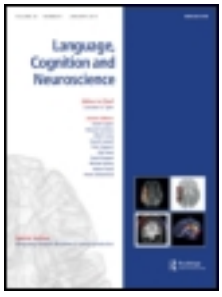

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Morphological activation in sentence context: when the root prevails over the meaning

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Morphological activation in sentence context: when the root prevails over the meaning

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Two experiments explore the extent of morphological root-based spreading activation in adult skilled readers of Hebrew. Participants performed semantic judgements on sentences in Hebrew, half of which included sentence-final incongruent targets. Critical targets were morphologically related but semantically unrelated to an expected but non-presented congruent sentence completion, and control items had no such morphological relation. Participants were slower and more error-prone in correctly rejecting critical targets than controls, due to the morphological relation with the congruent completion. These results demonstrate that prediction-based lexical activation in the absence of form exposure can support morphologically based spreading activation in Hebrew. Furthermore, semantic constraints do not completely eliminate activation of morphologically related but semantically incongruous lexical candidates, similar to patterns found for ambiguous lexical items in other languages. Taken together, these results support and extend the central role of the morphological root in shaping lexical organisation and dynamics of lexical access in Hebrew.

Keywords: morphology; semantic; ambiguity; context

Human languages vary in how information is distributed over different levels of linguistic representation and specifically in the richness of their morphological structure. These cross-linguistic differences have consequences for processing written and spoken language (Frost, 2012). Lexical organisation and activation in speakers of morphologically rich languages, such as Hebrew, are greatly influenced by morphological structure and principles (Frost, Forster, & Deutsch, 1997). To date research on morphological representation in Hebrew has focused mainly, though not exclusively, on the processing of single words. Furthermore, studies have mostly used various priming paradigms to examine the degree to which morphological information can be rapidly extracted during language processing. The purpose of the current study is to examine how morphological principles might exert their influence on lexical activation when words are embedded in meaningful linguistic context, and especially when morphological relations do not align with the semantics arising from the sentence.

Morphology is an important organising principle of the lexicon of Hebrew speakers. Most content words in Hebrew are comprised of two morphemes – a tri-consonantal root and a word pattern – which consist of vowels or vowels and consonants (though for a different view see Berent, Vaknin, & Marcus, 2007; Vaknin-Nussbaum & Shimron, 2011). The morphology of Hebrew is non-concatenated, such that the root morpheme is intertwined with the word pattern. In most cases, the root morpheme carries the basic meaning of the word, and the word pattern gives specific connotations – but this is not always the case, as will be detailed below. Word patterns also carry the grammatical information – word class (noun/verb), grammatical gender and number, and in the verb system also tense and aspect.

There is abundant evidence supporting the central role of morphology in Hebrew language processing. Developmentally, Hebrew-speaking children show awareness of morphology as early as age 3, by coining new words that adhere to the morphological principles of the language (e.g. Berman, 2000). Morphological knowledge also plays a central role in the acquisition of literacy and spelling in Hebrew by children (e.g. Ravid & Bar-On, 2005) and by young adults learning Hebrew as an L2 (Frost, Siegelman, Narkiss, & Afek, 2013). Research on skilled adult readers of Hebrew has demonstrated that the root morpheme influences lexical access of visually presented words. Robust effects of morphological priming, that are not reducible to phonological similarity, were demonstrated using masked priming of single words (Deutsch, Frost, & Forster, 1998) and cross-modal priming (Frost, Deutsch, Gilboa, Tannenbaum, & Marslen-Wilson, 2000). These authors have also demonstrated that root-based morphological priming in Hebrew is apparent in the absence of semantic relatedness, again using masked- and cross-modal priming methods (Frost et al., 1997, 2000). This last finding is especially relevant for the present study,

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which will also examine the influence of a common root morpheme in the absence of semantic relatedness between words.

