.35$, $p < 0.70$. This comparison supported the assumption that at lag 15 there is no "pure" semantic priming effect and justified the use of response latencies to semantic targets in the lag 15 (S15) condition as a neutral baseline. In the following analyses and description of the results, priming effects will be calculated relative to the S15 baseline.

Post hoc analyses (Tukey-A) revealed that, at lag 0, the effects of semantic priming in the S condition (48 msec) and of semantic and morphological priming in the SM condition (51 msec) were both significant ($p < 0.01$) and did not differ between themselves. The effect of "pure" morphological repetition in the M condition at lag 0 (21 msec) was also significant ($p < 0.05$), but it was significantly smaller than the other two effects ($p < 0.01$). The facilitation effects at lag 15 were significant for both M and SM conditions (24 msec ($p < 0.05$) and 28 msec ($p < 0.01$), respectively). In contrast to lag 0, at lag 15 the facilitation effect in the M condition was not significantly smaller than the effect in the SM condition.

The differential effect of lag on the repetition effect in the M and in the SM conditions was assessed by a second 2 × 2 ANOVA with repeated measures of lag (0,15) and prime type (M, SM) (The pure semantic priming condition was excluded). The ANOVA showed that the Lag × Prime Type interaction was significant both for the subject analysis, $F(1, 95) = 5.37$, $MSe = 3018$, $p < 0.025$, and for the stimulus analysis, $F(1, 23) = 4.43$, $MSe = 764$, $p < 0.05$. In summary, 15 stimuli intervening between the prime and the target attenuated the repetition priming effect in the SM condition but had no significant influence on the pure morphological repetition effect.

Non-word Analysis. As summarized in Table 2, the RTs to target non-words, at both lag 0 and lag 15, were faster than to prime non-words with which they shared a meaningless root.

The effect of structural repetition on RTs to non-words was examined in a one-way ANOVA with repeated measures in the subject analysis, and for independent groups in the stimulus analysis. The stimulus condition (viz., prime, target at lag 0, or target at lag 15) significantly affected the RTs to non-words: $F(2, 190) = 13.77$, $MSe = 981$, $p < 0.0001$ and $F(2, 46) = 12.24$, $MSe = 1101$, $p < 0.0002$, for the subject and stimulus analyses, respectively. Post hoc analysis showed that the RTs to prime non-words were significantly longer than the RTs to target non-words at both lag 0 and lag 15. The magnitude of facilitation was similar at both lags. These results should be considered with caution, however, because comparison of the responses to prime non-words and filler non-words revealed that although the difference

TABLE 2
RTs in Msec (SEM) and Percentage of Errors to Non-words

	Stimulus Condition		
	Targets		
Primes	*Lag 0*	*Lag 15*	*Fillers*
721 (10) 5.6%	675 (9) 6.2%	686 (6) 4.8%	694 (8) 8.1%

between the two conditions was not significant for the stimulus analysis, $t(46) = 1.80$, it was highly significant for the subjects analysis, $t(95) = 3.35$, $p < 0.002$. This comparison suggests that the RTs to non-words were very variable.

The absolute number of errors to words was extremely low. Note, that 2.1% represents 8 errors out of 384 responses (i.e. 16 subjects with 24 stimuli per condition). Therefore, no meaningful analysis of errors to words was possible. More errors were made to filler non-words than to any of the other non-word types: $F(3, 285) = 5.06$, $MSe = 36$, $p < 0.0025$. A similar percentage of errors was made to prime non-words and to the two target non-word conditions.

