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Cognition 104 (2007) 254–286
COGNITION
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Roots, stems, and the universality of lexical representations: Evidence from Hebrew ☆,☆☆

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Received 18 August 2005; revised 19 June 2006; accepted 21 June 2006

Abstract

Is the structure of lexical representations universal, or do languages vary in the fundamental ways in which they represent lexical information? Here, we consider a touchstone case: whether Semitic languages require a special morpheme, the consonantal root. In so doing, we explore a well-known constraint on the location of identical consonants that has often been used as motivation for root representations in Semitic languages: Identical consonants frequently occur at the end of putative roots (e.g., *skk*), but rarely occur in their beginning (e.g., ss*k*). Although this restriction has traditionally been stated over roots, an alternative account could be stated over stems, a representational entity that is found more widely across the world's languages. To test this possibility, we investigate the acceptability of a single set of roots, manifesting identity initially, finally or not at all (e.g., *ssk* versus *skk* versus *rmk*) across two nominal paradigms: CéCeC (a paradigm in which identical consonants are rare) and CiCúC (a paradigm in which identical consonants are frequent). If Semitic lexical representations consist of roots only, then similar restrictions on consonant co-occurrence should be observed in the two paradigms. Conversely, if speakers store stems, then the restriction on consonant

☆ This manuscript was accepted under the editorship of Jacques Mehler.

☆☆ This research was supported by NIH R29DC03277-017 and R01DC003277 grants to Iris Berent. We wish to thank Outi Bat-El, Diamandis Gafos, and Donca Steriade for helpful discussions of this research.

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0010-0277/$ - see front matter © 2007 Published by Elsevier B.V.
doi:10.1016/j.cognition.2006.06.002

co-occurrence might be modulated by the properties of the nominal paradigm (be it by means of statistical properties or their grammatical sources). Findings from rating and lexical decision experiments with both visual and auditory stimuli support the stem hypothesis: compared to controls (e.g., *rmk*), forms with identical consonants (e.g., *ssk*, *skk*) are less acceptable in the CéCeC than in the CiCúC paradigm. Although our results do not falsify root-based accounts, they strongly raise the possibility that stems could account for the observed restriction on consonantal identity. As such, our results raise fresh challenge to the notion that different languages require distinct sets of representational resources.
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Keywords: Root; Stem; Paradigm; Morphology; Phonology; Semitic; Hebrew

Is the structure of lexical representations universal, or do different languages rely on fundamentally different types of lexical representations? On the surface, the structure of lexical representations clearly seems to vary across languages. Indo-European languages (e.g., English), store strings of consonants and vowels (i.e., stems), whereas Semitic words are often assumed to be represented by means of a special morpheme, the consonantal root (hereafter, roots). Consistent with this notion, words manifesting the same root often share their core meaning. For instance, many Hebrew words generated from the root *svv* share the semantic feature "round" (see Table 1). Moreover, words sharing the same root prime each other relative to orthographic controls (e.g., Boudelaa & Marslen-Wilson, 2004; Deutsch, Frost, Pollatsek, & Rayner, 2000; Feldman & Bentin, 1994; Frost, Forster, & Deutsch, 1997; Frost, Deutsch, & Forster, 2000), and the root's consonants tend to interact in word-games and word-production by normal speakers and an aphasic patient (for review, see Prunet, Beland, & Adrissi, 2000).

Still, such facts might in principle derive from another source: a system for storing information about unaffixed strings of consonants and vowels (hereafter, stems[1]), which might be more widely found across languages. The storage of stems would allow speakers to extract information about the stem's consonants – the main carriers of lexical distinctions across all languages (Nespor, Peña, & Mehler, 2003). Although speakers of Semitic (and non-Semitic) languages can track the

[1] We use the terms *root* and *stems* to distinguish between two types of putative lexical atoms, those including only consonants (roots), and those including consonants and vowels without affixes (i.e., stems), either bound or free (for discussion, see Ussishkin, 2005). The root vs. stem debate in Semitic essentially concerns the phonological structure of lexical atoms. This question should not be confused with the question of whether morphological processes are confined to lexical roots (atomic lexical elements devoid of any syntactic or functional material), or extend to words (the output of word formation processes). These two questions are, in principle, orthogonal: Arad (2003) shows that lexical roots can correspond to strings of consonants and vowels. Unlike the consonantal-root, whose psychological reality has been recently questioned by linguistic evidence, the psychological reality of stems is widely supported by the existence of grammatical processes that operate over any noun- and verb-stems, such as regular inflection (e.g., Noun-plural → Nounstem+s; for discussion, see Pinker, 1999). Such processes imply the representation of noun- and verb-stem units by mental variables.

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Table 1
An illustration of some Hebrew words generated from the root *svv*

Word	Hebrew Transcription	Gloss
sivúv	סיבוב	A turn
sévev	סבב	A round
sovév	סובב	He turned
sevivón	סביבון	A dradle
svivá	סביבה	Surroundings

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co-occurrence of stem-consonants, such representations might not necessarily play a role in the Semitic grammar. At stake then, is whether roots are genuinely represented by the grammar as atomic lexical units – consistent with the particularist hypothesis that each language might choose a different set of representational primitives, or whether atomic lexical representations are universally stems. In a series of six experiments described below, we report observations demonstrating that Hebrew speakers possess productive knowledge regarding the co-occurrence of consonants and vowels in the stem. As a case study of a single system in a single language, the results can neither confirm nor falsify either broad view, universalist or particularist (root-or stem). But in view of the central role of Semitic morphology in motivating a particularist root-based explanation, the current set of results – which suggests that roots may not be required for an account of Hebrew word-formation – necessary calls for a serious reappraisal of the evidence for the standard, particularist view.

The hypothesis that speakers of Semitic do not store roots may initially seem quixotic, since it ostensibly appears to be contradicted by a large body of literature demonstrating the sensitivity of Semitic speakers to the morphological relationships among words that share their root. However, a closer inspection suggests that these findings can be accommodated with either root- or stem-based explanations. Consider, for example, the evidence for root priming. Root priming is established by comparing the contribution of primes that share the target's root (e.g., *gidel*, he raised-*gadal*, he grew) to controls (e.g., *gamal*, camel-*gadal*, he grew). Although forms that share the same root (e.g., *gadal*, *gidul*, from the root *gdl*) do not necessarily share the same stem, they might still be morphologically related. For example, Ussishkin (2005) suggests that the verb *gidel* (he raised) is productively formed by modifying the stem of *gadal* (he grew). Thus, the priming among *gadal* and *gidul* could reflect either the activation of their shared root, or the morphological priming among their stems, a phenomenon widely attested in non-Semitic languages (e.g., the priming among *grow* and *grew*, e.g., Longworth, Marslen-Wilson, Randall, & Tyler, 2005; Pastizzo & Laurie Beth, 2002; Stockall & Marantz, 2006; Tyler et al., 2002). A similar indeterminacy exists with respect to the high incidence of consonant interaction in Semitic stems. For example ZT, a bilingual aphasic patient, showed far greater metathesis errors (e.g., *naxl* 'palm-trees' → *xanl*) in Arabic than in French (Prunet et al., 2000). Although these findings are consistent with the storage of roots, they could also be accommodated with a stem-based account. A stem-based explanation might attribute the greater rate of metathesis errors in Arabic to the preponderance of Arabic stems that differ on the arrangement of their consonants. To use an analogous illustration from Hebrew, an error such as *naxal* 'river' → *xanal* might be due to intrusion from stems like *xanak*, 'strangled', and *xamal*, 'had pitty', stems which differ from the erroneous output on a single consonant. Thus, the experimental evidence from priming and speech errors might not require the extraction of a root as a special morphological representation.

In the case of Semitic, the stem's consonants might be particularly salient. Because word formation frequently modifies the stem's vowels, leaving consonants intact, the stem's consonants capture form and meaning invariance among members of large morphological families (Gonnerman & Seidenberg, 2000). However, an account of this invariance need not assume special grammatical mechanisms or special lexical units. Morphological processes that modify vowels are by no means specific to Semitic (Bat-El, 2003; we discuss this evidence below). Likewise, the ability to track the co-occurrence of consonants across vowels is not unique to speakers of Semitic. Recent psycholinguistic evidence (Bonatti, Pena, Nespor, & Mehler, 2005; Newport, Hauser, Spaepen, & Aslin, 2004) shows that speakers of Italian and English can learn the phonological dependencies among consonants across vowels even though their native languages by all accounts lack representations of consonantal-roots. Thus, the salience of the stem's consonants to speakers of Semitic might reflect quantitative differences in the statistical properties of the lexicon and the reliance of the grammar on vowel modification, rather than qualitative differences in the structure of the representations or grammatical mechanisms available to speakers of Semitic (Bat-El, 2003). An account of the psycholinguistic evidence from languages such as Hebrew and Arabic may not require the postulation of the root.

The proposal that Semitic words are generated from consonantal roots has been further challenged by linguistic evidence (e.g., Bat-El, 1994; Gafos, 1998; Ussishkin, 1999, 2005) suggesting that lexical representations might invariably encode stems. On these researchers' views, speakers' sensitivity to consonant co-occurrence in Semitic is explained not by a special type of morpheme (i.e., the root) but by the same representations and grammatical mechanisms postulated for concatenative morphologies. To the extent that Semitic morphology has played a central role in motivating language-particularist views of lexical representation, these observations call for a reevaluation of the hypothesis that the structure of lexical representations varies across languages.

In this paper, we take a fresh look at the status of putative roots in the Hebrew grammar by investigating the psychological status of a well-known asymmetry in the distribution of putative Semitic roots.[2] Our starting point is the observation that

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[2] Since Semitic words are traditionally described in reference to their root structure, we maintain the use of the term "root" in a purely descriptive sense to refer to the sequencing of the stem's consonants (irrespective of consonant quantity). Whether roots are, in fact, represented as atomic lexical units is, of course, the precise subject of our investigation.

in Semitic languages, identical consonants are frequent at the end of the putative root (e.g., *svv*), but rare in its beginning (e.g., *ssv*, Greenberg, 1950). Our earlier work has shown that Hebrew speakers generalize this restriction to novel forms, irrespective of the location of the (putative) root's radicals (i.e., consonants) in the word (Berent, Everett, & Shimron, 2001a; Berent, Marcus, Shimron, & Gafos, 2002; Berent, Vaknin, & Shimron, 2004). Those findings suggest that the Semitic grammar restricts the structure of atomic lexical representations, but leave open the question that is key for present purposes: is the domain of that restriction the *root* (consistent with the hypothesis that the structure of lexical representations varies across languages) or the *stem's consonants* (consistent with the hypothesis of Universally fixed lexical representations)?

