The Nature of Regularity and Irregularity: Evidence from Hebrew Nominal Inflection

Iris Berent,[1,4] Steven Pinker,[2] and Joseph Shimron[3]

Most evidence for the role of regular inflection as a default operation comes from languages that confound the morphological properties of regular and irregular forms with their phonological characteristics. For instance, regular plurals tend to faithfully preserve the base's phonology (e.g., rat-rats), whereas irregular nouns tend to alter it (e.g., mouse-mice). The distinction between regular and irregular inflection may thus be an epiphenomenon of phonological faithfulness. In Hebrew noun inflection, however, morphological regularity and phonological faithfulness can be distinguished: Nouns whose stems change in the plural may take either a regular or an irregular suffix, and nouns whose stems are preserved in the plural may take either a regular or an irregular suffix. We use this dissociation to examine two hallmarks of default inflection: its lack of dependence on analogies from similar regular nouns, and its application to nonroots such as names. We show that these hallmarks of regularity may be found whether or not the plural form preserves the stem faithfully: People apply the regular suffix to novel nouns that do not resemble existing nouns and to names that sound like irregular nouns, regardless of whether the stem is ordinarily preserved in the plural of that family of nouns. Moreover, when they pluralize names (e.g., the Barak-Barakim), they do not apply the stem changes that are found in their homophonous nouns (e.g., barak-brakim "lightning"), replicating an effect found in English and German. These findings show that the distinction between regular and irregular phenomena cannot be reduced to differences in the kinds of phonological changes associated with those phenomena in English. Instead, regularity and irregularity must be distinguished in terms of the kinds of mental computations that effect them: symbolic operations versus memorized idiosyncrasies. A corollary is that complex words are not generally dichotomizable as "regular" or "irregular"; different aspects of a word may be regular or irregular depending on whether they violate the rule for that aspect and hence must be stored in memory.

KEY WORDS: morphology; inflection; regularity; rule; Hebrew; faithfulness.

[1] Department of Psychology, Florida Atlantic University, Boca Raton, Florida.

[2] Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology.

[3] School of Education, University of Haifa, Haifa, Israel.

[4] To whom correspondence should be addressed at Department of Psychology, Florida Atlantic University, 777 Glades Road, P. O. Box 3091, Boca Raton, FL 33431-0991. email: IBERENT @FAU.EDU

INTRODUCTION

Many languages contrast regular (e.g., *rat-rats*) and irregular (e.g., *mouse-mice*) processes of inflection (for reviews, see Pinker, 1991, 1999). Regular and irregular inflection differ in their sensitivity to memorized forms. The application of regular inflection is general: It is easily applied to rare words, whose memory trace is weak (Gordon & Alegre, 1999; Ullman, 1999), and to novel words that do not resemble any existing words in memory and hence cannot get an inflected form by analogy (Berent, Pinker, & Shimron, 1999; Marcus, Brinkman, Clahsen, Wiese, & Pinker, 1995; Prasada & Pinker, 1993). In contrast, irregular inflection is highly dependent on memorized forms: Most irregulars are frequent; the rarer ones are likely to be regularized (Bybee, 1985; Marcus, Pinker, Ullman, Hollander, Rosen, & Xu, 1992), and people are unlikely to apply an irregular pattern to a novel word unless it is highly similar to an existing irregular (Berent *et al.,* 1999; Bybee & Moder, 1983; Prasada & Pinker, 1993).

There are also various grammatical processes that are selective with respect to regularity. For example, names take regular but not irregular inflection despite their similarity (or even identity) to existing irregular words (e.g., Julia and her husband are the *Childs,* not the *Children;* see Marcus *et al.,* 1995; Kim, Marcus, Pinker, Hollander, & Coppola, 1994). Conversely, compounds selectively admit irregular, but not regular plurals (cf. *mice-earters* versus *rats-eaters;* e.g., Alegre & Gordon, 1996; Gordon, 1985). The distinction between regular and irregular inflection is further evident in on-line priming effects (e.g., Kempley & Morton, 1982; Stanners, Neiser, Hernon, & Hall, 1979), developmental patterns (e.g., Marcus *et al.,* 1992), genetic disorders (Clahsen & Almazen, 1998; Ullman & Gopnik, 1999), and neurological dissociations (e.g., Marslen-Wilson & Tyler, 1997; Ullman, Berdiga, & O'Craven, 1997).

The words/rules account (Pinker, 1991, 1999) attributes the contrast between regular and irregular inflection to the properties of two distinct computational mechanisms. Irregular forms are stored in memory (which associates words by their sound, meaning, and spelling, allowing limited generalization by analogy to similar forms), whereas regular inflection is achieved by a rule[5] (e.g., $N_{plural} = N + \text{-}s$), applying by default upon the fail-

---

[5] We use the term "rule" to refer to any mental operation that combines variables productively, including principles, constraints, unification, optimality, and so on. In the linguistic literature, however, a "rule" has a more specific meaning, namely, an operation that transforms inputs into outputs, as opposed to a constraint, that directly circumscribes the forms of outputs. Our use of the term "rule" is neutral with regard to this distinction. Regardless of whether they operate on inputs or outputs, rules and constraints alike may apply to mental variables. It is the role of variables that is critical to our definition of a mental operation as a "rule."

ure to retrieve a stored irregular (or one highly similar to it) from memory. Numerous connectionist models, however, deny the existence of a rule (e.g., Daugherty & Seidenberg, 1992; Plunkett & Marchman, 1991; Plunkett & Nakisa, 1997; Rumelhart & McClelland, 1986). These accounts attribute both regular and irregular inflection to a single associative process that analogizes similar phonological forms. The distinction between regular and irregular forms is explained by the statistical phonological properties of the language. Indeed, much of the existing experimental evidence for the regular default comes from English, a language that largely confounds the morphological properties of regular and irregular words with their phonological characteristics. Regular inflection invariably attaches a consonantal suffix to the base, and it does not modify the stem's phonological form (e.g., *rat-rats*). Regular inflection is thus phonologically "faithful" to the base[6] (the term comes from Optimality Theory and refers to a family of constrains that require phonological outputs to be identical to their inputs in certain respects, e.g., Benua, 1997; McCarthy & Prince, 1995b, Prince & Smolensky, 1997). In contrast, irregular inflection tends to be phonologically unfaithful to the base, altering the base's phonological structure, primarily its vowels (e.g., *mouse-mice*). This systematic confound raises the concern that morphological regularity is an epiphenomenon of phonological faithfulness (e.g., Rueckl, Mikolinski, Raveh, Miner, & Mars, 1997; Stemberger, 1995, 1998).

A phonological explanation for morphological regularity must be examined because the phonological correlates of regularity are known to affect word identification and production. For instance, Stemberger (1995) notes that words that differ on their vowel are confusable; hence, they are more susceptible to substitution errors in speech production than words that differ on a consonant. Most irregular nouns in English differ from their bases on their vowels (e.g., *find-found, mouse-mice*), whereas regular nouns invariably differ from their base only on their final consonant (e.g., *rat-rats, thank-thanked*). Because irregular forms are more confusable with their base, speakers are more likely to replace the base by an irregular form on purely phonological grounds. Phonological confusability has also been claimed to explain the greater vulnerability of irregular verbs to overtensing (e.g., *founded*) compared to regular verbs (e.g., *thankeded*), and the admissibility of irregular, but not regular, plurals in compounds (cf., *mice-eater* versus *rats-eater*). Other contrasts between regular and irregular forms could be explainable by the fact that regular, but not irregular, inflection often produces a consonant cluster at the word's edge (e.g., *rats, thanked*). Stemberger (1995) suggests that the emergence of regularization errors in language development (e.g., *runned*) may not necessarily reflect the acquisition of a morphological

---

[6] More precisely, the stem in inflected forms is phonologically faithful to the singular base.

rule, but instead may be attributed to a milestone in phonological development, namely, the ability to form clusters at the word's edge. Phonological confounds may also contribute to the distinct patterns of priming observed for regular and irregular inflection. Several studies have demonstrated that regularly inflected words have a greater potential to prime their base compared to irregular words (Kempley & Morton, 1982; Stanners *et al.,* 1979). Morphological priming effects, however, are strongly sensitive to the degree of phonological and orthographic overlap between the target and prime (Pastizzo & Feldman, 2002; Rueckl *et al.,* 1997). Because regularly inflected words tend to be more faithful to the base than irregular targets, it has been suggested that their greater priming potential may be due to phonological/orthographic faithfulness (Rueckl *et al.,* 1997).

Though these phonological confounds complicate the interpretation of morphological regularity effects in English, they cannot, at present, explain all of these effects. A few irregular forms in English do preserve the stem faithfully, yet they follow the same grammatical constraints as irregular forms that change the stem. For example, irregular *oxen* preserves the stem *ox,* unlike *mouse-mice* and *tooth-teeth,* yet all three behave the same in regard to being admissible in compounds (compare *oxen power* with **horses power,* a contrast identical to *mice-infested* versus **rats-infested* and *teethmarks* versus **clawsmarks*). Similarly, the irregular participle *shaken* preserves the stem *shake,* yet it behaves just like stem-changing irregular participles in being regularized when the stem is derived from a noun. Just as one says *ringed the city* ("form a ring around"), not *rang,* one says *I can't have any more milkshakes: I'm shaked out* ("had too many shakes"), not *shaken* (Kim, Pinker, Prince, & Prasada, 1991). Moreover, this regularization effect holds across a wide variety of phonological patterns relating irregular past or participle effects to their stems.[7] Though it is unlikely that phonological confounds can account for all the phenomena related to regularity in English, the confound does raise an important and unanswered theoretical question: How does the regularity of an inflectional process depend on the phonological correspondence between the base and the inflected form? Specifically, does the role of regular inflection as a default require phonological faithfulness?

From the perspective of the words/rules account (Pinker, 1991, 1999), the correlation between regularity and faithfulness in English is of no par-

---

[7] These patterns include vowel change: *stick-stuck* versus *-high-sticked* ("hit with a stick"); no change: *cost-cost* versus *costed* ("computed the costs"); vowel-change plus suffix: *mean-meant* versus *meaned* ("computed the mean") rime replacement: *stand-stood* versus *grandstanded* ("play to the grandstand"); suppletion: *be-was* versus *to-be-or-not-to-be'd* ("recited 'to be or not to be'"). For experimental data, attested citations from speech, and additional examples, see Pinker (1999, Chapter 6).

ticular theoretical significance. The regularity of a form is defined with respect to an inflectional rule, which concatenates variables (abstract place-holders, e.g., *stem, suffix*) and is insensitive to the phonological content of the words they stand for. An output of a rule is thus regular (with respect to that rule), whereas a form that cannot be generated by a rule (hence, must be stored in memory) is irregular. However, a rule can apply regardless of anything else that might happen to the stem as a result of other rules or memorized associations. For example, the stem (regular or irregular) may be subject to phonological modifications. Although such modifications may well be irregular with respect to the phonological component of the grammar, they need not alter the regularity of the stem with respect to the inflection rule. Conversely, a form with an irregular suffix may exhibit regular or no phonological modifications to its stem. This proposal can thus account for the existence of morphologically irregular forms that are phonologically faithful (i.e., preserve the stem) as well as morphologically regular forms that are phonologically unfaithful. It follows under this theory that there is no such thing as a regular or irregular word per se. When a word is generated by a set of processes (phonological and morphological), some of these processes may be applied by rules, whereas others may require idiosyncratic output forms and must be retrieved from memory. The former parts or aspects of a word will be "regular" and the latter parts or aspects of *the same word* will be "irregular." The regularity or irregularity of one such part does not necessarily affect the regularity of others.