Discussion

In the present study, the distinction between a semantic and a pure morphological source of facilitation in morphological repetition priming was confirmed. A pure semantic relation (S) between prime and target induced a significant priming effect at lag 0, which disappeared completely at lag 15. By comparison, a pure morphological relation (M) between prime and target produced smaller, yet significant facilitation at lag 0. In contrast to semantic priming, however, facilitation due to morphological relatedness between prime and target was not reduced at lag 15 relative to lag 0. Finally, when prime and target were both semantically and morphologically related (SM), the magnitude of the facilitation at lag 0 was similar to that of pure semantic priming and greater than that of morphological relatedness alone. At lag 15, however, the magnitude of facilitation in the SM condition was similar to the level induced by a pure morphological relationship (M).[2]

[2] In principle, because targets at lag 0 were always preceded by words whereas at lag 15 they could have been preceded by non-words, the lag effect observed in the S and SM condition might have reflected a response repetition effect at lag 0 but not at lag 15. Response repetition effects, however, can be ruled out because in the M condition the RTs at the two lags were similar.

The priming effects at lag 15 in the M and SM conditions of the present study replicated those found in similar conditions and at comparable lags by Feldman and Stotko (Feldman, in press, a). Thus, in concert with others (e.g. Henderson et al., 1984; Monsell, 1985) the outcome of the present study indicates that at sufficiently long lags, morphological priming is independent of semantic overlap between prime and target.

At shorter lags, however, the interpretation of priming is more complex. Previous studies suggested that the effects of semantic priming and of word repetition in lexical decision are additive (den Heyer et al, 1985; Wilding, 1986). Indeed, it is conceivable that at short lags the repetition effect in the SM condition benefits from the two sources of similarity. However, at lag 0, the amount of facilitation in the SM condition was not significantly bigger than in the S condition. Therefore, in the present study the effects of repetition and semantic priming were not additive. It is possible that the divergence between our results and the results of previous studies where additivity was found were caused by methodological differences [such as using partial (root) rather than identical repetition]. However, other accounts should also be considered.

The S and the SM conditions in the present study can be compared with the "semantic" and the "morphological" conditions examined in English by Henderson et al. (1984, Experiment 1). In both studies, the sets of prime/target pairs were matched for rated semantic similarity, and the outcome revealed that pure semantic priming disappeared at the longer lag, whereas morphological priming persisted. In contrast to their study, SM facilitation in the present study was significantly attentuated at the longer lag relative to lag 0 such that SM facilitation and M facilitation became equivalent. This discrepancy might reflect a difference in the designs of the two studies. In the present study, there were 15 intervening items (compared with 0 items in Henderson et al.), and the ISI between the prime and the target in the long lag condition was approximately 52.5 sec (as compared with 4 sec). Note, however, that despite this long lag the magnitude of priming effect in the M condition was the same as at lag 0. Evidently, the lag between prime and target affects semantic processes but not morphological processes. Therefore, we suggest that the reduction in priming effects observed at long relative to short lags in the SM condition reflected, in fact, the effect of lag on semantic rather than on morphological priming.

In summary, pure semantic priming decays at lags of 4 sec between prime and target; when the prime and the target are both semantically and morphologically related, the magnitude of the priming effect is not affected

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Moreover, post-hoc examination of the lists revealed that 8 out of the 12 targets at lag 15 were preceded by words and two out of the 4 non-repeated cases were in the M condition where RTs at the two lags were similar.

by a lag of 4 sec but is reduced at about 50 sec. Lag, however, has no significant effect on pure morphological priming (at least within the lag-limits of the present experiment). Moreover, at lag 0, semantic priming and semantic + morphological priming were similarly big. Therefore, the present results suggest that semantic priming and morphological repetition effects are not necessarily additive. At least when the target is not an identical repetition of the prime, these two effects interact, reinforcing each other. One consequence of this interaction is that semantic priming decays at a slower rate.

The morphological repetition effect that was found between Hebrew derivatives in the present study is particularly interesting. Because the root was the only aspect of the word that was identically repeated in prime and target, the present demonstration of repetition effects implies that at least at some level of word processing the root was distinguished from the "word pattern". In contrast to morphological repetition in English studies, the common morpheme in the present study (the root), was not a word but a cluster of consonants that: (1) is not necessarily continuous; (2) forms an abstract linguistic unit; and (3) probably does not have an independent lexical entry. One consequence of its characteristic structure is that isolation of the root in Hebrew necessarily entails a process of extraction rather than a process of decomposition or of "stripping off" the affixes (cf. Taft 1985). From this perspective, it might be instructive to consider several possible sources of the morphological repetition effect.