In influential work, McCarthy (McCarthy, 1979; McCarthy, 1981) attributed the asymmetrical restriction on identical consonants to a grammatical constraint on the structure of (hypothesized) consonantal roots. His analysis started from the assumption that such root consonants are segregated from vowels and affixes, and accordingly represented as lexically adjacent (see Fig. 1). The ban on the location of identical consonants is attributed to a grammatical constraint that bans adjacent identical consonants, the Obligatory Contour Principle (OCP, Leben, 1973). According to McCarthy's view, roots like *svv* in which the identical consonants are adjacent cannot be stored as such in the lexicon. Instead, they are represented by means of a biconsonantal root, *sv*. Crucially, on this theory, even though it is not possible to *store* roots such as svv, words with identical consonants in their surface could nonetheless arise productively, during word formation. For instance, the Hebrew word *sevev* ('a round') could be formed as follows. First, the biconsonantal root *sv* would be aligned with the word's skeletal structure (a set of placeholders for consonants and vowels). The alignment would proceed from left to right, leaving an empty consonantal slot at the right edge. This empty slot would next be filled by the spreading

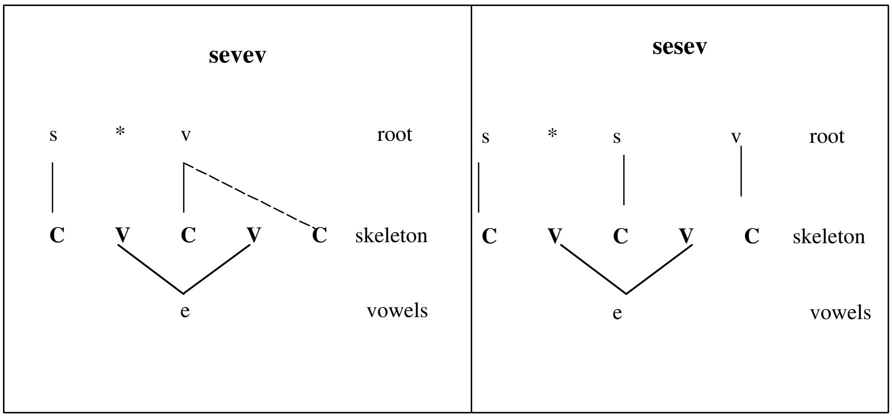

Fig. 1. The representations of the Hebrew nouns *sevev* and *sesev*. According to McCarthy (1979), the identical consonants in *sevev* are represented by the rightward spreading of a single consonant in a biconsonantal root *sv*. Conversely, forms like *sesev* are represented by means of roots with adjacent identical consonants, *ssv*, hence, they violate the OCP (OCP violations are marked by an asterisk).

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of the root's last radical, *v*, rightwards. The linking of that single final radical to two skeletal slots would then surface as the identical consonants in *sevev*. Crucially, this output would not violate the OCP, since the identical surface consonants are represented by means of a single underlying radical. In contrast, stems like *sesev* (which does not exist in Hebrew) could not be formed by spreading (a left-to-right alignment of the root *sv* does not leave an intermediate empty slot), hence, their lexical representation, *ssv*, would violate the OCP.

This explanation would depend crucially however on the assumption that Semitic words are represented by means of a consonantal root that is segregated from vowels and affixes – which, as indicated above, is assumption that has been recently challenged. One set of arguments against McCarthy's original root-based analysis is that it is unnecessary to account for Semitic – virtually all linguistic phenomena cited as evidence for a root-based morphology are not specific to Semitic languages. There are three major observations supporting the postulation of the Semitic root: (a) word formation restricts prosodic structure and expresses morphological relationships by modifying non-adjacent vowels (see Table 1); (b) morphologically related words share a consonantal root; and (c) root consonants are subject to co-occurrence restrictions. Bat-El (Bat-El, 2003) demonstrates that none of these phenomena is unique to Semitic morphology. For example, Yawelemani (a dialect of Yokuts, an American Indian language) expresses morphological relationships by enforcing prosodic templates (e.g., the stem *caw* 'shout', might be inserted in either a gerundial CVC(C)-inay template, *caw-inay*, or the durative CVCVV(C)-'aa template, *cawaa-'aa-n*). Likewise, Gta' (a south Munda language spoken in India) manifests semantic relations by modifying non-adjacent vowels (e.g., the use of the {a.a.} template to express the meaning of 'equivalent', as in *Kito*ŋ, 'god' → *Kata*ŋ 'being with powers equal to *Kito*ŋ'). The enforcement of morphological relationships by means of vowel modification yields families of morphologically related words that share the same consonant sequences (observation b), as in Semitic. Finally, long-distance co-occurrence restrictions on consonants across vowels (observation c) are found in many non-Semitic languages. For example, Yamato Japanese disallows the co-occurrence of voiced obstruents in the stem, whereas Russian disallows stems with identical or homorganic liquids (e.g., *greg, *gok). Thus, a restriction on the co-occurrence non-adjacent consonants in the stem does not require their representation by means of a special morphological constituent (see also Rose & Walker, 2004).

Not only is the root unnecessary to account for Semitic morphologies, but, in some views, such an account is incorrect. One challenge for the root-based hypothesis comes from the phenomenon of cluster transfer (Bat-El, 1994). Hebrew verbs typically exhibit fix templates, such as CiCéC, CaCáC etc. These verbal templates are frequent even in verbs generated from loan nouns. For example, the loan noun *code* gives rise to the verb *kided*, 'codified'. According to the root-based account, such forms are generated by extracting the root from the noun stem (e.g., *kd* from *kod*) and inserting it in a verbal template (e.g., *kd* + CiCeC → *kided*). In this view, the material transferred from the base noun would be stripped of any information regarding consonant–vowel ordering – the interdigitation of consonants and vowels is determined solely by the verb template. But Bat-El (1994) shows that such an

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analysis would fail to account for the formation of verbs from bases that include a cluster. In such cases, the cluster typically transfers from the noun to the derived verb. For example, the noun *praklit*, ‘lawyer’, yields the verb *priklet*, ‘to practice law’ (a transfer of an onset cluster), whereas *nostalgia* yields *nistelg* (he became nostalgic, a transfer of a final cluster). The phenomenon of cluster transfer is inexplicable by root-based accounts: if word-formation were informed by the root alone, then there should have been no reason for the verb *priklet* to preserve the onset cluster in the base *praklit*, since the root (a string of consonants, e.g., *prklt*) cannot convey information regarding the presence of a cluster (i.e., information regarding the co-occurrence of consonants and vowels). One might conjecture that the transfer of the cluster reflects independent phonological constraints (a preference to maximize the onset, or sonority sequencing restrictions), but this does not seem to be the case: The transfer does not necessarily maximize the onset (e.g., *nos.talg.ia* → *nis.telg* maximizes the coda) even though the dispreferred alternative (e.g *nis.tleg*, which maximizes the onset) is not phonologically ill-formed (cf, *tlamim*, furrows). Examples like these indicate that the representation feeding word formation is far richer than the simple sequencing of the root’s consonants. Instead, it suggests that speakers represent the interdigitation of consonants and vowels in the base morpheme – a conclusion consistent with the view of Semitic base morphemes as stems. The hypothesis that Semitic languages store roots is thus no longer taken for granted (for additional challenges for the root-based approach, see Gafos, 1998); instead, it is rejected by many recent linguistic accounts of word formation in Semitic (Bat-El, 1994, 2003, 2004; Gafos, 1998; Ussishkin, 1999, 2005). Although these proposals differ on their precise account for the restriction on the location of identical consonants[3] none assumes a special root morpheme; instead, in each, the minimal unit of sound-meaning pairings is the stem.

If speakers stored stems, a new possibility would arise. Unlike roots (e.g., *svv*), stems (e.g., *sevev*) represent both consonants and vowels. Lexical restrictions on the co-occurrence of consonants (e.g., the *svv*-*ssv* asymmetry) could thus be modulated by intermediate vowels. It is at this crucial juncture that stem- and root-based theories make distinct predictions.

Consider first root-based accounts. If the restriction on the location of identical consonants referred to the root domain, then similar restrictions on consonant co-occurrence should be observed across distinct paradigms.[4] Accordingly, other things being equal, two forms sharing the same root (e.g., *sivuv* vs. *sevev*) should be equally acceptable, independently of their vowels. The acceptability of *sivuv* and *sevev* could of course differ for reasons related to the acceptability of their word patterns alone (i.e., the acceptability of CiCúC and CéCeC in general), irrespective of root

[3] Some approaches (Bat-El, 1994; Gafos, 1998; Ussishkin, 1999) obtain $C_1VC_2VC_2$ stems by reduplicating biconsonantal nominal stems (the asymmetry in the location of identical consonants reflects grammatical restrictions on reduplication), whereas others attribute the restriction on stem structure to the properties of inflectional paradigms; Gafos, 2003. We return to these approaches in the Section 6.3.

[4] We use the term “paradigm” to refer to a word-formation template (e.g., CeCeC) as well as to its word outputs (e.g., *sevev*, a round) and their inflections (e.g., *sivvi*, ‘my round’).

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structure. It is likewise possible that the acceptability of identical consonants in various word patterns might differ for reasons related exclusively to the structure of the surface form.[5] Still, when such peripheral properties related to the acceptability of surface forms are held consonant, root-based approaches ultimately predict that two stems sharing the same root (e.g., *sivúv* vs. *sévev*) should be equally acceptable.

In contrast, stem-based accounts intrinsically enable the encoding of dependencies among consonants and vowels. Accordingly, the acceptability of two forms sharing the same root (e.g., *sivúv* vs. *sévev*) could differ even when controlling for the properties of the two word patterns and for their potential to violate constraints related specifically to their surface forms. Our goal was to test the differing predictions.

Even in advance of experiment, a careful inspection of the Hebrew lexicon suggests that the *frequency* of roots with identical consonants does vary depending on the intermediate vowels. For example, consider the frequency of roots with identical consonants in two nominal paradigms: CéCeC and CiCúC (following descriptive grammars of Hebrew, we refer to these paradigms as Péel and Piúl, respectively). Although both stem types appear to be (equally) well-formed, they differ on their frequency. An inspection of the Even-Shoshan Hebrew dictionary (Even-Shoshan, 1993) suggests that roots with identical consonants at their end (e.g., *svv*) are frequent in the Piúl paradigm (55 forms) but rare in the Péel paradigm: There is a total of seven such forms, two of them are moderately familiar (e.g., *sevev*, round; *retet*, vibration) and the remaining five are quite rare (*devev*, 'chatter', *shegeg*, 'error', *belel*, 'mix' *gelel*, 'dung', *melel*, 'talk'). Similar conclusions hold for roots with initial identity. Generally speaking, *ssv* type forms are rare in Semitic, but to the extent that there are productive counter-examples they are found only in Piúl (*mimun*, 'financing', *mimush*, 'realization'), and never in Péel. (Discussion of why such asymmetries might exist is deferred until the Section 6.3).

If speakers stored only roots, these asymmetries would be mere historical artifact, whereas on the stem account these distinctions between paradigms could be represented in a fashion that was generalizable (be it statistical or grammatical). To examine the synchronic reality of how these forms are represented in contemporary speakers, we asked experimentally how speakers would treat novel forms with identical consonants in the Piúl versus Péel paradigms. A finding that acceptability was not modulated by intermediate vowels would point towards roots; a finding that the acceptability is modulated by intermediate vowels would favor stem-based accounts. Although such a result would not falsify root-based approaches, it would call into question the need for a special morphological unit for Semitic.

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[5] Indeed, linguistic (McCarthy, 1986) and psycholinguistic evidence (e.g., Berent & Shimron, 1997; Berent et al., 2001a) suggests that surface forms in which identical consonants are truly adjacent (e.g., *massik*, from the root *ssk*) are far less acceptable than forms in which they are separated by vowels (e.g., *sisek*). Such restrictions appear to be unrelated to the structure of lexical representations, as they apply even when the root lacks identical consonants altogether (e.g., the verb *shalatti*, I ruled, from the root, *shlt* – note that the identical consonants in the surface form are strictly due to the concatenation of the stem and the suffix). Such phonological restrictions on surface words are not relevant to the debate concerning the base morpheme that feeds word formation, and they are readily captured by root-based accounts (McCarthy, 1986).

Table 2
An illustration of singular nouns generated from a single set of roots in two nominal paradigms

Root	Piúl	Péel
ססק	סיסוק	ססק
ssk	sisúk	sések
סקק	סיקוק	סקק
skk	sikúk	sékek
רמק	רימוק	רמק
rmk	rimúk	rémek

We tested these predictions by comparing the acceptability of a single set of novel roots across these two inflectional paradigms. Novel roots, all of which consisted of combinations of three consonants that do not exist in Hebrew, were drawn from three matched types that varied in their consonantal structure. One type had identical consonants root initially (e.g., *ssk*), another had identical consonants root-finally (e.g., *skk*), and the third type had no identical consonants (e.g., *rmk*). The latter two types (e.g., *ssk*, *rmk*) were equated for bigram frequency.