Recent imaging studies have also shown distinct morphological processing in skilled readers of Hebrew that again could not be simply reduced to phonological or semantic overlap (Bick, Frost, & Goelman, 2010; Bick, Goelman, & Frost, 2008, 2011). These studies demonstrated that lexical access in skilled adult readers of Hebrew involves morphological decomposition of the word and extraction of the root morpheme. Two recent studies have also examined the role of morphological facilitation in Hebrew language production, using the picture word interference paradigm. Deutsch and Meir (2010) showed root-based morphological facilitation from an auditory word distractor, and Kolan, Leikin, and Zwitserlood (2011) showed root- and pattern-based morphological facilitation from printed word distractors.

Offering more converging evidence, studies of eye movements in reading have also shown significant morphological facilitation in readers of Hebrew. A first study examining naming and lexical decision of single words demonstrated that the root morpheme can provide parafoveal preview benefits and facilitate reaction times (RTs) (Deutsch, Frost, Pollatsek, & Rayner, 2000). In two additional studies, Deutsch and colleagues extended these findings to sentence reading. The first study (Deutsch, Frost, Pelleg, Pollatsek, & Rayner, 2003) reported a significant parafoveal preview benefit in sentence reading from a noun derived from the same root as the target word in the sentence. Sentences used in this study had low-cloze probability of target completion, and there were no semantic relations between the target words and the previous words in the sentence. This is an important finding, showing that in the context of sentence reading skilled Hebrew readers indeed extract morphological information from briefly presented words, in the very early stages of word reading. However, in this study, possible semantic relatedness between the preview word and the target word were not controlled, as was the case in the previous single word studies (e.g. Frost et al., 1997, 2000).

A later study reported by Deutsch, Frost, Pollatsek, and Rayner (2005) examined the interaction between the sentence predictability and the extraction of morphological information from a parafoveally presented prime in greater detail. This study found a significant preview benefit in first fixation durations from a shared-root item when the sentence was low constraint, but not high constraint. However, in gaze duration, the pattern was different. Specifically, in gaze duration, greater facilitation from a morphologically related preview item was found for the semantically biased condition than for the neutral sentence. The authors interpret the absence of a contextual effect in the earliest measure, namely first fixation, as evidence that root extraction from the presented preview item was fast and not sensitive online to higher-order semantic processes. Importantly, in this study as in the work of Deutsch et al. (2003), the semantic relatedness between the preview item and the target item was not controlled.

The conclusion that can be reached based on the studies described above is that the lexicon of Hebrew speakers is at least to some extent organised according to morphological principles, though there is still a debate regarding the exact manner in which the morphological information is realised in the lexicon, and at what level of representation (Kolan et al., 2011; Velan, Frost, Deutsch, & Plaut, 2005). Importantly, the studies reviewed above have all presented participants with auditory or visual word forms in Hebrew, and tracked the impact of their bottom-up activation on linguistic performance – reading or articulation. The present study was designed to probe the possible activation of morphological representations in the absence of any external stimulus, based on semantic expectations arising during sentence reading, and it therefore probes the organisation of the mental lexicon in a less modality specific way.

Our choice of probing morphological activation of words embedded in sentences also raises questions regarding the manner in which semantic context might constrain activation of lexical candidates. As detailed above, research on single word reading in Hebrew reliably demonstrates activation of the morphological root, and spreading of activation from the root to other lexical items derived from it, even in the absence of semantic relatedness (Bick et al., 2010; Frost et al., 2000). Studies examining sentence reading have also shown that morphological information is extracted quickly, in parafoveal presentation, and is not sensitive to online semantic context (Deutsch et al., 2003, 2005). However, the sentence reading studies did not directly control the semantic relatedness between the preview words and the target words.

Most Hebrew morphological roots carry a basic semantic meaning that is shared by the lexical items derived from them. For example, the root z.m.r connotes the meaning of singing or music, which is shared by the words derived from this root – zamár (male singer), zémer (a song), zimér (he sang) and more remotely tizmóret (a band). For these types of words, it would therefore be difficult to distinguish between morphological activation arising from the root and semantic activation spreading from the presented lexical item itself, due to the shared meaning or from expectations generated based on preceding context. Therefore, in the current study, we selected Hebrew roots that in fact have two distinct meanings or semantic fields. For example, the root x.s.n carries both the meaning of warehouse or storage (maxsan) and the meaning of vaccination (xisun). Employing these semantically ambiguous roots can allow us to uniquely identify activation of the morphological root in a sentence context,

because these are words derived from the same root that do not share the semantics of the sentence.