The coexistence of regular and irregular components within a single word are indeed attested in various languages. Consider English, for instance: Although English plurals are typically faithful to the base, a few regular plurals exhibit changes in voicing to the stem's final consonant (e.g., *knives, wolves, houses, mouths).* These changes are unpredictable, because they are absent in comparable contexts (cf., *wives* versus *waifs, mouths* versus *booths,* etc.). In some phonological theories the stem change is effected by a limited-scope phonological rule of "regressive-voicing" (e.g., Chomsky & Halle, 1968); in others (Lieber, 1980) the altered stem is simply stored as a suppletive form in memory (e.g., *knive-knive*plural). The idiosyncrasy in the stem, however, does not prevent it from taking the regular suffix by a rule. Evidence for the regularity of such plurals is their inadmissibility to insertion in compounds, similar to other regular, not irregular, plurals. Senghas, Pinker, Kim, and Collins (1991) showed that subjects reject regressive-voicing plurals in novel compounds (**scarves-holder, *thieves-trainer*) to the exact same extent that they reject faithful regular plurals in novel compounds (**slaves-keeper*). These hybrids regular/irregular forms appear even more plentiful in languages with richer inflectional systems. For example, French, like other Romance languages, has several conjugational classes for verbs (*-er, -ir, -re*),

one of which (-er) serves as a default (e.g., the class that novel verbs derived from nouns will naturally fall into). However, once a verb is assigned to one of these classes, it may or may not take a standard set of inflections for that class. For example, within the nondefault (irregular) -re class, *vendre* "sell" undergoes a regular conjugation, with participle *vendu,* whereas *prendre* "take" is irregular, with a participle *pris* that must be memorized. Likewise, Italian verbs that undergo phonological changes to the stem may take regular suffixes (cf., the faithful *am-are/am-a-to,* loved versus the unfaithful *piang-ere/pian-to,* cried). Although Orsolini and Marslen-Wilson (1997) failed to find evidence for default inflection in this language, it is conceivable that this result may be due to the admissibility of unfaithful nouns to the inflection rule (Orsolini and Marslen-Wilson considered such items as morphologically irregular), rather than to the confound of regularity effects in English with phonological correlates, as suggested by these authors.

According to the words/rules account, faithfulness is not only unnecessary for rendering a word regular (the inflection rule may tolerate unfaithful stems—it is also insufficient for people to perceive it as irregular: The inflection rule may be blocked for morphologically irregular stems despite their phonological faithfulness. Evidence supporting this prediction has been recently observed in German by Sonnenstuhl, Eisenbeiss, and Clahsen (1999). Sonnenstuhl *et al.* (1999) demonstrated that morphologically regular words show a greater priming potential even when regular and irregular forms each preserve the segmental contents of the base. In particular, irregular participles showed a reduced priming effect despite the fact that they did not alter the stem's segments or syllabic structure (e.g., *schlafe-geschlafen,* sleep). These findings clearly demonstrate that morphological regularity is not an artifact of faithfulness to the base's segmental contents. However, proponents of the phonological account of inflection could still attribute regularity effects to prosodic properties. Regular participle and noun plural suffixes (-*t,* and -*s,* respectively) typically do not add a syllable to the stem, whereas irregular suffixes, (-*en* and -*er*) often add a syllable. The role of these regular German suffixes as a default may thus be due to a preference for shorter words (Stemberger, 1998). Furthermore, although the German results elegantly demonstrate that morphological irregularity tolerates phonological faithfulness, they do not allow one to determine whether the morphological default permits phonological unfaithfulness.

Hebrew presents a complete dissociation between phonological faithfulness and morphological regularity. It frequently exhibits irregular stem modifications within otherwise morphologically regular forms, as well as faithful reproduction of the stem within irregularly suffixed forms. Hebrew thus provides an opportunity to examine in more detail the possibility that morphological regularity may coexist with either phonologically faithful or

phonologically unfaithful stems, which in turn would show that regularity is not a by-product of phonological faithfulness.

Hebrew words include two ingredients: the consonantal root[8] and the word pattern. The root is a sequence of typically three consonants. The word pattern provides vowels and affixes and specifies their location relative to the root consonants by means of abstract placeholders. Words are formed by inserting the consonantal root in the word pattern. For instance, the words *tamár* (date) and *zanáv* (tail) are each formed by inserting the roots *znb* and *tmr* in the word pattern CaCaC (C stands for any consonant), whereas *shikór* (drunk) and *kinór* (violin) are generated by inserting their respective roots (*shkr* and *knr*) in the CiCoC word pattern. Hebrew nouns are further marked for gender as either masculine or feminine. Masculine regular nouns are inflected by concatenating the -*im* suffix to the base, whereas irregular masculine plurals take the -*ot* suffix (The -*ot* suffix also happens to be the regular plural marker for female nouns). For instance, *tamár* and *shikór* are regular masculine nouns that take the plural suffix -*im,* whereas *zanár* and *kinór* are irregular masculine nouns, and their plural takes the -*ot* suffix.

Many plurals, however, manifest phonological alterations to the base. These changes typically result in vowel deletion, and, in some cases, vowel epenthesis. For instance, the inflection of the regular noun *tamár* (date, pl. *tmarím*) not only adds the regular suffix, -*im,* but also deletes the initial vowel. Such changes appear to be motivated by the prosodic properties of the singular word pattern (for a prosodic account of the broken plural in Arabic, see McCarthy & Prince, 1990; 1995a). Words sharing the same singular word pattern tend to exhibit similar changes to the stem in the plural form (Table I). Stem alteration is indeed not specific to inflection; similar (albeit not necessarily identical) alterations apply also in compounding and derivation. Although stem alterations are statistically sensitive to the properties of the singular word pattern, they are not entirely predictable in Modern Hebrew. For instance, the words *gamál* (camel) and *gamád* (*dwarf*) share the same singular word pattern; yet, the former is unfaithful to the base in

[8] There is some ambiguity in the linguistic literature concerning the notion of a root (Aronoff, 1994). A root is used to refer to (at least) two distinct concepts. One is specific to word and pattern morphologies: The root is the sequence of (three) consonants that are inserted in word pattern templates. A second, more general, meaning of a root is of a "lexical atom" carrying stored idiosyncrasies. These two meanings may not overlap. Indeed, two Hebrew words sharing the same consonantal root may differ on their plural suffix (e.g., *dimyon-dimyonot,* imagination versus *dimuy-dimuyim,* images); hence the constituent marked for regularity may well include some aspects of the word pattern. To discriminate between these concepts, we refer to the consonantal root as the "root melody," whereas the carrier of idiosyncrasies is referred to as a "canonical root."

Table I. The Sensitivity of Stem Alterations to the Singular Word Pattern

Singular	Plural	Gloss
CaCáC	CCaC-suffix	
gamal	gmalim	Camel
barak	brakim	Lightning
zanav	znavot	Tail
CaCéC	CCeC-suffix	
zaken	zkenim	Old
kaved	kvedim	Liver
gader	gderot	Fence
CéCeC	CCaC-suffix	
kelev	klavim	Dog
sefer	sfarim	Book
nefesh	nfashot	Soul

its plural (*gmalím*), whereas the latter (*gamadím*), is faithful.[9] Such arbitrary changes must be stored in the lexicon as irregular suppletions (e.g., [*gamal*]-[*gmal* -plural]), similar to the representation proposed for English unfaithful plurals (e.g., *knife-knive*-plural).

The striking property of Hebrew is that stem alterations are orthogonal to morphological regularity. Stem modification is motivated (though not completely determined) by the phonological properties of the singular word pattern. Because regular and irregular nouns often share the same word pattern, they may undergo identical phonological changes. For instance, the plurals of *zanáv* and *tamár* alter the base's phonology in a similar fashion, but one is suffixed regularly as *tmarím,* whereas the other is suffixed irregularly as *znavót*. These plural forms contrast in the regularity of their suffix despite their identical pattern of phonological unfaithfulness. Conversely, the plurals of *shikór* and *kinór* differ on their morphological regularity despite sharing complete phonological faithfulness to their bases (Table II).

---

[9] Stem alterations appear to be triggered by vowel and consonant length, phonological contrasts that were present in Tiberian Hebrew, but have been lost in Modern Hebrew (Bolozky, 1978). For instance, Tiberian Hebrew contrasted the words *gaamaal* (camel) and *gammaad* (dwarf) on vowel length and syllabification (Bat-El, 1996). The open initial syllable in *gaa-maal* triggered vowel deletion in its plural, *gmaa-lim,* whereas the plural of *gam-maad,* whose initial syllable is closed, remained faithful to the base (e.g., *gam-maa-dim*). Modern Hebrew erases the distinction between these two words with respect to consonant/vowel length and syllabification (e.g., *ga-mal, ga-mad*). Consequently, the presence of stem alteration in *gamal* and its absence in *gamad* appears arbitrary. Although many stem modifications are arbitrary in Modern Hebrew, certain aspects of stem modifications may be predicted by the grammar. For instance, the vowel reduction in CCaC-suffix may indicate a preference for a bysyllabic word (for a similar preference in the Hebrew verbal system, see Bat-El, 1994; Ussishkin, 1999). The contribution of grammatical constraints versus stored associations to stem alterations in Hebrew requires further research.

Table II. An Illustration of the Dissociation Between Morphological Regularity and Phonological Faithfulness in the Inflection of Hebrew Nouns

	Regular suffix	Irregular suffix
Phonologically faithful	shikor-shikorim	kinor-kinorot
Phonologically unfaithful	tamar-tmarim	zanav-znavot

This natural dissociation between the phonological faithfulness of the stem and the morphological regularity of the suffix permits examining whether the psychological distinction between regular and irregular inflection (characterized here as symbol manipulation versus memory lookup) depends on phonological faithfulness. One aspect of this distinction concerns the role of regular inflection as a default. Regular inflection applies across the board upon failures to retrieve a target noun from memory or failure to retrieve a set of nouns similar to the target, which may be used as an analogy. Such failures occur for two general reasons. One is a target noun that is dissimilar from familiar irregular nouns. A second is a target noun that lacks a canonical root and hence is never looked up among, or compared to, the canonical noun roots stored in memory. Irregularity is a property of canonical roots: arbitrary pairings among a meaning, a sound (following a language-specific canonical template), and a grammatical category stored in memory (Marcus *et al.,* 1995; Pinker, 1999; Pinker & Prince, 1988). A word may lack a canonical root—that is, it may be perceived as lacking a canonical, arbitrary sound-meaning pairing—because it is onomatopoeic, eponymic (derived from a proper name), formed by artificial means (truncations and acronyms), or derived from a different category (a verb from a noun or vice versa). If so, speakers will not access their memory system of canonical roots in which irregular forms (also arbitrary sound-meaning pairings) are stored. Such words will not take irregular inflection either by lookup or by analogy. Importantly, if a regular default rule exists in the language, such failures of retrieval or analogy will not leave speakers without an available form; they will apply the rule and end up with a regularly inflected form that is perceived as more natural for that word, even if speakers are unable to explain why.