To assess the psychological validity of stems, we compared the acceptability of these putative roots in the Péel and Piúl paradigms (see Table 2). To assure that differences in the acceptability of stems with identical consonants are not caused by the inherent acceptability of the word pattern (e.g., the dislike of *sések* is not due to a dislike of Péel forms in general), we assess the acceptability of stems with identical consonants relative to control roots in the same paradigm. For example, to assess the effect of the paradigm on the acceptability of *ssk*-type roots, we compare the acceptability of *sis*úk relative to *rim*úk with *séksek* relative to *rémek*. If speakers represent the consonantal root and constrain the location of identical consonants strictly within the root domain, then the acceptability of roots with identical consonants relative to controls should be similar in Piúl and Péel. Conversely, if speakers store the stem, then the relative acceptability of these forms might differ across the two paradigms: Compared to *rmk*-controls, roots with identical consonants (i.e., *ssk* or *skk* roots) should be more acceptable in Piúl than in Péel. Experiments 1–4 test these predictions using visually presented stimuli whereas Experiments 5–6 use auditory materials.

1. Experiment 1

Experiment 1 compares the acceptability of roots with identical consonants in the Piúl and Péel paradigms using off-line ratings. Participants were presented with word-triplets, generated from three matched root-types: one type had identical

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consonants at the beginning of the root, another had identical consonants root-finally, and the control had no identical consonants (e.g., *ssk*, *skk*, *rmk*). The word-triplets were matched on their morphological paradigm and differed solely on their root structure. Participants were asked to rate the members of the triplets relative to each other, and indicate which word sounds the best, which one is intermediate and which one is the worst (we hereafter refer to this procedure as *relative rating*). If speakers constrain the co-occurrence of identical consonants within the stem, then the acceptability of the roots might differ in the two nominal paradigms: compared to the controls with no repeated consonants (e.g., *rmk*), roots with identical consonants (e.g., *ssk*, *skk*) should be less acceptable in Péel compared to Piúl.

1.1. Method

1.1.1. Participants

Sixteen native Hebrew speakers, students at the University of Haifa, participated in the experiment. They volunteered to take part in the experiment, and they were tested within a class setting.

1.1.2. Materials

The materials consisted of 30 triplets of novel roots (combinations of three consonants that do not exist in Hebrew, see Appendix A). One root triplet had identical consonants at the beginning of the root (e.g., *ssk*), one had identical consonants at the end of the root (e.g., *skk*), and the control had no identical consonants (e.g., *rmk*). The triplet members with identical consonants were matched on their segments. We also attempted to match root members for the frequency of their consonant combinations (C1C2, C2C3, and C1C3), determined by the co-occurrence of these radicals in a database including all productive Hebrew roots listed in the Even-Shoshan Hebrew dictionary (for further discussion, see Berent et al., 2001a). Because *ssk* roots are extremely rare, it was impossible to control for their radical co-occurrence. However, the roots with final identity ($X = 13.9$, $SD = 5.08$) were matched on their summed positional bigram frequency to controls ($X = 13.8$, $SD = 4.97$). Each root triplet was next conjugated in singular masculine base form of the Piúl and Péel paradigms, yielding a total of 60 word triplets. Members of the word-triplet were matched on their word pattern and differed only on root structure. The resulting word-triplets were randomized for the order of triplets, as well as the order of each word within the triplet. The list presented vowel information by using the Hebrew diacritic system.

1.1.3. Procedure

Participants were asked to compare the triplet members as to how they sounded as a possible Hebrew word. Participants were asked to silently pronounce each word-triplet, and then rate its members, assigning 1 to the word that sounds best, 3 to the word that sounds worst, and 2 to the one that sounds intermediate. To express high ratings by means of larger numbers for the purpose of data analysis, we transformed all assigned ratings by subtracting them from 4.

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1.2. Results and discussion

One triplet was removed from all analysis because one of its members (*letet*) corresponded to a real word in Péel. For the remaining items, mean acceptability ratings as a function of root type and paradigm are presented in Fig. 2. An inspection of the means suggests that the acceptability of roots with identical consonants is strongly affected by the morphological paradigm. This pattern is confirmed by the significance of the root (3) × paradigm (2) interaction in the ANOVA's on participants and items ($F_1\,(2,30) = 15.00$; MSE = .039, p < .0001; $F_2\,(2,56) = 14.77$, MSE = .07, $p < .0001$). The simple main effect of root type was significant in both the Piúl ($F_1(2,30) = 4.77$; MSE = .14, $p < .02$; $F_2(2,56) = 8.54$, MSE = .14, $p < .0007$), and Péel ($F_1\,(2,30) = 8.77$; MSE = .18, $p < .002$; $F_2\,(2,56) = 22.78$, MSE = .12, $p < .0002$) paradigm. However, planned comparisons of the means showed that the relative acceptability of roots with identical consonants differ markedly in the two paradigms.

Consider first roots with final identity (e.g., *skk*). When these roots were presented in Piúl, *skk*-type roots were as acceptable as *rmk*-type identity-free controls ($t_1\,(30) < 1$, n.s.; $t_2\,(56) = 1.21$, $p < .25$, n.s.). But when the same roots were presented in Péel, they were significantly less acceptable than *rmk*-type controls ($t_1\,(30) = 2.79$, $p < .01$; $t_2\,(56) = 4.49$, $p < .0001$). Similar conclusions emerged for roots with initial identity (e.g., *ssk*). Replicating previous results, these roots were unacceptable compared to *rmk*-type controls in either the Piúl ($t_1\,(30) = 2.09$, $p < .05$; $t_2\,(56) = 2.81$, $p < .007$), or Péel paradigm ($t_1\,(30) = 4.10$, $p < .0003$; $t_2\,(58) = 6.61$, $p < .0001$). However, the *ssk*-disadvantage in Péel ($\Delta = .61$) was twice as large as in Piúl ($\Delta = .28$). The simple interaction, comparing the *ssk* and *rmk*-types across the two paradigms was significant ($F_1\,(1,15) = 10.18$, MSE = .04, $p < .007$;

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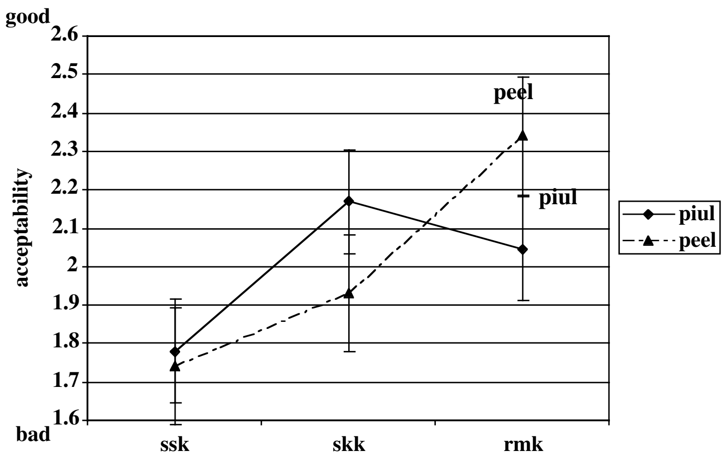

Fig. 2. The acceptability of novel roots with initial, final and no identity in the Péel and Piúl paradigms in Experiment 1 (relative rating of visual stimuli). Error bars represent the confidence interval constructed for the difference among the means.

$F_2\,(1,28) = 11.99$, MSE = .07, $p < .002$). Thus, when compared to controls, roots with identical consonants are less acceptable in Péel, a paradigm in which these roots are relatively rare. The relative unacceptability of these roots in Péel is inexplicable by their surface properties (e.g., *sések* does not manifest identical consonants that are adjacent in its surface form) nor can it be attributed to an across the board dislike of the Péel paradigm (since roots with identical consonants are compared to controls in the same paradigm). Thus, the dislike of roots with identical consonants in Péel reflects productive knowledge concerning their co-occurrence with vowels, a result consistent with the representation of stems.

2. Experiment 2

The results from the relative rating task suggest that the acceptability of roots with identical consonants depends on the properties of the morphological paradigm. However, our use of relative rating, a task that requires comparison among words that differ only on their root-structure, could have encouraged attending to the stem's internal structure. Consequently, the outcomes of this task might over-estimate speakers' actual sensitivity to stem structure. To assess the generality of these results, Experiments 2–6 probe for the effect of paradigms under conditions that do not encourage attention to the root. Experiment 2 retests the acceptability of the same items using a slight modification in the rating procedure. Participants are now presented with the materials in a randomized list, and they are asked to assess the inherent acceptability (hereafter, *absolute rating*) of each item on its own (rather than to compare among words that contrast on their root structure). This modification allowed participants to perform the task by attending to properties other than root structure (e.g., the overall acceptability of the word pattern). If participants automatically constrain the location of identical consonants in the stem, and if this restriction is modulated by intermediate vowels, then roots with identical consonants should again be less acceptable in the Péel paradigm relative to Piúl.

2.1. Method

A new group of seventeen native Hebrew speakers, students at Haifa University volunteered to take part in this experiment within a class setting. The materials and design were the same as in Experiment 1. The only difference concerns the rating procedure. Participants were presented with the materials in a randomized printed list. They were asked to silently pronounce each word and indicate its acceptability using a 1–5 scale (1 = very bad, 5 = excellent).

2.2. Results and discussion

As in Experiment 1, we removed one triplet from all analyses because one of its members was a real word. Mean acceptability rating as a function of root type and paradigm for the remaining items are presented in Fig. 3. An inspection of

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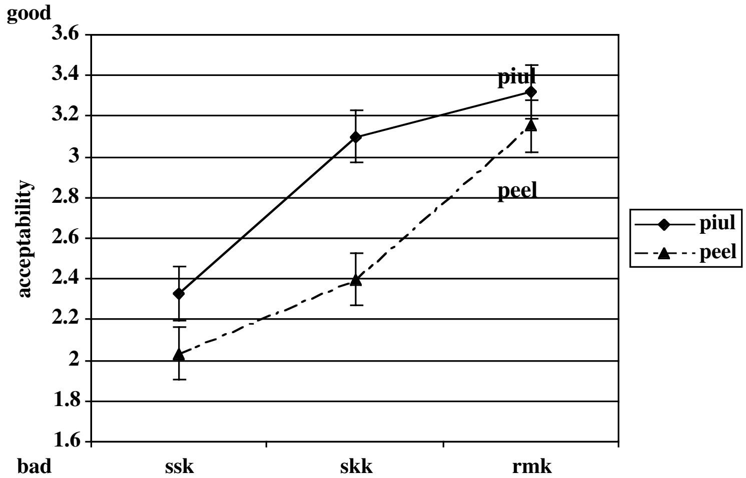

Fig. 3. The acceptability of novel roots with initial, final and no identity in the Péel and Piúl paradigms in Experiment 2 (absolute rating of visual stimuli). Error bars represent the confidence interval constructed for the difference among the means.

the means suggests that novel roots were overall more acceptable in Piúl relative to the Péel paradigm. This observation, confirmed by the significant main effect of paradigm in the ANOVA (3 root type × 2 paradigm, $F_1\,(1,16) = 5.54$, MSE = .71, $p < .04$; $F_2\,(1,28) = 85.99$, MSE = .078, $p < .0001$) is consistent with the greater productivity of the Piúl paradigm in Hebrew. This finding suggests that, as expected, the change in the rating procedure (i.e., the evaluation of each word by itself, rather than in comparison to other words that share the same word pattern) increased the sensitivity of participants to the word pattern. Although participants were not encouraged to attend to the root, the findings show a strong effect of root structure. Importantly, the acceptability of the root was modulated by the properties of the paradigm, resulting in a significant root × paradigm interaction ($F_1\,(2,32) = 11.86$, MSE = .057, $p < .0002$; $F_2\,(2,56) = 13.13$, MSE = .088, $p < .0001$).