Roots with two distinct semantic fields are similar to ambiguous words that have two unrelated meanings, such as BANK in English – the 'financial institution' meaning and the 'riverside' meaning (see also Rodd, Gaskell, & Marslen-Wilson, 2002). Previous research on meaning activation of ambiguous words embedded in sentential context has demonstrated that both meanings of an ambiguous word embedded in a sentence are at least momentarily activated (Duffy, Morris, & Rayner, 1988; Gernsbacher, 1993; Onifer & Swinney, 1981). The extent and duration of activation of the meaning that does not fit the sentence frame depend both on the basic frequency of the two meanings and on the degree of bias introduced by the sentence. The analogous question in the present study is whether activation of root morphemes of expected but non-presented words when reading sentences in Hebrew would spread to words that are derived from the root but do not fit the meaning and the semantic field activated by the sentence frame. The alternative is that the semantic context provided by the sentence might act to limit the spreading of morphological root activation only to a subset of lexical items that are derived from the root and that also match the meaning of the sentence.

In the current study we examined these questions by presenting native Hebrew-speaking university students with sentences in Hebrew. Participants read the sentences word by word and decided whether they made sense semantically. Critical sentences had high-cloze probability regarding the expected sentence-final word, which was always a word derived from an ambiguous morphological root. However, this expected word was never presented to the participants, but rather it was replaced with a semantically incongruent word, calling for a negative acceptability judgement. The critical comparison was between incongruent words that shared the morphological root of the expected word and incongruent words that did not.

When called to perform an acceptability judgement, speakers evaluate the fit of the sentence-final target word with the existing sentence frame stored in working memory. Furthermore, there is convincing evidence that readers anticipate upcoming words in sentences and processing is facilitated when highly predictable words are then presented. This has been demonstrated for sentence reading using event related potentials (ERPs) (e.g. Kutas & Hillyard, 1984; Molinaro, Conrad, Barber, & Carreiras, 2010; Prior & Bentin, 2006) and eye-tracking methodologies (Ashby, Rayner, & Clifton, 2005; Ehrlich & Rayner, 1981) and for spoken language comprehension using eye tracking (e.g. Kamide, Altmann, & Haywood, 2003). Additional ERP studies have demonstrated that words that are acceptable given the existing sentence context, but that differ from the predicted high-cloze probability word, lead to specific patterns of neural activity supporting the idea that readers had predicted a specific lexical item (e.g. Otten & Van Berkum, 2008; Van Berkum, Brown, Zwitserlood, Kooijman, & Hagoort, 2005; see Federmeier, 2007, for a review). These studies show that sentence-based expectations do not only activate conceptual representations of appropriate words, but also activate the expected lexical items themselves. Specifically, Molinaro et al. (2010) showed an interaction between cloze probability and orthographic neighbourhood of words presented following a sentence frame, in a design similar to the one we used in the current study. Their results support the notion that in high-predictability sentences, preceding context leads to activation of target words including the full lexical form. Along similar lines, studies have also demonstrated prediction of specific lexical items given a sentence context, by demonstrating an enhanced response to an article that was unexpected given the predicted word (DeLong, Urbach, & Kutas, 2005, for English; Van Berkum et al., 2005, for Dutch).

Therefore, in the current study, we assume that before encountering the sentence-final target word, it is already activated above the resting point by the preceding sentential context. Because, as described above, roots are an important organising principle of the mental lexicon of Hebrew speakers, it is possible that when a lexical item is activated by preceding context, activation spreads from the word to the morphological root and then further to other lexical items derived from the same root. In the current experiment, the participant is then presented with one of the two types of incongruent sentence-final words – morphologically related or morphologically unrelated to the congruent sentence completion that is already activated by the preceding context.

What we propose is that if indeed activation spreads via the root from the contextually activated lexical item to the morphologically related incongruent target that is actually presented, participants will find it harder to reject these targets as acceptable sentence completions. The above-threshold activation of the sentence incongruent item will delay the negative response, lead to more errors in this condition, or both. Conversely, incongruent target final words that are morphologically unrelated to the contextually activated congruent sentence completion will not have been primed or activated by it, and will therefore be rejected more easily by the participant as acceptable sentence completions.