The following experiments examine two such cases in which access to stored irregular forms is expected to fail. Experiments 1 and 2 examine the inflection of novel words whose similarity to familiar regular and irregular nouns is manipulated; Experiment 3 probes for the inflection of names. We investigate whether the application of the regular default depends on the phonological properties of the stem, including both phonological faithfulness and its similarity to regularly suffixed attracting forms. The statistical properties of Hebrew provide a unique opportunity to assess each of these aspects. Unlike English, for instance, in which regularizations are often

analogous to regular neighbors (e.g., *childs,* is analogous to *wilds*), Hebrew has irregular sounding words that lack any regular neighbors. If regular inflection is achieved by associative memory, then speakers should not apply the regular suffix to such words. Furthermore, if regular inflection requires phonological faithfulness, then evidence for default inflection should be found only when the plural form is phonologically faithful to the base. In contrast, if default inflection is achieved by a morphological rule, then it may be independent of the phonological properties of the stem or its neighbors. Specifically, the words/rules account predicts that (1) a regular suffix may be applied regardless of whether the form is faithful, and (2) a regular suffix may be applied regardless of whether the result is phonologically similar to an existing regular plural. In fact, the selection of the inflectional suffix may be dissociable from the phonological properties of the stem altogether, a special case of our proposal that the regular/irregular distinction is a distinction between rule and memory that applies separately to every part or aspect of a morphologically complex word, rather than as a binary classification of entire words. Our experiments test these predictions.

SELECTIVE SIMILARITY EFFECTS

Experiments 1 and 2 examine the inflection of novel words (targets) generated by analogy to familiar regular and irregular nouns (sources). Targets analogous to regular sources are considered regular, whereas targets analogous to irregular sources are irregular. According to the words/rules account, regular inflection is achieved by a rule; hence, it should be relatively unaffected by the similarity of the target to familiar regular words (except when dissimilarity from stored regular words correlates with similarity to stored irregular words, which will then block or interfere with the rule). Conversely, irregular inflection requires that the target activate an irregular word from memory, which, being associative, will activate words that are similar to, not just perfect matches with, the target. Irregular inflection should thus be sensitive to similarity: As the similarity to familiar irregular words decreases, targets should be less likely to take irregular inflection and more likely to take regular inflection, by default. In a recent study, Berent *et al.* (1999, Experiment 1) observed a general application of regular inflection to novel Hebrew nouns, regardless of their similarity to existing regular nouns, coupled with a strong similarity effect for irregular targets. These findings support the hypothesis that the regular *-im* suffix operates as a morphological default for the inflection of masculine nouns. Unfortunately, the materials confounded regularity and faithfulness: All the regular nouns had stems that were faithful (identical) to the base, whereas about half of the irregular

nouns manifested phonological alterations to the stem. Thus the ability of the regular suffix to function as a default could have been due in part to a lack of change in the stem, rather than to the nature of the operation applying the suffix.

These experiments addresses the problem by examining the effect of regularity while controlling for phonological faithfulness. The regular and irregular targets employed in Experiment 1 are all generated from word patterns that are phonologically unfaithful to the base: inflecting such targets systematically changes the stem. In contrast, the targets employed in Experiment 2 are invariably faithful, preserving the stem in the plural form. To demonstrate that regular inflection does not require similarity to regular words, the regular and irregular targets employed in Experiment 1 were selected from two different word patterns that are each strongly consistent on its suffix (regularity is manipulated between items). Because the irregular-sounding targets in this experiment are exclusively associated with irregular nouns in the language, and are dissimilar to regular nouns, they are extremely unlikely to take regular inflection by analogy to regular words. To ensure that the differences between regular and irregular forms are not due to idiosyncratic aspects of their distinct word patterns, Experiment 2 compares regular and irregular forms that are matched on their (faithful) word patterns (a within-item manipulation of regularity). In view of the differences in the manipulation of regularity for unfaithful and faithful targets (between-versus within-item manipulation, respectively), the effect of faithfulness must be examined in separate experiments. To minimize response strategies that may be triggered by a homogeneous block of targets (e.g., encouraging phonologically faithful responses in the presence of faithful targets), we mixed these two types of materials in a common list, presented to a single group of participants.

EXPERIMENT 1

Experiment 1 examines the inflection of targets generated by analogy to regular and irregular sources. The plurals of these source words were strongly unfaithful and highly consistent on their plural suffix. Specifically, these irregular sources were not similar to any regular word. Using these source words, we generated a set of regular and irregular targets by systematically manipulating their similarity to the source, a method previously used in both English (Bybee & Moder, 1983; Prasada & Pinker, 1993) and Hebrew (Berent *et al.,* 1999). "Highly similar" targets were constructed by replacing one of the phonemes in the source with a phoneme that shares the same place of articulation. "Moderately similar" targets also differed from the source by one phoneme, but the new phoneme had a different place of articulation

from the one in the source. Finally, "dissimilar targets" preserved none of the source's root consonants in their original position (Table III). Participants were presented with a printed list of these targets and asked to write down their plural forms. Because the plurals of the source nouns invariably alter the stem's phonology, we expect the inflection of our targets to manifest changes to the stem. The words/rules account predicts that, despite their phonological unfaithfulness, which should make the word as a whole be referred to similar forms in memory, regular targets should elicit a regular suffix, irrespective of similarity. In contrast, irregular suffixes should be elicited most strongly when the target is highly similar to nouns in memory; as the similarity to source nouns decreases, the irregular targets should be less likely to elicit an irregular suffix, and they should take the regular suffix, by default.

Method

Participants

Twenty University of Haifa native Hebrew speakers participated in Experiments 1 and 2. Participants were paid to take part in the experiment.

Materials

The source nouns were 15 regular and 15 irregular masculine nouns whose plurals exhibit phonological changes to the base (i.e., they are unfaithful). Irregular source nouns were all members of the CiCaCón word pattern, whereas regular sources were members of the CéCeC word pattern. These sources were selected for the high predictability of their plural suffix and stem alteration. The predictability of the source's suffix may be captured by comparing the number of word pattern members that take its suffix (morphological friends) and those that take a different suffix (morphological enemies). For example, the morphological friends of the regular source word *kélev* (dog, plural: *klavím*) include the word *gézer* (carrot, plural: *gzarím*), whereas its

Table III. An Illustration of the Regular and Irregular Targets and Their Sources in Experiment 1

	Regular suffix	Irregular suffix
Source	beged	zikaron
	(pl. bgadim, clothes)	(pl. zikronot, memory)
Target		
Highly similar	beget	zikalon
Moderately similar	begem	zikavon
Dissimilar	gelev	rizagon

enemies include the word *regesh* (feeling, plural: *rgashot*). Likewise, the strength of evidence supporting the phonological form of the plural may be operationalized in terms of phonological friends versus enemies. Phonological friends are nouns that share the target's singular and plural phonological forms, whereas phonological enemies share the target's singular stem pattern but take a different stem pattern in the plural. For instance, the noun *régesh* is a phonological friend of the source *kélev,* whereas *?emet* (truth, plural: *?amitót*) is its phonological enemy. We estimated the characteristics of our source words using a database of 1778 nouns listed in a Hebrew grammar book (Goshen, Livne, & Shafan, 1970; for further discussion, see Berent *et al.,* 1999). Table IV provides the number of morphological and phonological friends and enemies of the source words.

Members of the word pattern CiCaCón, the pattern used to generate our irregular targets, are highly predictable with respect to both their suffix and stem form. All members of this pattern take the irregular *-ot* suffix, and the stem is invariably altered to CiCCon-suffix.[10] In fact, these changes appear obligatory, because there is no existing Hebrew word whose plural has the stem CiCaCon-suffix. Predictability of stem and suffix is also characteristics of our regular targets, albeit to slightly lesser extent. Regular targets were generated by analogy to nouns in the CéCeC word pattern. This word pattern includes 158 members; 155 are inflected as CCaC-suffix, and 148 take the regular suffix. However, because the Hebrew writing system does not indicates stress, novel words manifesting the singular CeCeC pattern may also be interpreted as belonging to the CeCéC singular word pattern.[11] This

---

[10] Members of the CiCaCon word patterns whose initial consonant is guttural are inflected as CeCCon-suffix, rather than CiCCon-suffix. Because vowel raising for gutturals is a predictable phonological process, we do not distinguish between these two plural patterns.

[11] The classification of this word pattern is uncertain. The orthography captures the initial vowel by a schwa, and its realization as /e/ may well be due to a predictable phonological change, triggered by the following glottal consonant, shared by all its members (e.g., *ze?ev-ze?evim*).

Table IV. The Number and Proportion of Morphological and Phonological Friends and Enemies for the Source Nouns Used in Experiment 1 as a Function of the Source's Regularity

	No. Friends	No. Enemies	% Friends	% Enemies
Morphological friends				
Regular	154	11	93.3	6.7
Irregular	38	0	100	0
Phonological friends				
Regular	155	10	93.9	6.1
Irregular	38	0	100	0

word pattern (including 7 members; 6 of them are regular), takes various plurals forms that are all different from CCaC-suffix. The morphological and phonological neighborhoods of regular targets reported in Table IV are thus summed across the CeCéC and CéCeC word patterns. Although the stem of the regular targets is not perfectly predictable, it is largely so, because almost all of the neighbors of the regular and irregular sources are high consistent with respect to either stem alterations or suffix. People are thus likely to analogize the targets created from such consistent word patterns using the source's suffix and its (altered) stem. To ensure that the sources of regular and irregular targets are matched for their familiarity, we obtained familiarity ratings from 10 native Hebrew speakers on a 1–5 scale (1 = unfamiliar; 5 = familiar). The mean ratings for regular and irregular sources, respectively, were 3.78 and 3.74 [$F_s(1,28) < 1$, MSE = .028, $F_i(1,14) = 1.01$, MSE = 1.01, $p = .93$, n.s.].

For each of these source nouns, we generated targets that are highly similar, moderately similar, or dissimilar as described above (see Appendix A). These 90 targets were mixed with the set of 120 phonologically faithful words from Experiment 2 and presented in a randomized printed list. The vowels of all words were specified using diacritic marks.

Procedure

Participants were told that the purpose of the experiment is to examine how Hebrew speakers produce the plural form of novel words. They were asked to silently pronounce each word and write down the plural form that sounds the best. Participants were asked to indicate the pronunciation of their responses using diacritic marks.