The simple main effects suggested that participants were sensitive to the properties of the root in both the Piúl ($F_1\,(2,32) = 32.70$, MSE = .14, $p < .0002$; $F_2\,(2,56) = 58.47$, MSE = .133, $p < .0002$), and the Péel ($F_1\,(2,32) = 31.65$, MSE = .17, $p < .0002$; $F_2\,(2,56) = 54.74$, MSE = .17, $p < .0002$) paradigms. Planned comparisons suggested that *ssk*-type roots were unacceptable relative to *rmk*-type controls in both the Piúl ($t_1\,(32) = 7.69$, $p < .0001$; $t_2\,(56) = 10.28$, $p < .0001$), and Péel ($t_1\,(32) = 7.80$, $p < .0001$; $t_2\,(56) = 10.25$, $p < .0001$) paradigms. Although the dislike of *ssk*-type roots was numerically larger in Péel (a trend consistent with the findings of Experiment 1), the simple interaction comparing the acceptability of *ssk* and *rmk*-type roots in the two paradigms did not reach significance ($F_1\,(1,16) = 1.86$, MSE = .04, $p < .20$; $F_2\,(1,28) = 2.01$, MSE = .066, $p < .17$). Thus, unlike in the relative rating task, stems with initial identical consonants were no less acceptable in Péel. However, the two rating procedures do converge on the findings concerning roots with final identity: roots with final identical consonants were not rated reliably lower than controls in the Piúl paradigm (t_1 (32) = 1.68, $p < .11$, n.s.; t_2 (56) = 2.24, $p < .03$), whereas in Péel, these roots were significantly disliked (t_1 (32) = 5.26, $p < .0001$; t_2 (56) = 6.92, $p < .0001$). The simple interaction comparing *skk*-type roots to *rmk*-type controls in the two paradigms was reliable (F_1 (1,16) = 14.38, MSE = .078, $p < .002$; F_2 (1,28) = 19.89, MSE = .11, $p < .0002$). These findings suggest that roots with final identical consonants are less acceptable in the Péel paradigm.

3. Experiment 3

The greater dislike of $C_1éC_1eC_2/C_1éC_2eC_2$ stems might suggest that identical consonants are disliked in the entire Péel paradigm. However, the results of Experiments 1–2 are limited insofar that they are based on a single Péel form, the singular. Although we see no reason to attribute the findings to the surface properties of Péel singulars themselves (our experiments control for such properties by comparing the acceptability of *ssk*/*skk* roots to controls in the same paradigm, and we are unaware of any phonological motivation for the dislike of identical consonants in CéCeC) it is nonetheless desirable to demonstrate the generality of our results across the paradigm.

To this end, Experiment 3 compares the acceptability of plural forms in Péel and Piúl (see Table 3). A number of facts about Hebrew plurals are noteworthy here. Hebrew plurals typically manifest a stress-shift to the suffix. For example, the singular form *sisúk* yields the plural *sisukím*, with a final stress. In Péel, however, the stress shift typically triggers the deletion of the initial vowel (e.g., *kelev*, dog → *klavím*, dogs), except when the resulting cluster is illicit (e.g., for clusters that being with a sonorant, e.g., *rexev* → *rexavím*, vehicles). Because clusters with identical consonants are universally illicit, the plurals of *ssk*-type forms are invariably repaired by the epenthesis of a vowel (e.g., *sesek* → *sesakím*). Consequently, the prosodic properties of Péel plurals (e.g., *sesakím*) are quite similar to Piúl plurals (cf., *sisukím*): Both plurals are tri-syllabic, and their stress patterns are identical. These plurals thus

Table 3
An illustration of plural nouns used in Experiment 3

Root	Piúl plural	Péel plural
ססק *ssk*	סיסוקים sisukím	ססקים sesakím
סקק *skk*	סיקוקים sikukím	סקקים skakím
רמק *rmk*	רימוקים rimukím	רמקים remakím

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allow us to investigate whether the greater dislike of consonant identity in Péel generalizes even for forms that are matched for their prosodic properties. Experiment 3 investigates this question using absolute rating, the rating procedure used in Experiment 2. If speakers generalize their knowledge throughout the morphological paradigm, then plurals with identical consonants should be rated lower in Péel than in Piúl.

3.1. Method

A new group of 16 native Hebrew speakers, students at Haifa University volunteered to take part in this experiment within a class setting. The materials were mostly identical to those in Experiments 1–2, with the exception of four of the thirty triplets, which were changed (one triplet was changed because it includes a real word; three other triplets were changed because their plural forms resembled real words). The procedure (absolute rating) is identical to the one in Experiment 2.

3.2. Results

Mean acceptability rating as a function of root type and paradigm is presented in Fig. 4. An ANOVA (3 root × 2 paradigm) yielded significant main effects of root type ($F_1\,(2,30) = 54.25$, MSE = .217, $p < .0001$; $F_2\,(2,58) = 101.79$, MSE = .217, $p < .0001$) and paradigm ($F_1\,(1,15) = 14.09$, MSE = .15, $p < .002$; $F_2\,(1,29) = 20.39$, MSE = .19, $p < .0002$). As in Experiment 2, participants rated novel forms higher in Piúl than in Péel, a finding that might reflect the greater productivity of the Piúl paradigm. Importantly, however, the paradigm modulated the acceptability of root structure, resulting in a significant root × paradigm interaction ($F_1\,(2,30) = 27.75$, MSE = .025, $p < .0001$; $F_2\,(2,58) = 6.38$, MSE = .203, $p < .004$). The simple main effect of root type was significant in either Piúl ($F_1\,(2,30) = 29.66$, MSE = .13, $p < .0002$; $F_2\,(2,58) = 32.15$, MSE = .22, $p < .0002$), or Péel ($F_1\,(2,30) = 76.62$, MSE = .11, $p < .0002$; $F_2\,(2,58) = 82.48$, MSE = .19, $p < .0002$). We next evaluated the acceptability of *ssk*- and *skk*-type roots in each paradigm by means of planned contrasts.

Plurals with *skk*-type roots were significantly less acceptable than controls in either the Piúl ($\Delta = 0.62$, $t_1\,(30) = 4.88$, $p < .0001$; $t_2\,(58) = 5.08$, $p < .0001$) or Péel paradigm ($\Delta = 0.59$, $t_1\,(30) = 5.01$, $p < .0001$; $t_2\,(58) = 5.20$, $p < .0001$), but the magnitude of their dislike was statistically indistinguishable (both $F < 1$ for the simple interaction).[6]

[6] The dislike Piúl plurals with final identical consonants contrasts with the results obtained with their singulars, which did not reliably differ from controls in previous experiments. The discrepancy might be due to differences in syllabification. Unlike singulars, in which identical consonants occupy distinct syllabic positions (i.e., onset and coda, e.g., *si-kúk)*, in the plural, they both occupy onset positions (e.g., *si-ku-kím*). Plag (1998) proposes that the grammar specifically bans adjacent identical elements at onset positions. The presence of adjacent identical onsets in *sikukim* may thus decrease its acceptability. This might have both reduced the acceptability of Piúl plurals with final identical consonants (e.g., *si-ku-kim*) relative to singulars (e.g., *si-kuk*), and eliminate their expected advantage over Peél plurals (e.g., *ska-kim*).

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In contrast, paradigm membership modulated the acceptability of forms with initial identical consonants. As expected, *ssk*-type roots were less acceptable than *rmk*-type controls in either Piúl ($t_1\,(30) = 7.60$, $p < .0001$; $t_2\,(58) = 7.91$, $p < .0001$) or Péel ($t_1\,(30) = 12.30$, $p < .0001$; $t_2\,(58) = 12.77$, $p < .0001$). However, the dislike of *ssk*-type forms was larger in Péel ($\Delta = 1.46$) than in Piúl ($\Delta = 0.96$). Accordingly, the simple interaction comparing *ssk*- and *rmk*-type roots in the two paradigms was significant ($F_1\,(1,15) = 23.95$, $\mathrm{MSE} = .04$, $p < .0003$; $F_2\,(1,29) = 11.58$, $\mathrm{MSE} = .16$, $p < .003$), a finding that agrees with the results of Experiment 1 (a similar non-significant trend emerged in Experiment 2). Thus, despite their similar prosodic properties, stems with initial identical consonants were dispreferred in Péel compared to Piúl.[7] These results suggest that the dislike of stems with initial identical consonants is greater in Peél than in Piúl with either plurals or singulars (in Experiments 1–2). The convergence between the findings with singulars and plurals suggests that the dislike of identical consonants extends to the entire Péel paradigm.

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[7] One might worry that the dislike of forms like *sesakim* might be due to participants' failure to correctly encode their phonological form from print. Recall that forms with identical consonants escape the default deletion of the initial vowel in Péel. But whether vowel deletion is blocked cannot be determined from the orthographic representation of the word. If readers failed to enforce this constraint on the decoding of the printed material, then the resulting form might be *ssakim*, a highly illicit form with adjacent identical consonants. Thus, the dislike of *sesakim* could be due to its incorrect decoding from print, rather than the properties of the paradigm. We took three steps to assess this explanation. First, we examined whether readers are sensitive to the phonological structure of other clusters that escape vowel deletion – stems that being with a sonorant. Because sonorant-initial clusters are illicit, such forms do not undergo vowel deletion (e.g., *rexev*, vehicle → *rexavim*, vehicles). If readers fail to enforce this constraint in reading, then sonorant-initial stems should be less acceptable than those that do not begin with a sonorant. To asses this prediction, we compare the acceptability of plurals generated from control (*rmk*-type) roots that begin with a sonorant (e.g., *rmk*) to those that do not being with a sonorant (e.g., *smk*). The ratings of sonorant-initial plurals ($M = 3.58$) did not differ reliably from non-sonorant ones ($M = 3.63$, both $F < 1$). As a stronger test, we conducted another rating experiment that compares the acceptability of the three root types in the singular and plural forms of the Péel paradigm. If readers fail to decode the plural form of *ssk*-type roots correctly, then these plurals should be less acceptable than their singular counterparts. However, the ratings for singulars ($M = 2.23$) and plurals ($M = 2.13$) did not differ reliably (both $F < 1.14$), whereas each form was rated reliably lower than non-identity controls (for singulars: $M = 2.75$, $t_1\,(30) = 4.6$, $p < .0001$; $t_2\,(54) = 5.54$, $p < .0001$; for plurals: $M = 2.85$, $t_1\,(30) = 6.9$, $p < .0001$; $t_2\,(54) = 5.63$, $p < .0001$). The similar rating of *ssk*-type stems for singulars and plurals converges with the findings of our main experiment to suggest that their dislike is inexplicable by their prosodic properties. Finally, we replicated Experiment 3 using aural presentation. In the auditory modality, *ssk*-type roots ($M = 2.27$, $M = 2.07$, for Piúl and Péel, respectively) were equally acceptable in the two word patterns ($\Delta = 0.37$, for both paradigms). However, the two paradigms did differ on the acceptability of roots with final identity. In Piúl, *skk*-type roots ($M = 2.59$) were as acceptable as controls ($M = 2.65$, $t < 1$), whereas in Péel, *skk*-type roots ($M = 2.24$) were less acceptable than controls ($M = 2.44$, $t\,(58) = 1.96$, $p < .07$; $t\,(58) = 2.21$, $p < .04$). Thus, plural stems with identical consonants are less acceptable in the Peél paradigm. Although the specific manifestation of this dislike (for *ssk* or *skk* forms) might vary depending on presentation modality, the dislike of identical consonants in Peél generalizes when the materials are either printed or spoken.