If the results align with this hypothesised pattern, this would support the conclusion that morphologically root-based spreading activation operates even in the presence of contextual constraints, and is not limited to semantically related lexical items. This would lend further support to the pivotal role of the morphological root in determining patterns of connectivity and dynamics of activation in the mental lexicon of Hebrew speakers, and putatively also for speakers of other semitic languages with similar morphological structures, such as Arabic.

Experiment 1

Method

Participants

Participants were 20 native Hebrew-speaking undergraduate students at the University of Haifa with no history of reading or learning disabilities and with normal or corrected vision (mean age = 25.1, SD = 2.23; 9 males). All participants gave informed consent and were compensated for their participation.

Stimuli

The targets were 30 Hebrew word pairs, that were derived from the same root, but that were unrelated semantically (Frost et al., 1997; Seroussi, 2011). For example, the word 'zman' (time) and word 'mezuman' (cash) are both from the root z.m.n. For each pair, two sentence frames were constructed such that each of the words would constitute a congruent sentence-final word for one of the sentences. The generated sentence frames were presented to an additional group of 26 participants from the same population, who were requested to complete them with a single word. Based on the sentences generated by this group, the cloze probability for the matching completion was 70.03% on average. None of the participants who took part in the sentence completion were included in the experimental task.

In the actual experiment, the sentence frames were never presented with their congruent completion. Each sentence was presented in one of two conditions, across participants. In the morphologically related condition, the final target word was sentence incongruent, for example: 'Checks are not accepted, only TIME', and was derived from the same morphological root as the congruent completion, i.e. CASH. In the unrelated condition, the final target word was again sentence incongruent, 'Checks are not accepted, only SCRIPT', but in this case it was not related semantically or morphologically to the congruent completion (for a full example see Table 1).

The 60 experimental sentences were divided into two lists, such that each list contained both sentence frames that were constructed for each pair. However, across lists the same sentence frame was presented once with the morphologically related completion and once with the unrelated completion. Thus, each list contained 30 sentences which appeared with the morphologically related non-congruent sentence-final word and 30 sentences which appeared with the control non-congruent final word. The lists were constructed such that within each list a given sentence frame was presented only once, but the same frame appeared with both control and critical completions across participants. In addition, 60 congruent sentences were used as fillers. The filler sentences were perfectly matched in overall length with the target sentences, with a mean sentence length of 5.4 words (range = 3–8, SD = 1.09) in both conditions. Ten participants were tested on each list, allowing each participant to provide data points in each condition, yet avoiding stimulus repetitions. The stimuli were ordered randomly for each participant.

Morphologically related and morphologically unrelated sentence-final target words were perfectly matched in length (mean length in letters was 4.55, range 3–7, SD = 0.87). Word frequencies were extracted from Frost and Plaut (2005), a word-frequency database for printed Hebrew. This is a database of frequency estimations based on unpointed Hebrew script, and thus does not distinguish between homographs, but it is the only existing frequency database for printed Hebrew. The two target types were not significantly different in frequency ($p > 0.05$), but there was large variability, due mostly to several high-frequency items.[1]

Procedure

The experimental task was presented using E-Prime 2 with a serial response box (Psychological Software Tools Inc., Pittsburgh, PA, USA) to ensure accurate RT measurement. Participants were seated approximately 50 cm from the monitor. Participants performed a semantic acceptability judgement on visually presented sentences, using button press to indicate their choice – 'yes' responses were given with the right index finger and 'no' responses were given with the left index finger.

The experimental session started with a short practice block of four congruent and four incongruent sentences. After ensuring that participants had understood the task, the 120 experimental sentences were presented in three blocks of 40 sentences each, with self-paced breaks

Table 1. Example stimuli and sentence frames used in Experiment 1.