Coding Scheme

Participants' responses were scored for the analogical transfer of the source's stem and suffix. A response was coded as analogizing the source's suffix if it had the same suffix as the source (e.g., regular suffix for regular sources). Likewise, a response was coded as analogizing the source's stem if it had the same phonological form as the source's plural. Note that for the phonological unfaithful sources used in this experiment, a response that analogizes the stem to the plural of its source invariably differs from the target's (and source's) singular base. The coding schemes for the suffix and stem are independent: A response may analogize the stem without analogizing the plural suffix or vice versa. Stem and suffix analogizing are expressed as mean correct responses; hence, the difference between the mean and

100% indicates the proportion of responses that differed from the stem or suffix (as the case may be) of the source. Note that for stems the score reflects the proportion of times that people faithfully copied over the stem verbatim, as opposed to changing it the way the source noun does. Suffix errors are failures to respond, failures to provide any suffix, or an error in the consonantal form of the singular. Erroneous response with respect to the stem were mostly failures to fully specify the phonological structure of the plural (because of the omission of diacritic marks), an alteration of the base's consonantal structure, or, on rare occasions, a form whose base matches neither the singular nor the plural form of the source noun.

Results

Participants were generally accurate in their responses. Suffix and stem errors amounted to 1.1% and 5.6% of the total observations, respectively, and they were equally distributed across the combinations of similarity x regularity.

We next assessed the effect of similarity on the use of regular and irregular suffixes and altered and unaltered stems. The proportions of responses analogizing the suffix and stem of the target are provided in Table V. Participants analogized the stem alternation pattern of the source noun on 94.3% of the trials. There was a slightly higher tendency for irregular targets to use their source's (altered) stem pattern, compared to regular targets: an ANOVA (2 regularity $\times$ 3 similarity) on proportion of stems analogized to the target yielded a significant effect of regularity in the analysis by items [$F_s(1,19) < 1$, MSE $=$ 356.37; $F_i(1,28) = 4.83$, MSE $=$ 22.71, $p = .04$]. This is probably because regular sources had slightly more

Table V. Experiment 1: Proportion of Responses That Analogized the Suffix or Stem Pattern of the Source for Regular and Irregular Targets

Stem analogies	Regular	Irregular
Highly similar	94.3	95.0
Moderately similar	92.1	97.9
Dissimilar	92.3	95.7

Suffix analogies	Regular	Irregular
Highly similar	98.7	89.7
Moderately similar	98.0	87.0
Dissimilar	95.7	74.1

phonological enemies (with stems unaltered in the plural) than did irregular sources. No other effects were significant.[12]

Given that most regular targets tend to alter the stem of their singular form in accord with their source, we can now examine whether such phonological unfaithfulness precludes regular inflection from serving as a default. An ANOVA (2 regularity $\times$ 3 similarity) conducted on proportion of suffixes that were analogized from their sources yielded significant effects of regularity [$F_s(1,19) = 32.86$, MSE $= 174.81$, $p < .0001$; $F_i(1,28) = 52.63$, MSE $= 82.18$, $p = .0001$], similarity [$F_s(2,38) = 12.27$, MSE $= 79.53$, $p = .0001$; $F_i(2,56) = 11.87$, MSE $= 59.94$, $p = .0001$], and their interaction [$F_s(2,38) = 7.31$, MSE $= 61.81$, $p = .0021$; $F_i(2,56) = 5.43$, MSE $= 59.94$, $p = .007$]. The simple main effect of similarity was only marginally significant for regular targets [$F_s(2,38) = 3.25$, MSE $= 15.35$, $p = 05$; $F_i(2,56) < 1$, MSE $= 59.84$]. None of the differences among regular targets reached significance by planned comparisons[13] (all $p > .23$). In contrast, a significant simple main effect of similarity was observed for irregular targets [$F_s(2,38) = 10.93$, MSE $= 126.00$, $p < .001$; $F_i(2,56) = 16.69$, MSE $= 59.94$, $p < .001$]. Dissimilar targets were less likely to analogize their source's irregular suffix compared to both moderately [$F_s(1,38) = 26.75$, $p < .0001$; $F_i(1,56) = 19.42$, $p < .0001$] and highly similar targets [$F_s(1,38) = 38.67$, $p < .0001$; $F_i(1,56) = 31.83$, $p < .0001$]. The difference between the suffix analogizing for highly versus moderately similar irregular targets was not significant [$F_s(1,38) = 1.14$, $p = .29$; $F_i(1,56) = 1.04$, $p = .31$]. Thus, as the similarity of irregular targets to the base decreases, they are likely to analogize to their source's irregular suffix, and they are more likely to take the regular suffix by default.

Discussion

Experiment 1 examined the effect of similar source nouns on the inflection of regular- and irregular-sounding targets when the sources in the

---

[12] The ANOVA (2 regularity $\times$ similarity) on the accuracy of stem responses yielded no significant effects in the analysis by participants or items (all $p > .13$). Likewise, the analysis on correct suffix reports reflected no significant effects in the analysis by participants (all $p > .12$). The analysis by items yielded a significant effect of regularity [$F(1,28) = 6.86$, MSE $= 1.98$, $p = .01$] and a marginally significant effect of similarity [$F(2,56) = 2.85$, MSE $= 2.85$, $p = .06$]. These effects indicate slightly higher accuracy in reporting the suffix for regular (M $= 99.89$) than irregular target (M $= 99.1\%$), as well as for similar (M $= 100\%$) compared moderately similar (M $= 99.3\%$) or dissimilar (M $= 99.2\%$) targets. However, none of these differences reached significance (Tukey HSD contrasts, all $p > .05$).

[13] In this and all subsequent experiments, planned comparisons are performed using the mean square error from the relevant effect in the omnibus ANOVAs.

language undergo systematic phonological changes to the stem. Despite this phonological unfaithfulness, regular and irregular targets were differently affected by similarity to existing nouns. Replicating our previous findings (Berent *et al.,* 1999), the generalization of an irregular suffix was sensitive to similarity: The more similar a target was to an existing irregular noun, the more likely participants were to analogize its irregular suffix. If the use of such graded analogies was triggered by the phonological unfaithfulness of the plural stem to the base stem, then, other things being equal, participants' use of regular suffixes should be sensitive to similarity, too. Contrary to this expectation, no reliable similarity effects were observed for regular unfaithful targets. These findings demonstrate that a distinction between regular and irregular forms is maintained despite the fact that the relevant phonological factors are equated: they both manifest stem alterations, and their inflection adds a suffix to the stem. This is consistent with the view that the similarity-insensitivity of regular inflection previously demonstrated for English, German, and Hebrew is not an artifact of a confound of regularity with faithful copying of the stem.

The pattern of usage of irregular suffixes may be explained as follows. The irregular sources were unusually consistent: members of the CiCaCón pattern, which are completely irregular (in contrast, most word patterns in Hebrew are dominated by regular members). This created a particularly tempting analogy for use of the irregular suffix, accounting for its use between 74% and 90% of the time (similar figures have been reported in English and German for verbs that are highly similar to fairly consistent irregular families; *spling,* for example, is commonly inflected as *splang* or *splung;* Bybee & Moder, 1983; Prasada & Pinker, 1993; Marcus *et al.,* 1995). Interestingly, when the similarity to this highly consistent class is relaxed by changing the consonants, people use the regular suffix, underscoring the potency of the regular suffix to apply as a default despite the absence of analogous regular words.

EXPERIMENT 2

Experiment 2 examines the inflection of novel words modeled after regular and irregular sources whose plural form does not change (i.e., is faithful to) the base's phonology (Table VI). Regular and irregular sources shared the same word patterns in their singular and plural forms. For example, the regular source *dfus* (press, pl.: *dfusim*) was compared with the irregular source *gvul* (border, pl.: *gvulot*). Consequently, regular and irregular targets are strictly matched on the phonological form of the stem and the number of phonological neighbors. If the role of regular inflection as a

Berent, Pinker, and Shimron

Table VI. Illustration of the Regular and Irregular Targets and Their Sources in Experiment 2

	Regular suffix	Irregular suffix
Source	dfus (dfusim, press)	gvul (gvulot, border)
Target		
Highly similar	dvus	gful
Moderately similar	dlus	grul
Dissimilar	kluk	pruf

default is an epiphenomenon of phonological confounds, then no evidence for the regular acting as the default should be obtained when targets are equated on their phonological properties: The generalization of the irregular suffix -*ot* to novel nouns should be unaffected by similarity to existing irregular nouns, just as we see in the generalization of the regular suffix -*im.* That is, the similarity manipulation should yield comparable effects for regular and irregular targets. Conversely, if default inflection is independent of faithfulness (because more generally, regularity of one part of a word may be independent of the regularity of another part), the generalization of irregular suffixes should still depend on similarity despite the faithfulness of the phonology of the plural stem to the phonology of the base stem. As before, dissimilar irregular targets that fail to activate their irregular source should take the regular -*im* suffix by default.

Method

Participants

Twenty University of Haifa students who participated in Experiment 1 served as participants.

Materials

The source nouns were 19 regular and 19 irregular masculine nouns whose plural form does not change the stem's segments. Each regular source was matched to an irregular source exhibiting the same word pattern. The number of morphological and phonological neighbors of these source words is listed in Table VII. These source nouns were each modified to create a highly similar, moderately similar, and dissimilar target as described in Experiment 1 (see Appendix B). The targets constructed to the regular and irregular source-pairs were matched for the position of the changed letters within the word. The mean number of letters for our regular and our regu-

Table VII. The Number and Proportion of Morphological and Phonological Friends and Enemies of the Source Nouns Used in Experiment 2 as a Function of the Source's Regularity

	No. Friends	No. Enemies	% Friends	% Enemies
Morphological friends				
Regular	13.8	5.7	70.7	29.3
Irregular	5.7	13.8	29.3	70.7
Phonological friends				
Regular	22.9	1.7	93.0	7.0
Irregular	22.9	1.7	93.0	7.0

lar targets was 4.47 (SD = 0.51) and the mean syllable length was 1.84 (SD = 0.37). The resulting 114 targets were mixed with the 90 targets used in Experiment 1 and presented in a randomized printed list. The experimental list also included six additional targets generated from one additional pair of sources that did not clearly contrast in regularity; these targets were removed from all analyses. The mean frequency ratings (using a 1–5 scale; 1 = unfamiliar, 5 = familiar) assigned to these targets by a group of 10 native Hebrew speakers were 3.78 and 3.75, for regular and irregular targets, respectively [$F_s(1,10) < 1$, MSE = .025; $F_i(1,18) < 1$, MSE = .469].

The procedure and data scoring were as described in Experiment 1.