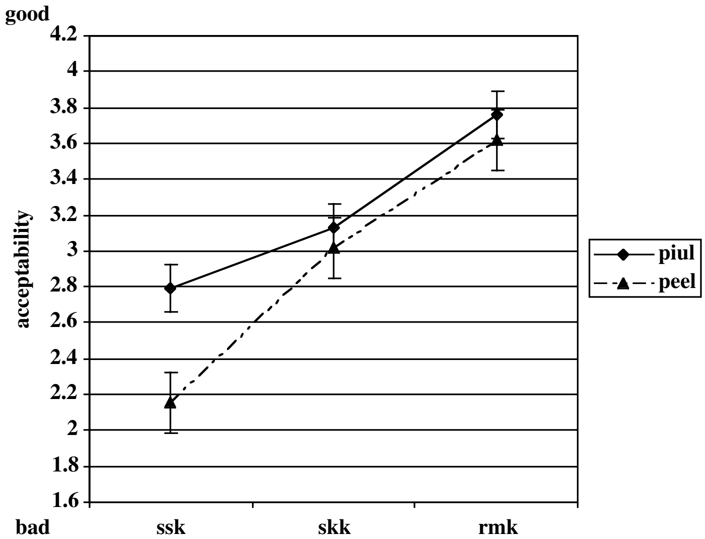

Fig. 4. The acceptability of novel roots with initial, final and no identity in plural forms of the Péel and Piúl paradigms in Experiment 3 (absolute rating of visual stimuli). Error bars represent the confidence interval constructed for the difference among the means.

4. Experiment 4

To test whether these effects pertain only to reflective off-line tasks, or extend more broadly, Experiment 4 examines whether speakers' knowledge of morphological paradigms constrains performance on-line, in a lexical decision task. In view of the convergence between the findings obtained with singulars and plurals, our subsequent investigation is conducted over singular forms. In each trial, participants were presented with a letter string corresponding to a singular noun. They were asked to determine whether the letter string was a real word. Our interest here concerns the performance with nonwords (traditionally referred to as "foils", relative to words, but in our case the primary focus of interest; for previous use of this methodology, see Berent, Shimron, & Vaknin, 2001b; Berent et al., 2002, 2004).

These nonwords were generated from a new set of novel roots, as a further test for the generality of the paradigm effect across items. This new set of novel roots had either initial identical consonants, final identical consonants or no identical consonants (e.g., *ssk*, *skk*, *rmk*). To examine the effect of the paradigm, we compared the acceptability of these three types of roots across two groups of participants: one group was presented with the roots in Piúl, whereas a second group was presented with the same roots in Péel (see Table 4). To assure that participants correctly decode the nonwords of interest (since the stimuli were presented in the standard vowel-less Hebrew print, their pronunciation was ambiguous), we presented the nonwords mixed with real words from the same paradigm,[8] (correctly) anticipating that

[8] We did not attempt to disambiguate the printed materials by presenting them with diacretic marks because there is evidence that this information is ignored in on-line lexical decision (Bentin & Frost, 1987).

Table 4
An illustration of the words and nonwords used in Experiment 4

	Piúl	Péel
Real words	טיפול tipúl (treatment)	כלב kélev (dog)
Nonwords	סיסוק sisúk	ססק sések
	סיקוק sikúk	סקק sékek
	רימוק rimúk	רמק rémek

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participants would generalize the word pattern of the real words to the nonwords of interest. The representation of the word-pattern was further verified by asking each participant to name the stimuli aloud during a practice session, conducted prior to the experimental phase. As expected, participants decoded the nonwords using the same word patterns as the real words. The key question is whether the acceptability of roots with identical consonants is modulated by the properties of the morphological paradigm. If roots with identical consonants (e.g., *ssk* or *skk* type) were relatively unacceptable in Péel, then nonwords manifesting those roots should be rejected more quickly and accurately in Péel compared to Piúl.

4.1. Method

4.1.1. Participants

Two groups of 22 native Hebrew speakers each, students at the University of Haifa, participated in the experiment. Participants were paid for taking part in the experiment.

4.1.2. Materials

Each participant was presented with 90 words and 90 nonwords of interest. The 90 nonwords were generated from novel Hebrew roots (see Appendix B). These roots were arranged in triplets: One member had identical consonants root initially, another had identical consonants root finally, and the control had no identical consonants. The roots with initial and final consonants were matched on their phonemic contents. Roots with final identity and controls were matched for their mean summed positional bigram frequency (for *skk*-type roots: $X = 10.77$, $SD = 3.33$; for controls: $X = 10.7$, $SD = 3.11$, bigram frequency was calculated as explained in Experiment 1).

The nonwords of interest were next conjugated in one of two paradigms: Piúl and Péel. The existing words corresponded to familiar Hebrew words from the same morphological paradigm as the nonwords candidates: one group of participants was presented with real words and nonwords candidates in Piúl, whereas the other group was presented with stimuli in Péel. The materials were presented in the standard Hebrew script, which omits most vowel information.

To assure that the vowels are correctly decoded from the script, we presented participants with a short practice session prior to the experimental phase. The practice included 10 real words and 10 nonwords, presented twice in a random order. These materials had the same word-pattern as the experimental materials. Participants were asked to name each stimulus aloud.

4.1.3. Procedure

Each trial began with a fixation point, followed by a letter string presented at the center of the computer screen. Participants were asked to determine whether the letter string corresponds to a familiar Hebrew word and indicate their responses by pressing either the 1 or 2 keys (for word vs. nonword responses, respectively). Inaccurate and slow responses ($RT > 1500$ ms) triggered a computerized warning message. Participants were tested individually.

4.2. Results and discussion

To protect from the effect of outliers, we removed from the latency analyses responses falling 2.5SD above each group's grand mean or faster than 200 ms (2.7% and 3% of the observations in the Piúl and Péel groups, respectively). Three word-triplets were removed from all analyses because one of their members generated over 40% errors.[9] The analyses of response accuracy were conducted on the proportion of correct responses.

Mean response latency to nonwords as a function of root type and paradigm is presented in Fig. 5 (the respective accuracy means are given in Table 5). The figure indicates that the effect of root structure was modulated by the paradigm. The ANOVA (3 root × 2 word pattern) yielded a significant interaction in both response time ($F_1\,(2,84) = 5.04$, $MSE = 864.70$, $p < .009$; $F_2\,(2,52) = 4.62$, $MSE = 931.90$, $p < .02$) and response accuracy ($F_1\,(2,84) = 3.11$, $MSE = .17$, $p < .05$; $F_2\,(2,52) = 3.34$, $MSE = .002$, $p < .05$). The main simple effect of root type was significant in Piúl ($F_1\,(2,42) = 8.01$, $MSE = 801.45$, $p < .001$; $F_2\,(2,52) = 4.85$, $MSE = 2234.63$, $p < .02$; $F_1\,(2,42) = 15.55$, $MSE = .001$, $p < .0002$; $F_2\,(2,52) = 4.68$, $MSE = .006$, $p < .02$, for response time and accuracy, respectively). In Péel, the effect of root type was significant in the analyses of response latency ($F_1\,(2,42) = 28.09$, $MSE = 927.95$, $p < .0002$; $F_2\,(2,52) = 13.40$, $MSE = 2165.00$, $p < .0002$) but not in response accuracy ($F_1\,(2,42) = 2.37$, $MSE = .003$, $p < .11$; $F_2\,(2,52) = 1.91$, $MSE = .004$, $p < .16$). However, planned comparisons demonstrated that the effect of root type differed markedly in the two word patterns.

Consider first the acceptability of *skk* type roots. In Piúl, response times did not differ for *skk* type roots relative to *rmk*-type control (both $t < 1$). Participants were

[9] These nonwords were xemet, kevev, pedel, which resemble the spellings of existing Hebrew words.

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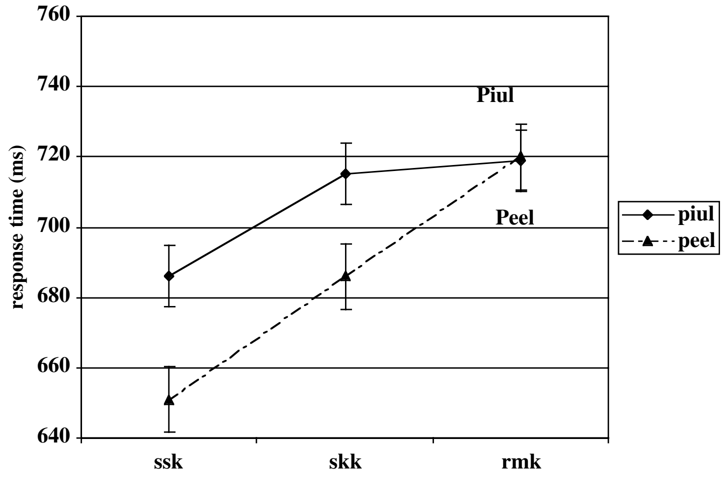

Fig. 5. Mean response latency to nonwords generated from novel roots with initial, final and no identity in the Péel and Piúl paradigms in Experiment 4 (visual lexical decision). Error bars represent the confidence interval constructed for the difference among the means.

Table 5
Mean response accuracy (% correct) for the nonwords presented in Experiment 4 as function of root structure and paradigm

	Piúl	Péel
ssk	96.86	95.59
skk	90.77	93.45
rmk	93.85	92.23

slightly less accurate in rejecting *skk*-type roots (albeit not reliably so, $t\,(42) = 2.79$, $p < .008$; $t_2\,(52) = 1.46$, $p < .16$), indicating that, if anything, such roots were more wordlike than *rmk*-type controls. In contrast, when these roots were presented in Péel, *skk*-type roots were rejected significantly faster ($t_1\,(42) = 3.70$, $p < .0007$; $t_2\,(52) = 2.22$, $p < .04$) than *rmk*-type controls, suggesting that they were relatively unacceptable (there were no significant differences in response accuracy, both $t < 1$). These results indicate that roots with final identity are less acceptable in Péel compared to Piúl.

The properties of the paradigm also modulated the acceptability of roots with initial identity. As expected from past research, roots with initial identity are easier to reject than controls in either Piúl or Péel, a finding that was significant in response latency ($t_1\,(42) = 3.68$, $p < .0007$; $t_2\,(52) = 2.62$, $p < .02$; $t_1\,(42) = 7.45$, $p < .0001$; $t_2\,(52) = 5.17$, $p < .0001$; for Piúl and Péel, respectively) and marginally so in response accuracy ($t_1\,(42) = 2.78$, $p < .008$; $t_2\,(52) = 1.61$, $p < .11$, n.s., $t_1\,(42) = 2.15$, $p < .04$; $t_2\,(52) = 1.91$, $p < .07$, for Piúl and Péel, respectively). This finding suggests that *ssk*-type roots are ill-formed. However, the magnitude of the ill-formedness depends on the paradigm: the dislike of *ssk*-type roots in Péel (69 ms) was twice as large as in Piúl (32 ms). The simple interaction comparing these two root types across the two paradigms was significant ($F_1\,(1,42) = 9.00$, MSE = 857.16, $p < .005$; $F_2\,(2,52) = 10.14$,

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MSE = 686.54, $p < .004$). These findings converge with the rating results to suggest that roots with identical consonants (either *ssk* or *skk*) are less acceptable in Péel, a paradigm in which these types are relatively rare. Crucially, the sensitivity to the properties of paradigm generalizes in an on-line reading task.

5. Experiment 5

The findings of Experiments 1–4 are consistent with the proposal that the restriction on the co-occurrence of consonants in the stem is modulated by the properties of the paradigm. Before accepting this conclusion, an alternative explanation must be considered. Recall that the materials in Experiment 4 were presented in the vowel-less Hebrew script. This representation encodes vowels letter in Piúl, but does not specify any vowel information in Péel. This orthographic difference could have affected readers' sensitivity to the presence of identical consonants in the two paradigms. One possibility is that the dislike of *skk*-type forms in Péel is due to the failure to assemble their phonology from print (e.g., the representation of *sekek* as *sekk*). However, this possibility is countered by several considerations. First, despite the absence of vowel letters, the phonological form of the nonwords was predictable, since it matched the paradigm of the real words, whose phonological form was invariably CéCeC. Indeed, there was no evidence that participants experienced any difficulty decoding vowel information during the practice session of Experiment 4 (in which decoding was monitored). Second, the results from lexical decision converge with those of the rating experiments, in which vowel information was provided in the script. Another possibility is that the lack of vowel letter in Péel could have artificially inflated readers' attention to the presence of identical consonants. This account, too, is countered by the results of previous research, in which verbal patterns derived from *skk*-type roots did not elicit any dislike relative to *rmk*-type controls despite the fact that, as in the present experiment, these forms lacked any orthographic vowel letters (Berent et al., 2001b, 2004). Thus, it is clearly not the case that the absence of vowel letters is sufficient to trigger an across-the-board dislike of *skk*-type forms.