Sentence frame	Sentence congruent completion (not presented)	Morphologically related target (sentence incongruent)	Morphologically unrelated target (sentence incongruent)
_____ הולכי רגל צריכים ללכת על ה	מדרכה (*midraxa, root d.r.x*)	מדריך (*madrix, root d.r.x*) orth. overlap = 4	מרדים (*mardim, root r.d.m*) orth. overlap = 3
Pedestrians should walk on the _____	Sidewalk	Guide	Anaesthesiologist

introduced between blocks. Sentences were presented in the centre of the screen word by word, at a rate of 200 milliseconds per word, after a pilot study ensured that this rate of presentation allowed participants to easily read and comprehend the sentences. Text was presented in 44 point David font, in black on a silver background. Each trial started with a fixation cross that was presented for 250 ms followed by the words of the sentence. The sentence-final word was presented until the participant responded or for a maximum of three seconds. A 200-ms blank screen followed the response, before the onset of the following trial. Participants took approximately 15 minutes to complete the task.

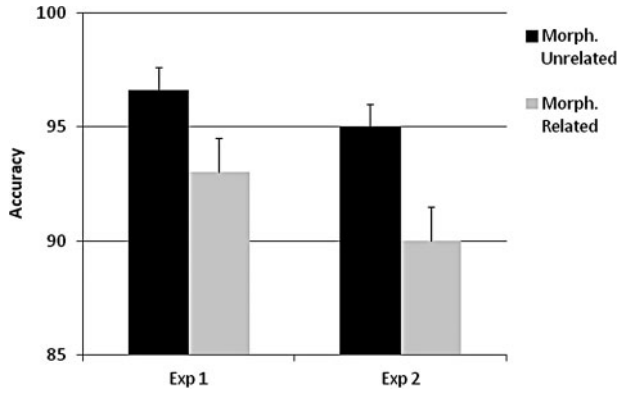

Figure 2. Mean accuracy rates (SEM) for morphologically related and unrelated incongruent targets in Experiments 1 and 2.

Results and discussion

Overall, accuracy rates in the task were very high (M = 0.96, SD = 0.03), as participants were very accurate in distinguishing congruent and incongruent sentences. We compared RTs for correct responses and accuracy rates for morphologically related and unrelated incongruent sentence-final words. Participants were slower to reject an incongruent target word when it was morphologically related to an expected congruent sentence completion than when it was morphologically unrelated ($t(19) = 4.15$, $p < .001$ for subjects, $t(59) = 3.71$, $p < .001$, for items). Participants also made more errors in incorrectly accepting incongruent sentences when they included a morphologically related as opposed to a morphologically unrelated target word ($t(19) = 2.5$, $p < .05$ for subjects, $t(59) = 2.74$, $p <. 01$ for items; see Figures 1 and 2).

The results support the notion that the morphologically related incongruent sentence-final word was difficult to reject because of overlap in root morpheme activation with the expected high-cloze sentence congruent completion word (which was not presented). However, a concern at this point might be that the target words that were morphologically related to the non-presented congruent sentence-final word were more orthographically or phonologically similar to it than the morphologically unrelated target words. This is because the morphologically related targets always shared at least the three root consonants with the congruent sentence completion, whereas the morphologically unrelated targets were not constrained in this manner. If this is the case, evidence for increased activation of targets in the morphologically related condition might be a result of orthographic or phonological similarity, and not constitute evidence for morphological activation per se.

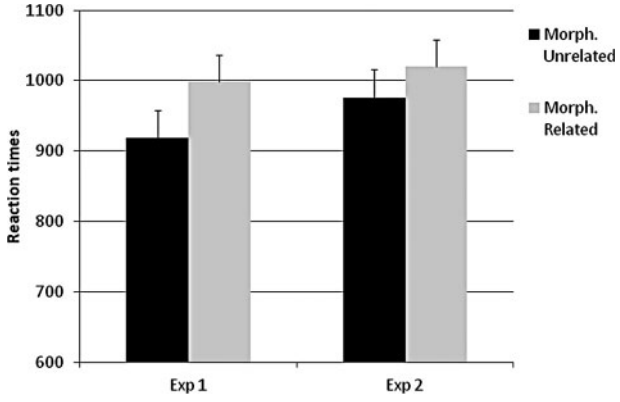

Figure 1. Mean reaction times (ms, SEM) for morphologically related and unrelated incongruent targets in Experiments 1 and 2.