Theoretically, persistent repetition effects for words in lexical decision can stem from three roughly defined (and not mutually exclusive) sources: (1) prelexical stimulus analysis, leading to a long-lasting facilitation of a match between the orthographic pattern and its lexical representation (i.e. facilitating access to the specific lexical entry); (2) lexical or post-lexical processing such as retrieval of phonological and semantic properties; and (3) decision- and/or response-related processes. Note that sources (2) and (3) might be mediated by episodic traces in memory, whereas (1) is an automatic process associated with defining the units for lexical access (for a more detailed description of possible sources of repetition effects see Monsell, 1985, 1987).

A long-lasting change in the accessibility of a lexical entry is the preferred explanation for repetition effects in several "parallel lexical access" theories of word perception, most notable that of Morton (Morton, 1969, 1979) (but see also McClelland & Rumelhart, 1981). Applied to morphological repetition, this view implies that the (repeated) morpheme is the unit of lexical access or repeated activation in the lexicon, and that during lexical access or lexical activation it is functionally stripped of its unrepeated affixes. It is sometimes assumed that the morpheme is identified at a prelexical stage and processed as a distinct unit. An attempt to model the role of the morpheme in lexical access assuming prelexical decomposition of affixed words is the Affix Stripping model (Taft, 1979, 1981, 1985; Taft & Forster, 1975, 1976).

According to this model, the lexical access units of both prefixed and suffixed words are their morphological stems, and, consequently, affixed words are automatically stripped of their prefixes and suffixes before the lexicon is accessed. This account was recently supported by a study of lexical decision in Dutch for prefixed words (but not suffixed words) of Latinate or Germanic origin (Bergman, Hudson, & Eling, 1988). However, the utility of prelexical decomposition, particularly for familiar words, has been challenged by many authors on both theoretical grounds (e.g. Caramazza, Miceli, Silveri, & Laudanna, 1985) and empirical grounds (e.g. Bradley, 1980; Feldman, in press-b; Henderson et al., 1984, Experiment 2; Manelis & Tharp, 1977). Although the possibility of some prelexical decomposition cannot be totally rejected, there seems to be a general consensus that it is not mandatory, and that, where viable, it must be limited to instances of very regular morphological formations, particularly to inflections.

It is unlikely that the words used in the present study can be appropriately described as regular morphological forms. Even if the root has an independent, abstract lexical representation (Ornan, 1971), it still cannot be defined a unit with clear and regular boundaries within multi-morphemic words. Accordingly, the process of extraction cannot be lexicon-independent. On linguistic and processing model grounds, we suggest that each of the derivatives used in the present study had its own, independent lexical entry. In conclusion, although it is possible that access to those entries was facilitated by reducing their thresholds of activation, it is difficult to see how this process could be induced by a prelexical morphological analysis and root extraction.[3]

A second way to facilitate access to lexical entries and to reduce their thresholds of activation is by assuming that the lexical entries are organized according to morphological principles (e.g. Dell, 1984; Fowler et al., 1985). For example, Lukatela, Gligorijevic, Kostic, and Turvey (1980) suggested that inflected nouns are organized in the lexicon into satellite formations composed of full forms with linkage between entries, so that the activation spreads among all forms with common morphemes facilitating lexical access.

One virture of this model in the context of Hebrew is that it represents full forms and does not require independent lexical entries of the root and the word pattern. As extended to repetition priming, however (Feldman &

[3] As an alternative to pre-lexical decomposition, post-lexical decomposition of lexical entries with respect to morphological structure for inflectional forms has been recently proposed (Caramazza, Laudanna, & Romani, 1988). No similar arguments, however, were made for derivations. Moreover, as explained in the text, the possibility that the root and the word pattern in Hebrew have separate lexical entries is unlikely.