Although our present findings are inexplicable by orthographic artifacts, it is desirable to demonstrate that the sensitivity to the properties of morphological paradigms extends to auditory materials. Experiments 5–6 replicate Experiments 2 and 4, respectively, with auditory stimuli and a new set of items (an aural replication of Experiment 3 (using plurals) is reported in footnote 7). Experiment 5 elicits absolute acceptability ratings for novel auditory stimuli whereas Experiment 6 examines lexical decision. If speakers encode the properties of morphological paradigms, then roots with identical consonants should be less acceptable in Péel compared to Piúl.

5.1. Method

5.1.1. Participants

A new group of 21 native Hebrew speakers, students at the University of Haifa, participated in the experiment. Participants were paid for taking part in the experiment.

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Table 6
Mean length of the auditory nonwords presented in Experiments 5–6

	Piúl		Péel	
	Mean	SD	Mean	SD
Initial identity	1191	108	999	102
Final identity	1195	103	1005	85
No identity	1177	101	995	97

The materials consisted of the same set of 30 root triplets (with initial identical consonants, final identical consonants or no identical consonants) from Experiments 1–2, presented in both the Piúl and Péel paradigms, resulting in 180 novel words. These words were recorded in a female voice of a native Hebrew speaker. The durations of the Piúl and Péel items is given in Table 6. The items with initial, final and no identical consonants did not differ on their length in either Piúl or Péel (both $F < 1$). The procedure was the same as in Experiments 2–3 (absolute rating) except that the items were presented aurally.

5.2. Results and discussion

Two root triplets were removed from all analyses because of their resemblance to real words (one triplet member, *letet*, was a real word and another, *pefen*, was perceived by many participants as a real word). The mean acceptability rating for the remaining items is presented in Fig. 6.

An inspection of the means suggests the acceptability of stems with identical consonants was modulated by their morphological paradigm. The analysis of variance (2 word pattern × 3 root) indeed yielded an interaction significant by participants ($F_1\,(2,40) = 6.42$, MSE = .031, $p < .0038$) and marginally significant by items

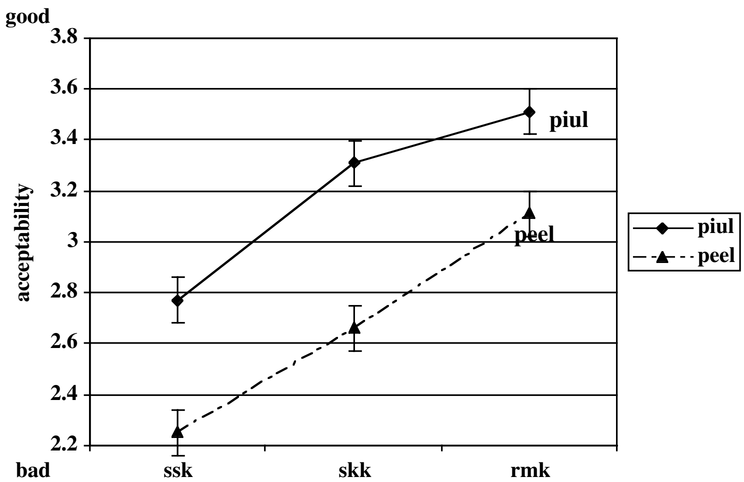

Fig. 6. Mean acceptability of novel roots with initial, final and no identity in the Péel and Piúl paradigms in Experiment 5 (absolute rating of auditory stimuli). Error bars represent the confidence interval constructed for the difference among the means.

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($F_2\,(2,54) = 2.80$, MSE = .077, $p < .07$). A test of simple main effects indicated that participants were sensitive to root structure in either Piúl ($F_1\,(2,40) = 39.15$, MSE = .08, $p < .0002$; $F_2\,(2,54) = 44.35$, MSE = .09, $p < .0002$) or Péel ($F_1\,(2,40) = 54.14$, MSE = .08, $p < .0002$; $F_2\,(2,54) = 42.58$, MSE = .12, $p < .0002$). In each paradigm, roots with initial identity were less acceptable than those with no identical consonants ($t_1\,(40) = 8.55$, $p < .0001$; $t_2\,(54) = 9.11$, $p < .0001$; $t_1\,(40) = 10.39$, $p < .0001$; $t_2\,(54) = 9.22$, $p < .0001$, for Piúl and Péel, respectively). Although the magnitude of this dislike was numerically larger in Péel ($\Delta = .88$) relative to Piúl ($\Delta = .74$), a test of the simple interaction between root type and word pattern was not significant ($F_1\,(1,20) = 2.57$, MSE = .04, $p < .13$; $F_2\,(1,27) = 1.39$, MSE = .07, $p < .25$).

In contrast, the acceptability of *skk*-type stems was reliably modulated by their morphological paradigm. Roots with final identity were less acceptable than *rmk*-type controls in either paradigm ($t_1\,(40) = 2.32$, $p < .03$; $t_2\,(54) = 2.51$, $p < .02$; $t_1\,(40) = 5.60$, $p < .0001$; $t_2\,(54) = 4.87$, $p < .0001$, for Piúl and Péel, respectively). Crucially, however, the magnitude of their unacceptability was twice larger in Péel ($\Delta = .47$) than in Piúl ($\Delta = .20$), resulting in a significant simple interaction of root type (*skk* vs. rmk) × word pattern ($F_1\,(1,20) = 20.95$, MSE = .019, $p < .0003$; $F_2\,(1,27) = 4.57$, MSE = .094, $p < .05$). Thus, roots with final identical consonants are less acceptable in Péel, a paradigm in which such roots are rare in Hebrew.

6. Experiment 6

The findings of Experiment 5 show that the acceptability of identical consonants in the stem is modulated by properties of its morphological paradigms. Experiment 6 seeks to determine whether such knowledge constrains on-line performance. To this end, we present the same nonwords in the context of an auditory lexical decision experiment, modeled after Experiment 4 (which used visual materials). If roots with identical consonants are less acceptable in Péel, then, relative to *rmk*-type controls, roots with identical consonants (*ssk* and *skk*) should be easier to reject in Péel relative to Piúl.

6.1. Method

6.1.1. Participants

Two groups of 26 native Hebrew speakers each, students at the University of Haifa, participated in the experiment. Participants were paid for taking part in the experiment.

6.1.2. Materials

The materials consisted of two sets of auditory items in Piúl and Péel. Each set included 90 real words and 90 nonwords. The nonwords corresponded to the same items employed in Experiment 5. Real words and nonwords were recorded by the same female native Hebrew speaker. Each set was presented to a distinct group of participants. All other aspects of the design are as in Experiment 4.

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6.1.3. Procedure

Each trial began with a fixation point, followed by an auditory stimulus. Participants were asked to determine whether the letter string corresponds to a familiar Hebrew word and indicate their responses by pressing either the 1 or 2 keys (for word vs. nonword responses, respectively). Inaccurate and slow responses (RT > 3500 ms) triggered a computerized warning message. Participants were tested individually.

6.2. Results

Two root-triplets were excluded from all analyses because of a high error rate (above 46%) and one participant was replaced due to extremely slow responses (over 2.5SD above the remaining participants). We also excluded correct responses falling 2.5SD above the mean (less than 2.3% of the total correct responses) and replaced them by the cutoff value. To correct for nonlinearity, the response time data were subjected to a natural log transformation. Mean correct response time is presented in Fig. 7. Response accuracy is provided in Table 7. The analyses of response accuracy were conducted on the proportion of correct responses.

The means of correct response time and accuracy were submitted to analyses of variance (3 root × 2 word pattern) by participants and items. The interaction was

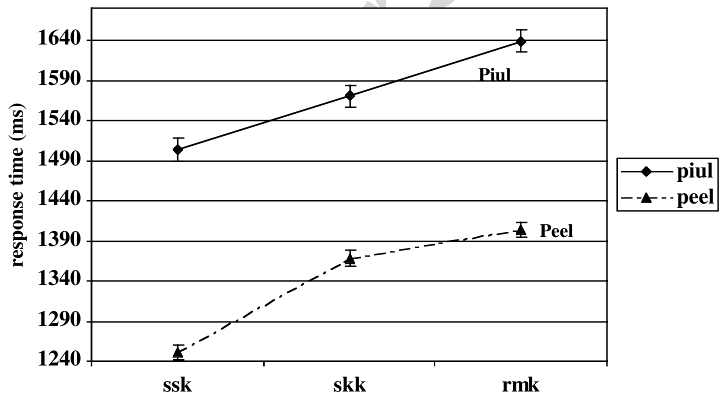

Fig. 7. Mean response latency to nonwords generated from novel roots with initial, final and no identity in the Péel and Piúl paradigms in Experiment 6 (auditory lexical decision). Error bars represent the confidence interval constructed for the difference among the means.

Table 7
Mean response accuracy (% correct) for the nonwords presented in Experiment 6 as function of root structure and paradigm

	Piúl	Péel
ssk	97.25	98.2
skk	94.65	95.88
rmk	96.56	91.77

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significant in the analysis of response accuracy ($F_1\,(2,100) = 9.51$, MSE = .002, $p < .0003$; $F_2\,(2,54) = 4.08$, MSE = .004, $p < .03$) and marginally significant in response time ($F_1\,(2,100) = 6.89$, MSE = .001, $p < .002$; $F_2\,(2,54) = 3.09$, MSE = .002, $p < .06$). To probe for the source of the omnibus interaction, we tested for the simple interactions comparing roots with identical consonants (either initial or final) and controls in Piúl and Péel.

Consider first *skk*-type roots. The simple interaction comparing *skk*- and *rmk*-type roots was significant in accuracy ($F_1\,(1,50) = 14.08$, MSE = .0017, $p < .0006$; $F_2\,(1,27) = 4.62$, MSE = .005, $p < .05$), albeit not in response time ($F_1\,(1,50) = 2.72$, MSE = .001, $p < .11$; $F_2\,(1,27) = 1.22$, MSE = .002, $p < .28$). In Piúl, responses to roots with final identical consonants did not differ reliably from controls ($t_1\,(50) = 1.75, p < .09$; $t_2\,(54) = 1.51, p < .14$). But when the same roots were presented in Péel, they elicited significantly fewer errors than controls ($t_1\,(50) = 3.70$, $p < .0006$; $t_2\,(54) = 3.08$, $p < .004$). These results suggest that *skk*-type roots were less acceptably in the Péel relative to the Piúl paradigm.

The properties of the morphological paradigm also affected the acceptability of roots with initial identical consonants. The simple interaction (2 root (*ssk* vs. *rmk*) × 2 word pattern) was significant in accuracy ($F_1\,(1,50) = 13.34$, MSE = .002, $p < .02$; $F_2\,(1,27) = 7.49$, MSE = .003, $p < .02$) and marginally so in reaction time ($F_1\,(1,50) = 4.05$, MSE = .001, $p < .05$; $F_2\,(1,27) = 3.29$, MSE = .001, $p < .09$). Roots with initial identity were rejected more quickly and accurately than *rmk*-type controls in either Piúl (In response time: $t_1\,(50) = 9.67$, $p < .0001$; $t_2\,(54) = 6.06$, $p < .0001$; In accuracy, both $t < 1$) or Péel (In response time: $t_1\,(50) = 17.14$, $p < .0001$; $t_2\,(54) = 7.13$, $p < .0001$; In accuracy: $t_1\,(50) = 5.79$, $p < .0001$; $t_2\,(54) = 4.87$, $p < .0002$), but the magnitude of this difference in Péel ($\Delta = 153$ ms; $\Delta = 6.43\%$) was larger than in Piúl ($\Delta = 135$ ms; $\Delta = 0.6\%$).