To this end, we examined the phonological and orthographic overlap between each of the target types (morphologically related and morphologically unrelated) and the congruent sentence completion. In order to assess the degree of similarity, we counted the number of repeated letters in the incongruent target and the congruent sentence completion. The results of this analysis showed that the morphologically related targets shared more letters with the congruent sentence completion (M = 3.3, SD = 0.56) than did the morphologically unrelated targets (M = 1.66, SD = 1.01), a statistically significant difference (t = 13.4, $p < .01$).

In light of these findings, we decided to conduct Experiment 2, with the same set of morphologically related target words, but with a new set of morphologically unrelated targets, that would be matched in their degree of orthographic and phonological overlap with the expected sentence congruent completion. Experiment 2 would also provide a replication of the findings of Experiment 1.

Experiment 2

Method

Participants

Participants were 30 native Hebrew-speaking undergraduate students at the University of Haifa with no history of

reading or learning disabilities and with normal or corrected vision (mean age = 26.8, SD = 4.2; 10 males). All participants gave informed consent and were compensated for their participation. None of the participants had participated in Experiment 1.

Stimuli and procedure

The same 30 Hebrew word pairs that were identified in Experiment 1 were used in Experiment 2. To recapitulate, the words of each pair were derived from the same root, but were semantically unrelated. The sentence frames and all details of the study were also identical to those described in Experiment 1. The only difference introduced in Experiment 2 was the identity and nature of the morphologically unrelated targets. As in Experiment 1, the morphologically unrelated targets were perfectly matched to the morphologically related targets on length (mean length in letters was 4.55) and did not differ in frequency ($p > .05$).[2] However, in this experiment, the morphologically unrelated targets were also matched to the morphologically related targets in their degree of orthographic overlap with the expected sentence congruent completion.

The orthographic overlap with the congruent (non-presented) sentence completion was 3.2 letters (SD = 0.83) for the morphologically related targets and 3.13 letters (SD = 0.99) for the morphologically unrelated targets, and did not differ statistically from each other ($t = 0.39$, $p = 0.69$; Table 2).

Results and discussion

Overall accuracy rates were again very high ($M = 0.94\%$ correct, SD = .04). We compared RTs for correct responses and accuracy rates for morphologically related and morphologically unrelated targets. Participants were slower to reject an incongruent target word when it was morphologically related to an expected sentence completion than when it was morphologically unrelated ($t(29) = 3.02$, $p < .01$ for subjects, $t(59) = 2.25$, $p < .05$ for items). Participants also made more errors in incorrectly accepting incongruent sentences when they included a morphologically related as opposed to a morphologically unrelated target word ($t(29) = 4.5$, $p <. 001$ for subjects, $t(59) = 2.89$, $p < .01$ for items). These results provide a full replication of the findings reported in Experiment 1, with a set of arguably better matched materials.

We also wished to explore whether the magnitude of the effects was similar or different across the two experiments, to probe the possibility that orthographic factors might have played a role in the results of Experiment 1, but not Experiment 2. If this is indeed the case, we would expect larger differences between the morphologically related and morphologically unrelated conditions in Experiment 1.

To this end, we conducted a two-way Analysis of Variance (ANOVA), with Experiment (1 and 2) as a between subjects variable and morphological relatedness (related, unrelated) as a within subject variable. In the analysis of RTs, there was a main effect of morphological relatedness ($F_1(1,48) = 27.57$, $MSE = 3383$, $p < .001$, $\eta^2 = .37$; $F_2(1,118) = 17.06$, $MSE = 13843$, $p <. 001$, $\eta^2 = .13$), because morphologically related targets were rejected more slowly than unrelated targets. The main effect of experiment was not significant ($F_1 < 1$, $F_2 = 3.5$, $p = .07$). The interaction was not significant in either the subject analysis ($F_1(1,48) = 2.59$, $MSE = 3383$, $p = .11$, $\eta^2 = .05$) or the items analysis ($F_2 < 1$). An examination of the means shows that the relatedness effect was numerically larger in Experiment 1 than in Experiment 2 (81 ms and 44 ms, respectively). We are reluctant to interpret this finding, because it did not reach statistical significance, but it might suggest that some part of the effect observed in Experiment 1 is due to the fact that the morphologically related targets had greater orthographic overlap with the high-cloze sentence completion than did the morphologically unrelated targets. This issue should be further explored in future studies.