Fowler, 1987; Feldman & Moskovljevic, 1987), it cannot adequately explain the duration of the morphological repetition effect because it is not based on principles that are radically different from semantic priming. Moreover, although it might explain how lexical access for words is facilitated by repetition, it fails to explain the pseudo-morphological repetition effects for non-words that were observed in the present experiment. Of course it is possible that the morphological repetition effect for non-words was mediated by a different mechanism than that which mediated the repetition effect for words, but it is more parsimonious to explain both effects using the same mechanism.

A lexical mechanism that might explain the morphological repetition priming assumes a top-down feedback from the semantic system. As described in the Introduction, the meaning of a Hebrew word is jointly determined by the root and the word pattern in which the root is embedded. If, as suggested by Morton (1982), when words are to be distinguished from morphologically legal non-words the lexical decision involves an extensive lexical analysis, it is conceivable that during this process the root is extracted and considered in isolation.

Along with others (e.g. Balota & Chumbley, 1984), we suggest that the differentiation between words and pseudo-words may be a two-stage process. First, an initial orthographic (and possibly phonological) analysis is made. At this stage, letter strings that do not conform to the orthographic and/or phonological constraints of the language are rejected. However, a distinction between legal morphological units that are words and those that are not is achieved only at the second stage, and it is based on a complete morphological and possibly even a semantic analysis. If a given combination of morphemes has a meaning (or at least such an association was established in the past), the stimulus is categorized as a word. If it is new to the subject or if the specific combination of morphemes is illegal or meaningless, it is categorized as a non-word. According to this model, both words and pseudo-words are subjected to a similar lexical process of analysis during the lexical decision. In particular, because all the non-words in our study were based on existing legal word-patterns (onto which nonsensical roots were legally embedded), the distinction between words and non-words could be made only by examining the root. What remains to be determined is how repetition facilitates the extraction of either real or nonsensical roots and the retrieval of the root-related lexical information.

One possibility is to assume that roots are represented in the lexicon as abstract orthographic patterns. Within network-type models, for example, Hebrew roots could represent an intermediate stage between the letters level and the word-unit level. (Of course, such a model must assume a similar status for word patterns.) Thus, repetition could facilitate access to that unit in a manner similar to the identical repetition of a word. This mechanism, however, cannot account for the repetition effects that may exist with nonwords.

Another possibility is that repetition facilitated procedural aspects of the lexical analysis using episodic memory traces which may facilitate either lexical or post-lexical processes or both. According to this view, when subjects encounter a repetition, they remember that they have seen that stimulus previously and the response they had made to it. This recollection may accelerate the response to repetitions by making some of the decision-making processes redundant (Jacoby, 1983; Jacoby & Brooks, 1984; Jacoby & Dallas, 1981; Forster & Davis, 1984) and by reducing the stimulus recognition time as a result of enhanced pattern familiarity (Feustel, Shiffrin, & Salasoo, 1983; Salasoo, Shiffrin, & Feustel, 1985). The episodic contribution to the identical repetition effect is supported by evidence that factors that affect the strength of the memory trace also affect the repetition effect. These include the depth of processing the prime (Bentin & Moscovitch, 1988) or the processing load during the priming condition (compare Monsell, 1987, Experiment 1, with Monsell & Banich, cited in the same paper). Additional evidence for an episodic contribution to the repetition effect can be found in the significant attenuation of the repetition effect when the first and the second presentations are in different modalities (Clarke & Morton 1983; Kirsner & Smith, 1974; see also Allport & Funnell, 1981), or in different languages (Kirsner, Brown, Abrol, Chadha, & Sharma, 1980; Kirsner & Dunn, 1985; Scarborough, Gerard, & Cortese, 1984). However, the viability of the "episodic" hypothesis as the *sole* account for the repetition effects has been seriously challenged by significant transfer of repetition effects across tasks (Clarke & Morton, 1983; Jacoby & Dallas, 1981; Monsell, 1985, Experiment 5; Scarborough, Gerard, & Cortese, 1979) and when the first and the second presentations were in the same language but in different alphabets (Feldman & Moskovljevic, 1987).