Results

The proportion of responses that used the suffix and stem of the target nouns is provided in Table VIII.[14] Consider first the use of the unaltered stem in the plural (which is consistent with the source nouns). Participants did so between 96% and 100% of the time. An ANOVA (2 regularity × 3 similarity) yielded a main effect of similarity [$F_s(2,38) = 9.56$, MSE = 15.47, $p = .0004$; $F_i(2,36) = 3.13$, MSE = 44.91, $p = .05$], showing that the slight difference comes from targets that were less similar to their sources, largely because of three noun pairs whose singular pattern, CaCóC, matches a group of unfaithful nouns (e.g., *karon-kronot,* wagon). The

---

[14] The rate of errors in reporting the suffix and stem was 1.2% and 4.1%, respectively. An ANOVA (2 regularity × 3 similarity) on suffix reports indicated that the rate of suffix report was slightly more accurate for irregular (M = 99.2%) than regular targets [M = 98.33%; $F_s(1,19) = 4.54$, MSE = 5.13, $p = .04$; $F_i(1,18) = 3.29$, MSE = 6.65, $p = .08$]. A similar analysis conducted on the correct reports of the stem yielded only a marginally significant interaction of regularity × similarity, significant only in the analysis by participants [$F_s(1,19) = 3.02$, MSE = 14.07, $p = .07$; $F_i(1,36) < 1$, MSE = 22.94]. None of the parities comparisons, however, was significant (Toukey, HSD test, all $p > .05$)

Table VIII. Experiment 2: Proportion of Responses That Analogized the Suffix or Stem Pattern of the Source for Regular and Irregular Targets

Stem analogies	Regular	Irregular
Highly similar	100.0	99.4
Moderately similar	96.4	98.3
Dissimilar	96.1	95.7

Suffix analogies	Regular	Irregular
Highly similar	73.3	63.0
Moderately similar	68.1	53.5
Dissimilar	66.3	28.0

interaction of similarity $\times$ regularity was marginally significant by participants only [$F_s(2,38) = 3.11$, MSE $= 6.38$, $p = .05$; $F_i(2,36) = 1.07$, MSE $= 18.51$, $p = .35$].

Does this very high degree of phonological faithfulness, which is characteristic of regular inflection in English, eliminate the sensitivity of irregular inflection to similar familiar irregular nouns? The ANOVA (2 regularity $\times$ 3 similarity) on the proportion of suffixes analogized form their source nouns yielded significant effects of regularity [$F_s(1,19) = 23.79$, MSE $= 560.92$, $p = .0001$; $F_i(1,18) = 5.34$, MSE $= 2398.02$, $p = .03$], similarity [$F_s(2,38) = 55.15$, MSE $= 82.15$, $p < .0001$; $F_i(2,36) = 21.85$, MSE $= 195.98$, $p < .0001$], and their interaction [($F_s(2,38) = 22.49$, MSE $= 101.155$, $p < .0001$; $F_i(2,38) = 9.38$, MSE $= 229.19$, $p = .0005$]. The simple main effect of similarity for regular targets was only marginally significant [$F_s(2,38) = 5.10$, MSE $= 51.77$, $p = .01$; $F_i(2,36) = 1.22$, MSE $= 186.85$, $p = .31$, n.s.]. Planned comparisons indicated that the rate of analogizing the source's regular suffix among highly similar regular targets did not differ significantly from moderately similar targets [$F_s(1,38) = 2.70$, $p = .11$; $F_i(1,36) < 1$)], and was only marginally higher compared to dissimilar targets [$F_s(1,38) = 4.82$, $p = .03$; $F_i(1,36) = 1.91$ $p = .17$]. The difference in analogizing the regular suffix among moderately and dissimilar regular targets was not significantly ($F < 1$). In contrast, the similarity effect for irregular targets was highly significant [$F_s(2,38) = 49.74$, MSE $= 131.54$, $p < .0001$; $F_i(2,36) = 26.03$, MSE $= 283.32$, $p < .0001$]. Irregular targets took the irregular suffix significantly more often when the target was highly similar to an existing irregular noun than when it was moderately similar [$F_s(1,38) = 8.80$, $p = .005$; $F_i(1,36) = 3.70$, $p = .06$], which, in turn, elicited irregular suffixes significantly more often than when the target was dissimilar to existing irregular nouns [$F_s(1,38) = 120.82$, $p < .0001$; $F_i(1,36) = 50.57$, $p < .0001$].

Discussion

The findings of Experiment 2 demonstrate that even when irregular forms preserve the stem of the base perfectly (which is typical of regular inflection, especially in English), people generalize an irregular suffix to a new noun primarily when it is highly similar to an existing irregular noun, whereas they generalize a regular suffix to a new noun at about the same rate whether the noun is similar or dissimilar to existing regular nouns. Even the weak effect of similarity for regular-sounding nouns may not have been caused by dissimilarity to existing regulars but rather by similarity to competing irregulars: Closer inspection of the results shows that the effect is largely due to a group of eight targets that end with the -on suffix, which is strongly associated with irregular inflection. The only Hebrew word pattern that is consistently irregular, CiCaCon, exhibits this singular suffix, and its use in Experiment 1 indeed resulted in a high rate of irregular inflection; the inadvertent resemblance of the "regular" targets to this irregular family via the unusual -on suffix may have resulted in a lower rate of regular inflection here. For the remaining regular items, the rate of suffix preservation was 85%, and it was unaffected by similarity (all $p < .18$). Importantly, among irregular-sounding targets, the phonological distance from the irregular source not only decreased the use of irregular inflection but increased the use of regular inflection. Dissimilar irregular targets took the regular suffix on 72% of the trial.[15] These findings underscore how regular and irregular inflection differ even when regular and irregular forms are strictly matched on their phonological properties.

EXPERIMENT 3: THE INFLECTION OF NAMES

Experiments 1 and 2 examined one case in which a novel noun cannot be inflected by analogy to existing nouns, namely, when there is no exist-

---

[15] The greater sensitivity of our faithful irregular targets to stored similar tokens also cannot be due to the existence of other unfaithful targets in the experimental list. The pattern of results replicates when the same targets are presented in a separate list. Eleven participants served in this experiment. The ANOVA (2 regularity × 3 similarity) on the rate of analogizing the source's suffix yielded significant interaction of regularity × similarity [$F_s(2,20) = 14.40$, MSE = .008, $p = .0001$; $F_i(2,36) = 13.12$, MSE = .017, $p = .0001$]. The simple main effect of similarity for regular targets was weak, significant by participants only [$F_s(2,20) = 6.02$, MSE = .008, $p = .0001$; $F_i(2,36) = 2.83$, MSE = .020, $p = .07$]. In contrast, significant similarity effect emerged for irregular targets [$F_s(2,20) = 26.11$, MSE = .008; $F_i(2,36) = 20.94$, MSE = .02]. As in Experiment 2, however, the weak effect of similarity for regular targets was primarily due to the activation of similar irregular targets by a group of regular targets ending with the -on suffix. The removal of these items eliminated the similarity effect for regular targets altogether (all p's $> .21$).

ing noun that is sufficiently similar to serve as the basis for the analogy. In this experiment we explore a more radical cut-off of the use of lexical memory that applies to words across the board. As mentioned earlier, according to the words/rules account (Pinker, 1999; Pinker & Prince, 1988), irregularity consists in the storage of idiosyncratic information in the canonical root of a word: the arbitrary pairing among a meaning, a grammatical category, and a canonical sound pattern. Nouns derived from names, because they are perceived to lack canonical roots, cannot access the irregular patterns stored in familiar noun roots even if they are phonologically similar or identical to those roots. When people see a noun derived from a name, they should not connect it to the noun roots they have stored in memory, regardless of the degree of phonological similarity or dissimilarity (of the whole word or of its root alone). For example, in English, people refer to families as *the Childs, the Manns,* and *the Footes,* not *the Children, the Menn,* and *the Feete* (Kim *et al.,* 1994; Marcus *et al.,* 1995).

In a language such as Hebrew, the perception of a word as lacking a canonical root may also affect its stem. Stem modification in Hebrew appears to be the product of an associative process. For instance, stem modifications such as *barak-brakim* (lightning) are stored as suppletive pairs (*barak-brak-*$_{\text{plural}}$). Because stem alterations are highly sensitive to the singular word pattern, novel words can analogize stem alterations of a familiar noun even when they do not share any root consonant. This explains why dissimilar irregular targets in Experiment 1 (sharing the word pattern with their source) analogized stem alterations, but not the suffix of their source. When a novel word is perceived as name, however, access to the lexical entry should be cut off. A cut-off to lexical entry of a name should block access to morphological irregularity, as well as idiosyncratic stem alterations. If the regular suffix and phonological content of the stem are achieved by distinct processes, then the blocking of access to stem modifications should not affect the application of the regular suffix by the rule. Because the regular suffix is triggered by a variable standing for the stem (e.g., "N"), the application of the rule can be insensitive to the phonological contents of the stem, in general, and its faithfulness to the base, in particular. Names constructed from unfaithful nouns should thus selectively elicit a regular suffix (whether or not the similar sources in memory possess that suffix), but should systematically fail to elicit any alterations to similar-sounding stems in memory. English has only a few cases in which regular suffixes accompany modified stems. These cases, however, are consistent with this prediction. For example, Mr. and Mrs. Wolfe are the *Wolfes,* not the *Wolves.* Phonological unfaithfulness among regular nouns is highly frequent in Hebrew. Nevertheless, the former Israeli prime minister Ehud Barak and his family are the *Barakim,* not the *Brakim.* Our experiment systematically investigates this phenomenon.

In this experiment, we asked Hebrew speakers to indicate the plural form of names that are homophonous to familiar regular and irregular Hebrew native nouns (hereafter: the source). These source nouns were all phonologically unfaithful to the base. For instance, the word *tamár* (date), a regular noun, and *nahár* (river), an irregular noun, both delete the singular's initial in their plurals, CCaC-suffix, that is *tmarim* and *nharot*.[16] The source nouns were presented in sentential contexts requiring their interpretation as either native nouns or names (Table IX). Each sentence was presented in a context calling for a plural form, indicated by a blank line. Participants were asked to choose the correct form among four alternatives, exhibiting the four combinations of unfaithful stem (like the source noun) with either regular or irregular suffix, and a faithful stem (unlike the source noun) with regular or irregular suffix.

We predict the plurals of proper nouns to take the regular suffix and revert to the base's singular form, because neither the suffix nor the stem of the homophonous canonical noun root in memory should be elicited by these nonroots. A comparison of the plurals of name and their native noun sources should thus yield dissociation between the analogical generalization of suffixes and stems (Table X). Regular-sounding nouns and names should

[16] Hebrew bans clusters with a coronal sonorant at the syllable's onset. Accordingly, the deletion of the vowel in *nharot* yields a phonologically undesirable output that is repaired by the epenthesis of a schwa (*neharot*), a predictable phonological process that occurs across the board, regardless morphological structure or regularity (cf. the irregular *nahar neharot* and the regular *naxash-nexashim* (snake); the irregular *regesh-regarshot,* feeling; vs. the regular *rexev-rexavim,* vehicles). Because the schwa epenthesis in *nharot* is triggered by the deletion of the base's vowel, we treat *nharot* and *tmarim* as members of the same word pattern. Our transcription captures this abstract phonological structure, rather than surface phonetics.