In the analysis of accuracy rates, only the main effect of morphological relatedness was significant ($F_1(1,48) = 22.77$, $MSE = 1.71$, $p < .001$, $\eta^2 = .32$; $F_2(1,118) = 15.6$, $MSE = .007$, $p < .001$, $\eta^2 = .12$), because participants made more errors in judging sentences including morphologically related as opposed to morphologically unrelated targets. The main effect of experiment was not significant ($p_{1,2} > .1$), and neither was the two-way interaction ($F_{1,2} < 1$).

Table 2. Example stimuli and sentence frames used in Experiment 2.

Sentence frame	Sentence congruent completion (not presented)	Morphologically related target (sentence incongruent)	Morphologically unrelated target (sentence incongruent)
____ החשודים השתחררו ב	ערבות (*arvut, root a.r.v*)	מערב (*ma'arav, root a.r.v*) orth. overlap = 3	עבדות (*avdut, root a.v.d*) orth. overlap = 4
The suspects were released on _____	Bail	West	Slavery

General discussion

The goal of the present study was to explore the extent of root-based spreading activation for adult skilled readers of Hebrew. Specifically, we wished to test the possible limits of the robust morphological influences previously demonstrated in this population. We approached this issue in two ways. First, by probing whether contextually activated but non-presented words might nonetheless show evidence of activating morphologically related items in the lexicon. Second, we examined the possible influence of semantic constraints arising from sentential context in limiting morphological activation only to lexical items semantically congruent with the context. In both cases, we found a very strong role for morphology, in that predicted but non-presented words activated lexical items via a shared morphological root, and that they did so even in the absence of semantic relatedness and when the activated items did not fit with the sentential constraints.

In Experiment 1, participants took longer to reject incongruent target items that were morphologically related to an expected sentence-final word than morphologically unrelated targets, and also made more errors. We wish to argue that this greater difficulty in rejecting the morphologically related targets arises from spreading activation from the expected sentence completion, via the shared morphological root. However, Experiment 1 did not provide sufficient controls to rule out activation resulting from orthographic overlap between morphologically related targets and the expected sentence completion, which could provide an alternative explanation for the observed results.

To rule out this possibility and to provide a replication of our findings, we conducted Experiment 2, using a more tightly controlled set of materials. Specifically, the orthographic resemblance between the expected sentence completion and the two target types was closely matched. Thus, morphologically related targets were no more orthographically similar to the expected sentence completion than were morphologically unrelated targets. The results provide a full replication of the effect observed in Experiment 1, even after controlling for the orthographic resemblance. Once again, participants exhibited greater difficulty detecting the incongruence in sentences in which the final (incongruent) word was morphologically related to the expected sentence-final word than in sentences with no such morphological relation. When comparing the magnitude of the observed effect in the two experiments, we found it to be numerically, though not significantly, larger in RTs in Experiment 1, suggesting that orthographic factors might have made some contribution. There was no difference in the magnitude of the accuracy effects. And crucially, the morphologically mediated effect was highly significant even in Experiment 2, in the absence of orthographic differences between the experimental conditions.

Although we suggest that the source of morphological activation in the present design, which inhibited participants' ability to correctly reject sentences appearing with morphologically related targets, comes from the predicted sentence congruent word, an alternative explanation is also possible. According to this view, it is not necessary to posit spreading activation from the predicted word, but rather it might be the case that upon encountering the target in the morphologically related condition it is morphologically decomposed and then activates other lexical items derived from the same root. In this case, the word predicted based on the sentence context is also activated by the target, therefore leading to greater difficulty in rejecting the sentence as semantically incongruent.