The greater ease in rejecting stems with identical consonants in Péel demonstrates that such stems are dispreferred in Péel, a paradigm in which stems with identical consonants less frequent than in Piúl.[10] These results converge with

[10] Although the results obtained in visual and auditory lexical decision converge, some differences are noteworthy. In visual lexical-decision experiments with Piúl singulars, *skk*-type roots were at least as difficult to reject as controls (see Experiment 4, as well as Berent et al., 2001b; Berent et al., 2004), whereas in auditory lexical decision, such roots were easier to reject. Likewise, in Experiment 5, auditory *skk*-type roots were rated as significantly less acceptable than control (a finding that diverges with the rating of printed materials, in Experiment 2). In previous research, we argued that the difficulty in rejecting *skk*-type roots in visual lexical decision is due to the representation of such roots as formed by a grammatical operation of reduplication (e.g., *sk* → *skk*): the hallmark of the grammar might increase the resemblance of such nonwords candidates to real words and thus impair the rejection. However, *skk*-type forms also manifest attributes that distinguish them from words. For instance, the type frequency of such forms is lower than that of roots with three distinct radicals. The difference in responses to such roots in the visual and auditory modality might reflect the temporal dynamics of computing these various attributes. If the computation of identity is faster than type frequency, visual lexical decision (which is typically faster than auditory lexical decision) might allow speakers to represent only the identity of root consonants, whereas the slower, auditory task might tap into the later stage at which type frequency information becomes available. Accordingly, *skk*-type roots should be more difficult to reject than controls in visual lexical decision, whereas in the auditory task, they might be easier to reject.

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the findings of previous experiments to suggest that the restriction on consonant co-occurrence is modulated by the properties of the stem's morphological paradigm. This result is consistent with the hypothesis that speakers of Semitic routinely store stems.

6.3. General discussion

We began by asking whether the structure of lexical representations is universal, or whether it varies across languages depending on the properties of specific morphologies. The canonical existing evidence for cross-linguistic variation came from a comparison between Indo-European and Semitic languages. Indo-European languages demonstrate the storage of stems, whereas in Semitic, there appeared to be evidence for a special type of morpheme, the consonantal root. A strong argument supporting the existence of the consonantal root came from the restriction on the co-occurrence of identical consonants in Semitic stems. An early well-known account attributed the restriction to a grammatical constraint on the structure of the root (McCarthy, 1979, 1981), but some subsequent proposals capture those facts by appealing to stems (Bat-El, 1994, 2003, 2004; Gafos, 1998, 2003; Ussishkin, 1999). More generally, some recent linguistic theories have attempted to capture morpho-phonological regularities by means of a universal set of representations and constraints, avoiding the need to invoke specialized mechanisms for Semitic morphology (Bat-El, 2003; McCarthy & Prince, 1995; McCarthy, 2005; Ussishkin, 2005).

To evaluate these explanations, we compared the acceptability of several putative root structures in two morphological paradigms, the logic being that the vowel-wise variation between the two paradigms should elicit differential responses only if speakers represent the pairing of consonants and vowels in the base morpheme, information most naturally captured by stems. In one paradigm, Piúl, roots with identical consonants are frequent, whereas in the Péel paradigm, such roots are rare. If the restriction on the stem's consonants were encoded in reference to the root only, then, other things being equal, the acceptability of identical consonants in the root (e.g., *ssk* vs. *rmk*) should be equal across the two paradigms. Conversely, if speakers store stems, then the acceptability of two stems manifesting the same root might be modulated by the properties of their morphological paradigm.

The results of Experiments 1–6 consistently show that roots with identical consonants are less acceptable in Péel compared to Piúl (see Table 8). Although the sensitivity of our different tasks varied – some detected paradigmatic effects in both *ssk*- and *skk*-forms, whereas others in only one – each experiment showed a greater dislike of identical consonants in Péel, and none showed the reverse pattern (a greater dislike of identical consonants in Piúl). The dislike of identical consonants in Péel cannot be attributed to an across the board dislike of the Péel paradigm, since the acceptability of $C_1eC_1eC_2$/$C_1eC_2eC_2$ stems is assessed relative to controls in the same paradigm (e.g., *rémek*). It is also unlikely that the relative

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Table 8
A summary of the results of Experiments 1–6

Experiment	Task	Materials		Is there a greater dislike of identical consonants in Péel?	
		Singulars/plurals	Modality	ssk-forms	skk-forms
1	Relative rating	Singulars	Visual	Yes	Yes
2	Absolute rating	Singulars	Visual	No	Yes
3	Absolute rating	Plurals	Visual	Yes	No
4	Lexical decision	Singulars	Visual	Yes	Yes
5	Absolute rating	Singulars	Auditory	No	Yes
6	Lexical decision	Singulars	Auditory	Yes	Yes

unacceptability of such stems in Péel is due to the ill-formedness of their surface forms. Indeed, the greater dislike of *ssk*-type forms in Péel generalizes to their plural forms, whose prosodic properties are similar to those of Piúl plurals. The preference for identical consonants in Piúl thus suggests that the putative restriction on "root" structure could actually be modulated partly or even entirely by the morphological paradigm of the stem.

Why are identical consonants disliked in Péel? We consider two general answers to the question. One explanation attributes these findings to the low frequency of such types in the Hebrew lexicon. As noted earlier, stems with identical consonants (both $C_1VC_1VC_2$ and $C_1VC_2VC_2$) are far less frequent in Péel relative to Piúl. The acceptability of stems with identical consonants could thus reflect their type frequency in each paradigm.

An alternative account attributes both the rarity and the dislike of $C_1VC_1VC_2/C_1VC_2VC_2$ stems to their grammatical ill-formedness. A recent proposal by Gafos (2003) suggests that the properties of entire inflectional paradigms of stems determine the grammatical well-formedness of their individual members (see also McCarthy, 2005). Gafos assumes that the grammar bans stems with (surface) adjacent identical consonants (the OCP), and enforces this constraint throughout the inflectional paradigm. Accordingly, if the inflection of a stem yields forms with adjacent identical consonants (i.e., they violate the OCP), and if such forms cannot be repaired without disrupting the integrity of the paradigm, then the stem in question will be uniformly banned from the entire paradigm. As mentioned earlier, the plurals of *ssk*-type forms in Péel potentially yield adjacent identical consonants (e.g., *sesek* → *ssakim*). Similar violations may also arise in the inflection of singulars with final identical consonants (e.g., *sevev* → *sivvi*). In contrast, no such violations emerge in Piúl. Although the violations of the OCP in the Péel paradigm are repairable (e.g., *ssakim* → *sesakim*) – Hebrew routinely uses schwa epenthesis for the repair of illicit clusters – the repair comes at the cost of obscuring the uniform prosodic properties of the paradigm. This might have led to the avoidance of the

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(otherwise well-formed) base forms *sévev* and *sésev*.[11] Our results cannot adjudicate between the type-frequency and paradigm-based explanations. Either way, however, the findings reflect a productive knowledge concerning the properties of stems.

These results are fully consistent with stem-based accounts of Semitic word formation. The support for stem, however, does not preclude accounts that postulate the storage of *both* stems and roots (such as those proposed by Arad, 2003; Davis & Zawaydeh, 2001 & Rose, 2003). In fact, the findings do not strictly falsify even the stronger hypothesis that people store *exclusively* roots. Note, however, that in order for root-based accounts to capture our findings, they must go beyond the uncontroversial assumption that speakers store information regarding the co-occurrence of specific roots with vowel patterns, and additionally postulate that people can freely *generalize* such knowledge to novel forms. It is not clear how one could distinguish an adequately modified root-based account modified from the alternative that people store stems, or even whether a sufficiently modified root-based account would really constitute a genuine alternative. Given that speakers possess productive knowledge regarding the co-occurrence of consonants and vowels in the stem, and given that such knowledge strongly modulates the well-formedness of stem structure, in such a modified theory it is not obvious what work the notion of a root would be doing.

Much of the psycholinguistic evidence for the root (see previous citations) rests on speakers' sensitivity to the sequencing of non-adjacent stem consonants across vowels. As we pointed out earlier, however, this evidence is consistent with either root- or stem-based accounts. Indeed, recent linguistic (e.g., Berkley, 1994; Kawahara, Hajime, & Kiyoshi, 2006) and psycholinguistic evidence (Bonatti et al., 2005; Newport et al., 2004) suggests that the restriction on consonant co-occurrence across intermediate vowels is not unique to Semitic. Thus, although adult speakers (of both Semitic and non-Semitic languages) might well detect relationships between

[11] The fact that the Piúl and Péel paradigms differ on their potential to violate the OCP does not demonstrate that this factor is the cause of our experimental results. There are also empirical and theoretical challenges to paradigm uniformity as an account for our findings. One question is why *ssk*-type forms are unacceptable in Piúl. Recall that paradigm uniformity bans stems that have the potential to yield adjacent identical consonants. The Piúl paradigm, however, lacks that potential: It never manifests stems with adjacent identical consonants. It is conceivable that this outcome is caused by the potential of such stems to violate the OCP in other Hebrew paradigms, but this possibility must to be formally examined. A second problem concerns the unacceptability of *ssk* and *skk* forms in Péel. If the avoidance of identical consonants in Peel reflects the avoidance of repair of illicit clusters, then it is unclear why the language does not exclude other stems that might yield such clusters (e.g., stems beginning with a sonorant, which, likewise require repair by epenthesis). Finally, the paradigm-uniformity explanation must be compared to alternative stem-based explanation for the uder-representation of identical consonants in Peel stem. One such alternative explanation hinges on the disconnect of the Péel paradigm from the verbal system. Bat-El (1994) suggested that $C_1VC_2VC_2$ verbs are generated by the rightward reduplication of a biconsonantal base, C_1VC_2. Accordingly, nominal paradigms that are productively linked to the verbal system can obtain their $C_1VC_2VC_2$ nouns from $C_1VC_2VC_2$ verbs. Since, unlike Piúl, the Péel nominal paradigm is not linked to the verbal system, it may lack the means to inherit $C_1VC_2VC_2$ forms. An in depth examination of these challenges awaits further research.

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consonants a distance, such observation by itself does not constitute evidence that those relationships have any particular grammatical function. The convergence between our present findings, which minimally do not require that a root is postulated, and others, showing where it plainly fails (Bat-El, 1994; Gafos, 1998; Ussishkin, 1999), calls for a reevaluation of its role. Stem-based models can naturally account for consonant–vowel interactions, as well as for each of the arguments motivating the postulation of the root, including the tendency of morphologically related words to share their stem's consonants, the expression of morphological relationships by vowel modification and prosodic templates, and the existence of restriction on consonant co-occurrence that operate across vowels (Bat-El, 1994, 2003, 2004; Gafos, 1998; Ussishkin, 1999).

The argument about stems and roots is long and vexed; it would be folly to think that such a long-standing debate could be resolved by a single set of findings or arguments. Ultimately, root- and stem-based approaches must each explain why are root consonants so salient to Semitic speakers. In stem-based approaches, the uniqueness of Semitic reflects the prominence and confluence of linguistic mechanisms that are not specific to Semitic (Bat-El, 2003), but their prominence remains unexplained. Root-based accounts can account for this question at the cost of postulating a special principle of morphological organization. While we take the current data to be consistent with stem-based accounts, our arguments against roots are clearly weaker. At best, we have a parsimony argument – that roots might not be necessary – and one that has been spelled out only in a single case, in Hebrew word formation. Similar arguments might possibly be made elsewhere, in other aspects of Semitic morphology or in altogether different domains in which stems and roots might both appear to be plausible representational elements – but we have not made those arguments explicit here. Moreover, even if every apparent use of roots turned out to be more properly explicated in terms of stems, the strong universalist position would still at most merely be strengthened, not proven; it could always turn out that there are language-wise variations in some other aspect of representational machinery.