Table IX. Illustration of the Sentential Contexts Generated for the Regular Noun
tamar (Date, Plural: *tmarim*)

Native Hebrew noun	
For dessert, I offered my guests _____	and almonds.
tmarim	
tamarim	
tmarot	
tamarot	
Name	
Joseph and Irit Tamar live upstairs. The _____	tend to make lots of noise at night
and wake me up from my sleep.	
tmarim	
tamarim	
tmarot	
tamarot	

Table X. The Predicted Plurals of Native Regular and Irregular Nouns
and Their Corresponding Names

	Singular	Native noun plural	Name plural
Regular	*tamar* (date)	tmarim	Tamarim
Irregular	*nahar* (river)	nharot	Naharim

share the source plural's (regular) suffix, but not its stem alterations. Conversely, irregular-sounding names should fail to share either the suffix or the stem of the source plural. Moreover, the plural form of a name should not depend on the similarity structure of the language's lexicon. To test this prediction, our materials included nouns whose predicted plural form (both suffix and stem) lacks any support from similar Hebrew nouns. If the selection of the regular suffix and the reversion to the base's singular form is governed by the application of a default rule, then it should not require analogies from morphological and phonological neighbors. Such forms should take the default suffix and revert to the base's singular form despite the absence of neighbors exhibiting this plural form.

Method

Participants

Twenty four University of Haifa native Hebrew speakers served as participants. They were all students in the school of Education at the University of Haifa. The experiment was administered as part of a course lecture. The participants received no compensation for their participation.

Materials

The materials consisted of 16 pairs of regular and irregular target words embedded in sentential contexts (see Appendix C). The selection of these targets was primarily guided by the attempt to control for the target's neighborhood as a potential constraint on the selection of the suffix and stem for names. For this end, we chose targets whose neighbors offer the weakest possible support for the predicted forms of the suffix and stem (Table XI). Because most Hebrew nouns are regular, it was virtually impossible to find a diverse set of targets whose neighbors do not favor the regular suffix. Among stems, however, the neighborhood sizes can be equated more easily. Our targets were all members of word patterns whose stems are unfaithful; that is, they undergo changes in the plural. Furthermore, the support for

Table XI. The Number and Proportion of Morphological and Phonological Friends and Enemies for the Source Nouns Used in Experiment 3 as a Function of Target Regularity

	Morphological neighbors			
	No. Friends	No. Enemies	% Friends	% Enemies
Regular	103.2	7.0	90.0	10.0
Irregular	21.0	37.2	48.2	51.8
	Phonological neighbors			
	No. Friends	No. Enemies	% Friends	% Enemies
Regular	108.9	12.1	90.0	10.0
Irregular	58.0	13.4	88.2	11.8

these stem alterations among phonological neighbors was stronger than for any other form, including the unaltered base.

Two Hebrew word patterns (the regular CéCeC and the irregular CiCaCóC word patterns; see also Experiment 1) permit yet a tighter control for the contribution of neighbors to the selection of stem. The phonological neighborhoods of these word patterns strongly reinforce the pattern of altered stems and offer no support for the pattern of unaltered stems. Specifically, there is no Hebrew word sharing the source's singular form that does not undergo these stem alterations in the plural. Moreover, there is no Hebrew word whose plural matches that of the unaltered base: No Hebrew plural has the phonological form CéCeC-suffix or CiCaCón-suffix. Thus, such default phonological forms cannot be computed by analogy to existing nouns. Six of our 16 pairs of regular and irregular targets were members of these two word patterns. The irregular word pattern CiCaCón is also fully consistent with regard to its suffix: all members of this word pattern take the irregular -ot suffix. Thus, this word pattern provides no support for either the default suffix or stem form predicted for names.

Because of the phonological uniqueness of the CiCaCon word pattern, these 6 irregular targets are slightly longer than their regular mates in terms of the number of letters and syllables. The remaining 10 pairs of regular and irregular nouns were CVCVC words whose members were matched for the number of letters and syllables. Our regular targets had a mean length of 3.31 letters (SD = 0.48) and 2 syllables (SD = 0), whereas our irregular targets had a mean of 4.19 letters (SD = 0.834) and 2.44 syllables (SD = 0.512).

Sentential Context

The targets were embedded in sentential contexts that presented them either in their original Hebrew meaning or as surnames (see Appendix D).

The name context consisted of two sentences. The first established the meaning of the word as a surname and the second introduced its plural. The name context also established the gender of the name as masculine by presenting the plural as referring to a group including at least one masculine name (the default gender of any group including a single masculine is masculine). All words in the contexts were presented in a Hebrew script without diacritic marks, except for the target word, whose vowels were indicated by diacritic marks. The location of the plural form in the sentence was indicated by a blank line. At the end of the sentence, participants were presented with four alternatives for the plural form. Two of the alternatives maintained the phonological form of the base, one with a regular suffix and one with an irregular suffix. The other two alternatives altered the phonological form of the base in a manner that corresponds to the native noun plural. One of these alternatives had a regular suffix and the other an irregular suffix. These four alternatives were presented in a random order. The regular and irregular target mates were all presented in essentially the same name contexts, with the exception of a few minor modifications designed to make the word appear a natural name and minimize associations with the original nominal meaning.

The 32 nominal and noun contexts were randomized and arranged in two lists according to a Latin square, such that (a) each participant was presented with an equal number of regularity $\times$ context combinations; (b) each word or context was seen only once by a single participants; and (c) each target $\times$ context combination was equally represented across participants.

Procedure

Participants were provided with the following instructions:

> "The purpose of the experiment is to investigate how Hebrew speakers produce the plural form of Hebrew words and people's names. We wish to examine what is the plural form: is the suffix, *-im* or *-ot,* and how is the word pronounced.
>
> In the following pages you are presented with short passages. In each passage, there is a missing word whose location is underlined. Please carefully read each sentence aloud several times. Then, please choose the plural form that sounds best to you according to the context in which it appears. It is very important for us to find out what is your "gut feeling": how you speak in everyday life, not how you think you "should" speak. It is also very important to pay attention to the context in which the word appears.

Please circle the alternative that sounds best to you.
Examples:
The radio is now broadcasting Hebrew   .
shirim
shirot
(the correct alternative circled is shirim, songs, masculine plural).

The   are sailing in the river.
sirot
sirim
(the correct alternative circled is sirot, boats, feminine, plural)."

Note that the above examples were regular native nouns that do not manifest phonological changes to the stem in the plural form. These examples thus provide no information regarding the inflection of names, nor do they indicate the possible disagreement between name and native nouns on either suffix or stem.

Results

Our analyses examine how often participants pluralized names using the suffix and stem alterations of homophonous nouns. There were no failures to respond. Table XII shows the proportion of time that participants used the plural stem and plural suffix associated with each noun, depending on whether the item was treated as a noun or a name. The overall pattern is clear both with suffixes and with stems. Not surprisingly, with native nouns, participants used the appropriate plural suffix for that noun, regular or irregular. Similarly, they altered the stem in a way that is correct for the language. But when that same sound was used as a name, participants overwhelmingly used the regular suffix: 96.6% of the time when the original noun was regular to begin with, and even 92.2% of the time when the original noun was irregular and using the regular suffix required them to abandon the irregular suffix. They also abandoned the stem alterations associated with the sound, more than two thirds of the time.

These patterns are confirmed by ANOVAs (2 regularity × 2 context) performed on the proportion of trials in which participants used the suffix and stem associated with the items' sounds. For suffixes, there were signif-

Table XII. Proportion of Nouns and Names Pluralized with the Suffix and Stem Alterations Associated with the Source Noun

	Use of the plural suffix associated with the source noun	
	Nouns	Names
Regular targets	100.0	99.5
Irregular targets	96.9	7.8

	Use of the altered plural stem associated with the source noun	
	Nouns	Names
Regular targets	91.1	32.8
Irregular targets	94.8	25.0

icant main effects of regularity [$F_s(1,23) = 331.24$, MSE $= 162.76$, $p <$ .0001; $F_i(1,30) = 1357.53$, MSE $= 26.47$, $p < .0001$], context [$F_s(1,23) =$ 357.37, MSE $= 134.37$, $p < .0001$; $F_i(1,30) = 1137.86$, MSE $= 28.21$, $p <$ .0001], and their interaction [$F_s(1,23) = 346.92$, MSE $= 135.59$, $p < .0001$; $F_i(1,30) = 1111.55$, MSE $= 28.21$, $p < .0001$]. Regular targets were equally likely to take the regular suffix when presented as nouns or names [$F_s(1,23) <$ 1, n.s.; $F_i(1,30) = 2.80$, $p = .104$], whereas irregular targets were significantly more likely to take the irregular suffix in the noun compared to the name context [$F_s(1,23) = 702.03$, $p < .0001$; $F_i(1,30) = 2268.20$, $p <$ .0001]. For stem alteration, there was only a significant effect of noun-versus-name context [$F_s(1,23) = 102.74$, MSE $= 958.73$, $p < .0001$; $F_i(1,30)$ $= 400.24$, MSE $= 164.06$]. Names were far less likely to show the stem alterations exhibited by the plurals of their homophonous nouns. Although this pattern was clearly evident for both regular [$F_s(1,23) = 293.80$, $p <$ .0001; $F_i(1,30) = 166.53$, $p < .0001$] and irregular nouns [$F_s(1,23) =$ 420.56, $p < .0001$; $F_i(1,30) = 238.40$, $p < .0001$], its magnitude was somewhat larger for irregular nouns, resulting in a marginally significant interaction of regularity and context [$F_s(1,23) = 5.67$, MSE $= 138.98$, $p = .02$; $F_i(1,30) = 3.20$, MSE $= 164.06$, $p = .08$].

Discussion

When native Hebrew nouns are interpreted as names, they take the regular suffix regardless of the regularity of the homophonous noun. This shows how the suffix -*im* serves as a default for the inflection of masculine nouns, a finding that extends our previous results (obtained with phonologically faithful nouns, Berent *et al.,* 1999). In addition, pluralized names discard the alterations of the stem that are associated with the homophonous noun in memory. The data are readily explained by the words/rules account (Pinker, 1991, 1999) as follows: Irregular phenomena in language consist of idiosyncratic information about any aspect of the word stored with the word's root, its arbitrary pairing of a sound, a meaning, and a grammatical category. When a word is perceived not to have a canonical root (because its sound comes from a proper noun, an environmental sound, an artificial means of creating its sound, or a word from another category), it is not looked up in the lexicon of stored roots. Homophonous and similar words in the lexicon therefore do not suggest their irregular stored forms to the inflection system, which reverts to the default. The default is a rule concatenating the regular suffix to a variable standing for the stem. The rule can thereby apply to any instance of a category (such as "Noun") even if its sound is unfamiliar or tied in memory to an irregular form. When Hebrew speakers pluralize a name, they thereby ignore both an irregular suffix stored with the homophonous noun,

and any stem alteration (which are not completely predictable and hence also irregular, by this theory), and apply the default regular suffix directly to the singular base. The plural will be the singular base plus the regular suffix, regardless of whether the homophonous noun has a regular or irregular suffix and/or a faithful or unfaithful stem.