Finally, another source of repetition effects must be, at least briefly, considered: The effect of formal repetition. Repetition of formal aspects of Hebrew words such as its orthographic or phonemic features produced partial repetition effects at short lags and at both short and long lags, respectively (Bentin, 1989). Moreover, masking studies in English reveal that even partial orthographic repetition is sufficient to increase significantly the identification of words (Evett & Humphreys, 1981) and to facilitate the rejection of pseudo-words in a lexical decision task (Scarborough et al., 1977). However, orthographic repetition cannot account for the observed morphological repetition effects, for several reasons: (1) The effect of formal repetition, particularly at long lags, tends to be small, and not consistently observed (compare Bentin, 1989 with Feldman & Moskovljevic, 1987; Hanson & Wilkenfeld, 1985; Napps & Fowler, 1987; Scarborough et al., 1977). (2) Several carefully designed studies in which morphological and orthographic repetition were compared directly revealed that orthographic repetition inhibited or had no effect on lexical decision for words (Henderson et al., 1984) and had no effect on tachistoscopic word identification (Murrell & Morton, 1974).

In summary, the present results in Hebrew suggest two sources of activation with different time courses. Pure morphological relatedness, in the absence of semantic similarity, facilitates lexical decisions similarly at short and at long lags. Semantic relatedness facilitates lexical decisions only at short lags. The interaction between these two sources may augment the repetition effect, causing a slower decay of the semantic priming. The pure morphological repetition effect, at least for the repetition of Hebrew roots, is probably a combination of facilitating lexical processes such as the retrieval of word meaning and of learning an association between stimulus and response, both of which might be partly mediated by episodic traces in memory.

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APPENDIX A

The 24 targets and their respective primes in each condition. (The English translations are in parenthesis).

Target	SM Prime	M prime	S Prime
1. ספריה (library)	ספרן (librarian)	מספר (number)	קריאה (reading)
2. מטבח (kitchen)	טבח (cook)	טבח (massacre)	מזון (food)
3. סעדה (feast)	מסעדה (restaurant)	מסעד (prop)	אכל (food)
4. גבור (hero)	גבורה (heroism)	מגבר (amplifier)	פחדן (coward)
5. מילדת (midwife)	לידה (birth)	תולדות (history)	תינוק (baby)
6. נחלה (estate)	מתנחל (settler)	נחל (river)	אחזה (estate)
7. פועל (labourer)	מפעל (factory)	פעלול (trick)	עובד (worker)
8. תושב (resident)	ישוב (settlement)	ישבן (buttock)	אזרח (citizen)
9. משקל (weight)	שקול (balanced)	שקל (Shekel)	כבד (heavy)
10. בטאון (newspaper)	התבטאות (expression)	מבטא (accent)	עתון (journal)
11. משקפת (binocular)	משקפים (spectacles)	שקוף (transparent)	עדשה (lens)
12. אהל (tent)	מאהל (encampment)	אהיל (lampshade)	מחנה (camp)
13. מאבן (fossil)	אבן (stone)	אבנית (fur)	קפוא (frozen)
14. עבודה (work)	עובד (worker)	מעבדה (laboratory)	מלאכה (craft)
15. ראיה (sight)	רואה (see)	ראוה (exhibition)	שמיעה (hearing)
16. אגדה (association)	אגוד (union)	אוגדן (file)	מועדון (club)
17. מכתב (letter)	כתבת (address)	כתבה (article)	בול (stamp)
18. ספור (story)	ספר (book)	מספר (number)	שיר (song)
19. רץ (runner)	ריצה (run)	מריצה (wheelbarrow)	הולך (walker)
20. שטיח (carpet)	שטוח (flat)	שטחי (superficial)	רצפה (floor)
21. מפלגה (party)	פלוג (partition)	מפלג (division)	כנסת (parliament
22. מחלקה (platoon)	חלק (part)	מחלקת (dispute)	פלגה (company)
23. מגדל (tower)	גדול (big)	גדול (tumor)	צריח (turret)
24. מפקד (commander)	פקדה (command)	פקיד (clerk)	חיל (soldier)