Nonetheless, we believe the results reported here represent a considerable advance. In making it clear that even the flagship case for roots could turn out to hinge instead on representations of stems – that are presumed universal – we believe that our results underscore two important conclusions. First, and quite simply, they show that universalist position deserves a fresh look. Second, and more broadly, our results illustrate how psycholinguistic evidence can in principle be brought to bear on fundamental questions about the nature of linguistic representation.

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Appendix A

The materials used in Experiments 1–3 and 5–6

Orthographic representation			Phonological representation		
$C_1C_1C_2$	$C_1C_2C_2$	$C_1C_2C_3$	$C_1C_1C_2$	$C_1C_2C_2$	$C_1C_2C_3$
טטג	גטט	מגס	ttg	gtt	mgs
זזל	לזז	לשף	zzl	lzz	lʃp
בבג	בגג	לסק	bbg	bgg	lsk
זזק	הקק	גדן	zzk	hkk	gdn
גגר	רגג	דמל	ggr	rgg	dml
בבט	בטט	בגש	bbt	btt	bgʃ
ננז	נזז	נפג	nnz	nzz	npg
ססד	דסס	רזב	ssd	dss	rzb
גגד	דגג	שפג	ggd	dgg	ʃpg
צצב	בצץ	סמג	ççb	bçç	smg
פפן	פנן	מדל	ppn	pnn	mdl
ללט	לטט	פדל	llt	ltt	pdl
ננט	נטט	בגל	nnt	ntt	bgl
ללם	למם	חגם	llm	lmm	xgm
ללש	לשש	גפש	llʃ	lʃʃ	gpʃ
ללד	לדד	חמג	lld	ldd	xmg
פפש	פשש	שמג	ppʃ	pʃʃ	ʃmg
ססק	סקק	רמק	ssk	skk	rmq
ששף	ישש	שבן	ʃʃf	yʃʃ	ʃbn
קקב	בקק	שרג	kkb	bkk	ʃrg
דדף	פדד	מלץ	ddf	pdd	mlç
חחס	חסס	חנף	xxs	xss	xnp
ססף	פסס	נסל	ssf	pss	nsl
ררד	דרר	בלק	rrd	drr	blq
ררז	זרר	גחל	rrz	zrr	gxl
ננש	נשש	חמן	nnʃ	nʃʃ	xmn
צצם	צמם	שמק	ççm	çmm	ʃmk
ממק	ימם	פצם	mmq	ymm	pçm
קקן	נקק	חמק	kkn	nkk	xmq
זזף	זפף	חלס	zzf	zpp	χls

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Appendix B

The nonwords used in Experiment 4

Orthographic representation			Phonological representation		
$C_1C_1C_2$	$C_1C_2C_2$	$C_1C_2C_3$	$C_1C_1C_2$	$C_1C_2C_2$	$C_1C_2C_3$
ללם	למם	חמת	llm	lmm	xmt
קקב	קבב	קדל	kkb	kbb	kdl
בבג	אבב	פדל	bbg	ʔbb	pdl
זזב	זבב	רזב	zzb	zbb	rzb
בבט	טבב	זחן	bbt	tbb	zxn
זזף	זפף	שבן	zzp	zpp	ʃbn
גגט	טגג	לשף	ggt	tgg	lʃp
גגס	סגג	נפג	ggs	sgg	npg
קקט	טקק	נקס	kkt	tkk	nks
צצג	צגג	לסק	ççg	çgg	lsk
גגן	נגג	גנש	ggn	ngg	gns
גגר	רגג	גדן	ggr	rgg	gdn
עעג	עגג	לבח	ʔʔg	ʔgg	lbx
גגב	בגג	צקב	ggb	bgg	çkb
חחב	בחח	נעב	xxb	bxx	nʔb
חחש	אחח	מעק	xxs	ʔxx	mʔk
פפן	פנן	סמג	ppn	pnn	smg
דדן	דנן	זמח	ddn	dnn	zmx
זזן	זנן	שרג	zzn	znn	ʃrg
ללט	לטט	שפג	llt	ltt	ʃpg
טטב	בטט	לקב	ttb	btt	lkb
טטג	גטט	מגס	ttg	gtt	mgs
ננט	נטט	גפש	nnt	ntt	gpʃ
צצב	עצץ	חמג	ççb	ʔçç	xmg
ססג	עסס	חקב	ssg	ʔss	xkb
גגצ	גצצ	בנס	ggç	gçç	bns
ללס	לסס	בגש	lls	lss	bgʃ
דדץ	דצץ	סחג	ddç	dçç	sxg
ללש	לשש	אגש	llʃ	lʃʃ	ʔgʃ
ססד	דסס	דמל	ssd	dss	dml

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References

Arad, M. (2003). Locality constraints on the interpretation of roots: the case of Hebrew denominal verbs. *Natural Language and Linguistic Theory, 21*, 737–778.

Bat-El, O. (1994). Stem modification and cluster transfer in modern hebrew. *Natural Language and Linguistic Theory, 12*, 571–596.

Bat-El, O. (2003). Semitic verb structure within a universal perspective. In J. Shimron (Ed.), *Language processing and language acquisition in a root-based morphology*. Amsterdam: John Benjamins.

Bat-El, O. (2004). Parsing forms with identical consonants: Hebrew reduplication. In D. Ravid & H. B. Z. Shyldkrot (Eds.), *Perspectives on Language and Language Development* (pp. 25–34). Dordrecht: Kluwer.

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

Berent, I., & Shimron, J. (1997). The representation of Hebrew words: evidence from the obligatory contour principle. *Cognition, 64*, 39–72.

Berent, I., Everett, D. L., & Shimron, J. (2001a). Do phonological representations specify variables? Evidence from the obligatory contour principle. *Cognitive Psychology, 42*, 1–60.

Berent, I., Shimron, J., & Vaknin, V. (2001b). Phonological constraints on reading: evidence from the obligatory contour principle. *Journal of Memory and Language, 44*, 644–665.

Berent, I., Marcus, G. F., Shimron, J., & Gafos, A. I. (2002). The scope of linguistic generalizations: evidence from Hebrew word formation. *Cognition, 83*, 113–139.

Berent, I., Vaknin, V., & Shimron, J. (2004). Does a theory of language need a grammar? Evidence from Hebrew root structure. *Brain and Language, 90*, 170–182.

Berkley, D. M. (1994). The OCP and gradient data. *Studies in the Linguistic Sciences, 24*, 59–72.

Bonatti, L. L., Pena, M., Nespor, M., & Mehler, J. (2005). Linguistic constraints on statistical computations: the role of consonants and vowels in continuous speech processing. *Psychological Science, 16*, 451–459.

Boudelaa, S., & Marslen-Wilson, W. D. (2004). Allomorphic variation in Arabic: implications for lexical processing and representation. *Brain and Language, 90*, 106–116.

Davis, S., & Zawaydeh, B. A. (2001). Arabic hypocoristics and the status of the consonantal root. *Linguistic Inquiry, 32*, 512–520.

Deutsch, A., Frost, R., Pollatsek, A., & Rayner, K. (2000). Early morphological effects in word recognition in Hebrew: evidence from parafoveal preview benefit. *Language and Cognitive Processes, 15*, 487–506.

Even-Shoshan, A. (1993). *Ha'milon ha'xadash [The new dictionary]*. Jerusalem: Kiryat-Sefer.

Feldman, L. B., & Bentin, S. (1994). Morphological analysis of disrupted morphemes: evidence from Hebrew. *Quarterly Journal of Experimental Psychology, 47*, 407–435.

Frost, R., Forster, K., & Deutsch, A. (1997). What can we learn from the morphology of Hebrew? A masked-priming investigation of morphological representation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23*, 829–856.

Frost, R., Deutsch, A., & Forster, K. I. (2000). Decomposing morphologically complex words in a nonlinear morphology. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*, 751–765.

Gafos, A. I. (1998). Eliminating long-distance consonantal spreading. *Natural Language and Linguistic Theory, 16*, 223.

Gafos, A. I. (2003). Greenberg's asymmetry in Arabic: a consequence of stems in paradigms. *Language, 79*, 317–355.

Gonnerman, L. M., & Seidenberg, M. S. (2000). Explaining derivational morphology as the convergence of codes. *Trends in Cognitive Science, 4*, 353–361.

Greenberg, J. H. (1950). The patterning of morphemes in Semitic. *Word, 6*, 162–181.

Kawahara, S., Hajime, O., & Kiyoshi, S. (2006). Consonant co-occurrence restrictions in Yamato Japanese. In T. Vance (Ed.), *Japanese/Korean Linguistics* (vol. 14, pp. 27–38). CSLI Publications.

Leben, L. (1973). *Suprasegmental phonology*. Mass, Cambridge: MIT press.

Author's personal copy

Longworth, C. E., Marslen-Wilson, W. D., Randall, B., & Tyler, L. K. (2005). Getting to the meaning of the regular past tense: evidence from neuropsychology. *Journal of Cognitive Neuroscience, 17*, 1087–1097.

McCarthy, J. (1979). Formal problems in Semitic phonology and morphology. Doctoral dissertation, MIT. New York, 1985: Garland Press.

McCarthy, J. (1981). A prosodic theory of nonconcatenative morphology. *Linguistic Inquiry, 12*, 373–418.

McCarthy, J. (1986). OCP effects: gemination and antigemination. *Linguistic Inquiry, 17*, 207–263.

McCarthy, J., & Prince, A. (1995). Prosodic morphology. In J. A. Goldsmith (Ed.), *Phonological theory* (pp. 318–366). Oxford: Basil Blackwell.

McCarthy, J. (2005). Optimal paradigms. In L. Downing, T. A. Hall, & R. Raffelsiefen (Eds.), *Paradigms in Phonological Theory* (pp. 295–371). Oxford: Oxford University Press.

Nespor, M., Peña, M., & Mehler, J. (2003). On the different roles of vowels and consonants in speech processing and language acquisition. *Lingue e Linguaggio, 2*, 223–229.

Newport, E. L., Hauser, M. D., Spaepen, G., & Aslin, R. N. (2004). Learning at a distance II. Statistical learning of non-adjacent dependencies in a non-human primate. *Cognitive Psychology, 49*, 85–117.

Pastizzo, M. J. F., & Beth, L. (2002). Discrepancies between orthographic and unrelated baselines in masked priming undermine a decompositional account of morphological facilitation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*, 244–249.

Pinker, S. (1999). *Words and rules: The ingredients of language*. New York: Basic Books.

Plag, I. (1998). Morphological haplology in a constraint-based morpho-phonology. In W. Kehrein & R. Wiese (Eds.), *Phonology and morphology of the Germanic languages* (pp. 199–215). Tübingen: Niemeyer.

Prunet, J. F., Beland, R., & Adrissi, A. (2000). The mental representation of Semitic words. *Linguistic Inquiry, 31*.

Rose, S. (2003). The formation of Ethiopian Semitic internal reduplication. In J. Shimron (Ed.), *Language processing and language acquisition in a root-based morphology* (pp. 79–97). Amsterdam: John Benjamins.

Rose, S., & Walker, R. (2004). A typology of consonant agreement as correspondence. *Language, 80*, 475–531.

Stockall, L., & Marantz, A. (2006). A single route, full decomposition model of morphological complexity. *The Mental Lexicon, 1*, 85–123.

Tyler, L. K., deMornay-Davies, P., Anokhina, R., Longworth, C., Randall, B., & Marslen-Wilson, W. D. (2002). Dissociations in processing past tense morphology: neuropathology and behavioral studies. *Journal of Cognitive Neuroscience, 14*, 79–94.

Ussishkin, A. (1999). The inadequacy of the consonantal root: modern Hebrew denominal verbs and output–output correspondence. *Phonology, 16*, 441–442.

Ussishkin, A. (2005). A fixed prosodic theory of nonconcatenative templatic morphology. *Natural Language and Linguistic Theory, 23*, 169–218.

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