An alternative account might view inflection as the association of the singular with a novel word. To use an English example, the inflection of the name *Wolfe* as *Wolfes* simply reflects the formation of a new association, analogous to the association of *mouse* with *mice*. The similarity between the stems of the singular (e.g., *Wolfe*) and plural forms (e.g., *Wolfes*) does not indicate a reversion to the singular base. Likewise, the abandonment of irregular suffixes and stem alterations in Hebrew is not a consequence of the architecture of the language system, but directly reflects a learned pattern that has embedded itself in the statistical structure of the Hebrew language, namely, a set of associations between names and their plurals (which just happen to consist of the name plus -*im*). If the plural forms of names were essentially new forms, produced by analogy to similar familiar forms, then the selection of the plural should depend on its phonological and morphological neighborhoods. This experiment provides evidence that such an effect exists, but cannot explain people's responses in the experiment.

The plural responses produced by participants were indeed sensitive to the statistical properties of similar plural forms. For instance, the reversion to the unaltered base was significantly more frequent when the resulting phonological form ([singular base] + suffix) had phonological friends (M = 80.1%) than when it had no phonological friends [M = 60.7%, $F_s(1,23) = 32.10$, MSE = 357.26, $p < .0001$; $F_i(1,28) = 18.61$, MSE = 158.88, $p = .0002$]. Such an effect is incompatible with the view that the reversion to the base in insensitive to similar familiar nouns. However, the existence of familiar similar forms is not *necessary* for the divergence between names and their homophonous nouns. Name plurals revert to the singular base and the regular suffix even when this form is utterly unfamiliar. First, the targets were designed so as to include six irregular nouns whose word patterns were consistently irregular, that is, without *any* regular neighbor. If default inflection required the existence of regular neighbors, then pluralized names based on these targets could not have taken the regular -*im* suffix, but in fact they took the regular default suffix on over 93% of the trials (compared to only 1.4% when presented as native nouns, [$F_s(1,23) = 294.43$, MSE = 322.04, $p = .0001$; $F_i(1,5) = 465.46$, MSE = 50.93, $p = .0001$]. Neighborhood support is also not necessary for reverting to the unaltered singular form of the stem. The materials included a group of seven regular and irregular nouns whose singular base is not supported by any phonological friend. For instance, the irregular form CiCaCon always changes in the plural to CiCCoCon-suffix.

Furthermore, no Hebrew word has a plural form whose stem matches the singular base, CiCaCon-suffix. When these nouns were presented as names, they nevertheless reverted to the singular base on 63.9% of the trials (compared to 1.8% of the trials when presented as native nouns [$F_s(1,23) = 49.54$, MSE = 1544.13, $p < .0001$; $F_i(1,12) = 221.022$, MSE = 119.05 $p < .0001$]. The plural of names thus revert to the singular base and the default suffix even if the resulting plural form is highly unfamiliar, contrary to what would be predicted if name plurals are simply stored phonological association with the singular form.

Another problem for the alternative account is to explain *why* the plurals of names diverge from homophonous nouns. The divergence cannot simply be attributed to the mismatch between the semantic features of names and their native nouns, because semantic mismatches that do not involve the root/nonroot distinction, such as metaphors, do not trigger the [singular base + regular suffix] pattern: Metaphors based on phonologically unfaithful irregular nouns manifest both the irregular suffix and stem alterations, such as *?aratsot haxaim,* lands of life, from the irregular *?erets,* land; *meorot gdolim,* great lights (referring to rabbinical authorities), from the irregular *ma?or,* light; and *nharot dam,* rivers of blood, from the irregular *nahar,* river. (This is what happens in English as well; see Kim *et al.,* 1991, 1994; Pinker, 1999). Moreover, this alternative account must explain why name plurals specifically consist of an unaltered stem plus the plural form that (as shown in the first experiment and in Berent *et al.,* 1999) also happens to serve as the default for unusual-sounding nouns, as opposed to a plural identical to that of the homophonous noun or to some arbitrary stem alteration and suffix. But an unaltered stem plus the suffix independently motivated as the default is exactly what is predicted by the words-and-rules theory.

One aspect of the data is not directly explainable by the words-and-rules theory: When pluralizing names, subjects reverted to the regular suffix more reliably (92.2%) than they reverted to the unaltered stem (71.1%). We suspect the difference comes from the fact that the reversion to the regular suffix has no significant phonological consequences, whereas the reversion to the unalterd base can yield a plural with a highly unusual prosodic pattern. For instance, all irregular nouns whose singular word pattern is CiCaCon invariably undergo vowel deletion in the plural (CiCCon-suffix, e.g., *kishalon-kishlonot,* failure). The reversion of such names to the base yields a plural form with four syllables (e.g., *kishalonim/kishalonot*). No native Hebrew noun has this phonological structure. In general, the number of syllables in a phonological word may well be constrained by the phonology of Hebrew; this has been documented in the Hebrew verb system (Bat-El, 1994; Ussishkin, 1999). The phonological markedness of the output plural form may have made subjects more squeamish about reverting to the

singular base than they were when selecting the suffix. On the majority of trials, however, names reverted to the unaltered stem and the regular suffix even though the resulting form was inconsistent with the plurals of identical nouns and their neighbors. The reversion of names to the default suffix and stem is thus clearly independent of the statistical structure of the language. These findings are explained by the view of the stem and suffix as variables. The plural forms of names are the product of distinct symbolic processes that assign the regular suffix and copy the singular stem.

GENERAL DISCUSSION

Three experiments examined a psychological theory of regular and irregular inflection, according to which irregular inflection consists of the storage in lexical memory (specifically, memory for roots) of unpredictable information about any aspect of a word form, and regular inflection consists in the application of a rule to the members of a category by default. According to this theory, differences in how people generalize regular and irregular patterns to new words cannot be reduced to differences in the phonological properties of those words (though they may occasionally interact with those phonological properties in circumscribed ways). In the languages in which the regular/irregular distinction has been explored most thoroughly, English and German, that distinction is partly confounded with whether the stem is altered (typical of irregular forms) or whether it comes through faithfully in the inflected form (typical of regular forms). Though there was already some evidence that the confound does not allow the regular/irregular distinction to be reduced to the faithful/unfaithful stem distinction (or any other phonological pattern), it is important that the effect be replicated in such a way that the psychological hallmarks or regularity in a language be disentangled completely from alterations versus faithfulness of the stem. Hebrew is such a language, because nouns with both regular and irregular plurals may undergo stem changes or fail to undergo them.

Experiments 1 and 2 showed that one hallmark of regular generalization, its relative insensitivity to similar stored nouns that would serve as a basis for analogy, takes place regardless of whether the stem is copied faithfully or altered. Experiment 3 further showed that a second hallmark of regular generalization, its application to names, even those homophonous to nouns with irregular plurals, also takes place regardless of whether the stem is copied faithfully or altered. Moreover, in pluralizing names, subjects avoided both the irregular suffix associated with the homophonous noun and the partly idiosyncratic stem alteration associated with the homophonous noun. The experiments show that the hallmarks of regular inflection

cannot be reduced to the phonological confounds seen in English, and also that the regular/irregular distinction is computed separately for the different parts or aspects of a word. A word may have an irregular stem change with a regular suffix or vice versa, though some grammatical circumstances, such as the inflection of nonroots, can select for regularity across the board by circumventing the comparison of the word to be inflected with phonologically similar words stored in memory.

Our findings raise several challenges to associative phonological accounts of inflection (Daugherty & Seidenberg, 1992; Plunkett & Marchman, 1991; Plunkett & Nakisa, 1997; Rumelhart & McClelland, 1986). These models view inflection as a phonological correspondence between singular and plural words. The representations participating in this correspondence, however, do not specify the word's formal constituents (e.g., stem, suffix) or grammatical properties (e.g., irregularity, rootlessness) by mental variables. Variables are eliminated from these models and play no role in inflection. Indeed, inflection operates in a similar fashion for regular and irregular forms, and any differences between them must be reduced to statistical differences in their associations. In particular, the distinction between regular and irregular inflection has sometimes been attributed to the differing faithfulness of regular and irregular forms to their stems (e.g., Stemberger, 1995, 1998; Rueckl *et al.,* 1997), their phonological clustering (e.g., Hare, Elman, & Daugherty, 1995; Plunkett & Nakisa, 1997), and differences in type frequency (e.g., Daugherty & Seidenberg, 1992; Marchman, 1997; Plunkett & Marchman, 1991, 1993; Rumelhart & McClelland, 1986).

The studies of Hebrew provide no support for these explanations. First, the psychological properties of regular inflection clearly cannot be reduced to phonological faithfulness. Second, the regular/irregular distinction cannot be reduced to differences in their phonological clustering (such as English irregulars forming clusters of similar-sounding verbs and regulars being distributed diffusely in the rest of phonological space), because in Hebrew, regular and irregular forms usually share the same word patterns, with the phonological clusters of regular and irregular forms overlapping (Berent *et al.,* 1999); nonetheless, the Hebrew regular suffix behaves like its English counterparts. Finally, the experiments with Hebrew demonstrate that the operation of the regular suffix as a default does not depend on an attraction to large numbers of similar regular-sounding forms. Names are given the regular suffix even when they are homophonous to irregular-sounding nouns whose morphological neighborhood is entirely irregular. Likewise, unfaithful dissimilar targets in Experiment 1 were more likely to receive a regular suffix even though their word pattern was consistently irregular. The role of the regular suffix as a default in Hebrew is thus inexplicable by the phonological correspondence between the singular and plural forms or by the statistical structure of phonological clusters.

In addition, if inflection consisted of a modification to an unstructured phonological representation of the base, as associative accounts propose, then, other things being equal, any two nouns sharing a singular form should have the same plural form, both suffix and stem. But names and their native Hebrew nouns disagree on their plural forms despite the homophony of the singular base. Proponents of phonological associative accounts of inflection point out that names and nouns have different semantic properties (e.g., MacWhinney & Leinbach, 1991; Plunkett & Juola, 1999). However, mere semantic mismatch does not, in general, turn an irregular word into a regular one, neither in English (Kim *et al.,* 1991, 1994; Pinker, 1999, Chapter 6), nor in Hebrew, where metaphors based on irregular nouns remain irregular both in stem and suffix. Moreover, the existence of a semantic difference cannot explain the novel form people produce for pluralized names. If the plurals of names are produced by associating unstructured representations, then why do regular sounding names analogize the suffix but not stem of their source nouns (e.g., *brakim-Barakim,* lightning); irregular sounding faithful names analogize the stem, but not the suffix (e.g., *sodot-Sodim,* secret); regular sounding faithful nouns analogize both stem and suffix (e.g., *Sir-Sirim,* pots); and irregular sounding unfaithful names analogize neither (e.g., *znavot-Zanavim,* tail)? Furthermore, why do speakers opt for such plurals despite no statistical support (for either stem or suffix) from similar plural forms?