We agree that the present design does not allow an unequivocal resolution of the issue regarding which 'direction' the flow of activation is proceeding along (from the activated non-presented predicted word or from the presented morphologically related target). However, even if this alternative account is accepted, the present results support morphologically based spreading activation that is not constrained by sentence context and that interacts with contextually generated expectations. Moreover, the interference we observed would come into play only if the sentence context had actually led to the activation of the expected lexical item. Additionally, Experiment 2 reinforces previous findings that lexical activation in Hebrew is governed by morphological and not orthographic similarity (e.g. Frost, 2009), because the morphologically unrelated but orthographically matched targets did not lead to any observed interference. Finally, given the substantial literature reviewed demonstrating robust lexical activation of predictable sentence constituent, we favour the account allowing for this type of lexical activation in the present study as well. However, future research should further investigate this issue perhaps using more sensitive online measures of prediction-based lexical activation and morphologically mediated spreading activation, such as ERPs or eye movements.

The current results extend the central role of morphology in lexical organisation and access in Hebrew speakers and readers in two important ways. First, we demonstrated morphologically based spreading activation even in the absence of explicit exposure to an external representation of a lexical item or root. Thus, lexical activation arising from semantic expectations was sufficient to allow for morphologically mediated activation of related lexical items. This finding suggests that the lexicon of Hebrew speakers is shaped by morphological principles not only in comprehension but also in top-down processes of expectation generation.

Second, the current study furthers our understanding of the interplay between automatic spreading activation and contextual constraints. Thus, the results demonstrated significant morphological influences even when the activation of lexical candidates could arguably be constrained by sentential context. Specifically, we found evidence showing that morphologically related but semantically unrelated items were robustly activated even when embedded in a sentence context that clearly leads to semantic incongruity. Based on these findings, we suggest that the high-cloze sentence frame leads readers to generate predictions, which activate the expected lexical item, showing influence of sentence context on lexical activation. However, it seems that once the predicted lexical item has been activated by the context, the spreading of activation along morphologically linked nodes in the lexicon is automatic and is not constrained by semantic/contextual fit with the unfolding sentence.

A caveat to this interpretation is that we used a word-by-word sentence reading paradigm and required participants to perform semantic judgments on each sentence. These conditions of course vary greatly from natural reading processes. Thus, the degree to which the current results might generalise to other reading contexts must be examined in future research.

Our results also speak to the theoretical debate regarding the principles governing lexical organisation and lexical access in speakers/readers of semitic languages, most notably Hebrew and Arabic (for a recent review, see Boudelaa, in press). In contrast to the root-based organisation described in the introduction, some researchers argue for a stem-based morphological structure in Hebrew, similar to that posited for non-semitic languages (Berent et al., 2007; Vaknin-Nussbaum & Shimron, 2011). However, the findings of the current study are hard to reconcile with such an approach, because the influence of the non-presented lexical items on processing of the target sentences was mediated solely by the root morpheme, importantly, in the absence of semantic overlap.

The current results also fit nicely with recent debates in the literature contrasting universal versus language specific patterns in reading (e.g. Frost, 2012). The process of generating expectations during sentence reading is most likely universal and has been demonstrated in different written languages using various experimental methodologies, as described in the introduction (Ashby et al., 2005; Kutas & Hillyard, 1984; Molinaro et al., 2010, Otten & Van Berkum, 2008; Van Berkum et al., 2005). Thus, words that are easily predicted based on existing sentence context are read more quickly and recognised more easily. Moreover, in sentence or discourse contexts that allow comprehenders to predict a specific lexical item (indexed by cloze probability) presenting a different word, or even an article inconsistent with the predicted lexical item, leads to processing delays and difficulties. However, the exact nature of the information activated in the mental lexicon based on these predictions and the dynamics of spreading activation within the lexicon might differ across languages. Our results suggest that for Hebrew speakers, activation from words accessed based on contextual prediction spreads automatically to morphologically related lexical items which are semantically unrelated and contextually incongruent. The current findings provide additional evidence supporting the defining role of morphological principles in the lexical organisation of Hebrew speakers, and most likely speakers of other semitic language as well.

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Notes

1. Mean frequency was 27.5 (SD = 57, median = 4) for morphologically related and 12.7 (SD = 28, median = 2.5) for morphologically unrelated items.
2. Mean frequency was 23.6 (SD = 49, median = 4) for morphologically related and 13.3 (SD = 26, median = 2.5) for morphologically unrelated targets.

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