The words-rules theory readily predicts this pattern by the proposal that the suffix and stems are distinct variables; hence they can independently revert to the singular base and regular suffix that acts as the default (as demonstrated by an independent test, namely its tendency to be applied to unusual-sounding nouns) regardless of the phonological properties of the resulting form and its familiarity. Associative phonological accounts have trouble explaining these findings and sometimes may fail to compute plural forms altogether. First, it is uncertain whether existing connectionist accounts can accurately capture the dissociation between the reversion to the default suffix and the base. Second, a reversion to the singular base is an identity mapping: It requires the ability to freely copy the base, regardless of its phonological contents. Marcus (1998, 2001) demonstrated that the elimination of mental variables prevents multilayer perceptrons from freely generalizing an identity function outside the model's training space. Contrary to the behavior observed in our experiments (see also Berent *et al.,* 1999; Prasada & Pinker, 1993), such models may be unable to produce the plural forms of stems that are phonologically idiosyncratic.

Hebrew nominal inflection thus presents several dissociations between the ways people generalize regular and irregular inflection and the phonological properties of regular and irregular inflection. Regular forms are generalized as a default, whenever access to memorized forms, or analogy to similar

memorized forms, fails. This default operation in turn suggests a cognitive architecture that can manipulate symbolic variables, and thus apply to all exemplars in a category regardless of their phonological content, and that can manipulate structures composed of such symbols, and thus can differentiate between phonologically identical words with different grammatical properties (Marcus, 2001; Pinker, 1991, 1999).

APPENDIX A: THE PHONOLOGICAL UNFAITHFUL TARGETS USED IN EXPERIMENT 1[17]

Source	Similar	Moderate	Dissimilar
Irregular			
bitaxon	bidaxon	bimaxon	xitamon
zikaron	zikalon	zikabon	rizagon
kishalon	gishalon	tishalon	shilafon
nitsaxon	nizaxon	nipaxon	xizanon
rikavon	rikafon	rikazon	bimakon
shiga?on	shika?on	shida?on	?igashon
shitafon	shitamon	shitagon	pikashon
shikaron	sikaron	pikaron	kimabon
timahon	timaxon	timadon	mixaton
dika?on	diga?on	diba?on	kilabon
kipa?on	kima?on	kila?on	shimakon
gilayon	ginayon	gibayon	dimakon
xisxon	xizaron	xibaxon	kilason
?iparon	?ipalon	?ipakon	kima?on
?ikaron	?igaron	?imaron	ripakon
Regular			
beged	beget	begem	gelev
berez	beres	berem	melev
gezer	geser	geper	repeg
gesher	geshel	geshed	sheged
zemer	semer	lemer	lesem
neshef	nesef	neref	meret
seret	sered	serem	getel
pesel	besel	nesel	seleb
derex	denek	deshex	pekesh
kesher	kezel	keshem	lekev
shekel	sekel	bekel	belek
gefen	kefen	befen	nefeg
kelev	kelef	keled	zefen
melek	menek	mebek	revesh
sheleg	shelek	shelen	reshek

[17] ? stands for a glottal stop; X stands for the initial phoneme in *chanuka;* sh and ts each correspond to a single Hebrew phoneme captured by a single-letter grapheme.

APPENDIX B: THE PHONOLOGICALLY FAITHFUL TARGETS USED IN EXPERIMENT 2

Source	Similar	Moderate	Dissimilar
Irregular			
vilon	vinon	vikon	pikon
gvul	gful	grul	pruf
rxov	rxof	rxod	plod
tsror	sror	lror	ldov
xalom	xanom	xashom	gashod
xalon	xalor	xalog	gamof
kinor	ginor	binor	binosh
tsinor	tsilor	tsikor	bikok
tinok	tinog	tinob	pixob
miktso?	mikso?	mikno?	mirpol
?ason	?ason	daxon	pason
xesron	xezron	xemron	shemgon
xesbon	xeshpon	xeshgon	lemkon
yitron	yidron	yimron	pidgon
kishron	kisron	kipron	bildon
pitron	pidron	pikron	biklon
shilton	shinton	shixton	mixpon
dimyon	dibyon	digyon	migshon
ra?yon	raxyon	ralyon	palkon
Regular			
xidon	xiton	xibon	dibon
dfus	dbus	dlus	kluk
kfor	kfon	kfom	shlod
dror	tror	nror	nkol
xamor	xamon	xamob	kasob
?alon	?alor	?alok	shabok
?iton	xiton	shiton	shimof
shikor	shigor	shimor	limog
mishor	mishol	mishog	birog
mishlox	mishnox	mishgox	milgof
?adon	?adon	gadon	gafon
xelbon	xenbon	xedbon	?edgon
yarxon	xarhon	yarzon	shapzon
timron	tibron	tishron	lishbon
kilshon	kinshon	kimshon	nimpon
tsiklon	tsiglon	tsirgon	tsibmon
shiryon	shinyon	shizion	pizkon
biryon	binyon	bipyon	mipron
?armon	?almon	?agmon	ragson

APPENDIX C: THE REGULAR AND IRREGULAR TARGETS USED IN EXPERIMENT 3—THEIR GLOSS AND PLURAL FORMS

	Regular			Irregular	
Singular	Gloss	Plural	Singular	Gloss	Plural
tamar	date	tmarim	nahar	river	nharot
mashal	proverb	mshalim	zanav	tail	znavot
naxal	river	nxalim	ya?ar	wood	y?arot
gesher	bridge	gsharim	regesh	emotion	rgashot
matos	airplane	mtosim	ratson	will	rtsonot
shatil	plant	shtilim	mazon	food	mzonot
sarid	remnant	sridim	ma?on	residence	m?onot
ratsif	dock	rtsifim	makom	place	mkomot
tsamig	tire	tsmigim	karon	wagon	kronot
sha?on	clock	sh?onim	malon	hotel	mlonot
seret	movie	sratim	gilayon	sheet	gilyonot
neshef	party	nshafim	zikaron	memory	zikronot
pesel	statue	psalim	kishalon	failure	kishlonot
gefen	vine	gfanim	?ikaron	principle	?ekronot
geshem	rain	gshamim	shitfaon	flood	shitfonot
sheleg	snow	shlagim	dika?on	depression	dik?onot

APPENDIX D: THE SENTENTIAL CONTEXTS FOR THE REGULAR AND IRREGULAR TARGETS USED IN EXPERIMENT 3

Regular Nouns

1. tamar

   For dessert, I served my guests *tmrim/tmrot* and almonds.

   Joseph and Irit Tamar live upstairs. The *tmrim/tmrot* tend to make lots of noise at night and wake me up from my sleep.

2. mashal

   The prime minister gave a long speech full of examples and *mshlot/ mshlim*.

   Dan and Michal Mashal are known for their strange taste in clothing. The *mshlot/mshlim* often wear one black shoe and one white shoe.

3. naxal

   Because of the heavy rains, the *nxlim/nxlot* were overflown.

The Naxal family includes eight children. The *nxlim/nxlot* like to dine in restaurants, but they are often unable to find a table for 10 people.

4. gesher

Due to the air strikes in Yugoslavia, many *gshrot/gshrim* on the Danube river were destroyed.

The famous Israeli pianist Dan Gesher and his wife, the violinist Esther, had a concert tour in Europe. The *gshrot/gshrim* will perform in Paris, Berlin, and London.

5. Matos

The aerial show displayed for the first time three new *mtosim/mtosot* produced by the Aerial Industry

Dan and Yael Matos got married in a widely attended ceremony. After the wedding, the *mtosim/mtosot* went on a honeymoon.

6. shatil

In the Tu Bishvat holiday, the kinder gardeners planted *shtilot/shtilim*.

The French Jazz singer Paul Shatil and his wife, the pianist Marie, arrived to the country for a concert tour. The *shtilot/shtilim* will perform in an open concert in Gan Ha'paamon in Jerusalem.

7. Sarid

The archeological excavations revealed amazing *sridim/sridot* dated from the first temple.

Yossi Sarid and his wife were last seen in a fancy Tel Aviv restaurant. The *sridim/sridot* raised a toast and looked happy.

8. ratsif

On Fridays, there are many passengers in the Israeli train, and the *rtsifot/rtsifim*.

The couple Edna and Joseph Ratsif are well-known scientist. To date, the *rtsifot/rtsifim* published hundreds of papers in common.

9. tsamig

In preparation for the winter, I changed the four *tsmigim/tsmigot* in my car.

During my visit to Italy, I became very friendly with the Tsamig family. The *tsmigim/tsmigot* are wonderful hosts, and I will never forget their generosity.

10. sh?on

Joseph Alon has never been late for a meeting since he keeps a collection of 10 *sh?onot/sh?onim* in his house.

The French scientists Jean and Marie Sha?on won the Nobel prize. The *sh?onot/sh?onim* discovered a gene controlling cell division.

11. seret

The Armon movie theater is presenting two foreign *srtim/srtot* and one Israeli movie.

The children of the Secret family are known for their musical talent. The *srtim/srtot* established a musical trio that was enthusiastically hailed by the press.

12. neshef

Despite their advanced age, my parents love to go on *nshfot/nshfim* until the late hours of the night.

The children of the Neshef family excel at math. Recently, the *nshfot/ nshfim* have won the youth tournament of the North.

13. pesel

Several valuable *pslim/pslot* are displayed at the garden of the Israel Museum.

Tali and Ran Pesel are celebrating their twentieth anniversary. To celebrate the event, the *pslim/pslot* went on a month tour in the Far East.

14. gefen

The Napa valley in California is known for its fertile soil that is especially fit for growing *gfnot/gfnim*.

Even though Yossi and Michal Gefen live upstairs, I have not met them yet. The *gfnot/gfnim* leave their home early in the morning and come back after midnight.

15. geshem

Last winter there were many *gshmim/gshmot* in the Galilee.

Alon and Rina Geshem live in the Galilee. About a year earlier, the *gshmim/gshmot* lived in Tel Aviv, but they had to leave due to the high cost of rent.

16. sheleg

In the spring, the *shlgot/shlgim* melted and the earth was covered with flowers.

The three sons in the Sheleg family are known for their misbehavior. Last year the *shlgot/shagim* were suspended from school five times.

Irregular Nouns

1. nahar

The Nile is among the longest *nhrim/nhrot* in the world.

Joseph and Irit Nahar live upstairs. The *nhrim/nhrot* tend to make lots of noise at night and wake up from my sleep.

2. zanav

A cow with two *znvot/znvim* was born in Kibbutz Eilon.

Dan and Michal Zanav are known for their strange taste in clothing. The *znvot/znvim* often wear one black shoe and one white shoe.

3. ya?ar

The Piraha is an Indian tribe living in the Brazilian *y?rim/y?rot.*

The Ya?ar family includes eight children. The *y?rim/y?rot* like to dine in restaurants, but they are often unable to find a table for 10 people.

4. regesh

The meeting with my ex-husband triggered in me some strong *rgsht/rgshim.*

The famous Israeli pianist Dan Regesh and his wife, the violinist Esther, had a concert tour in Europe. The *rgsht/rgshim* will perform in Paris, Berlin and London.

5. ratson

   The collective ratson is the combination of a group of people's *rtsonim/ rtsonot.*

   Dan and Yael Ratson got married in a widely attended ceremony. After the wedding, the *rtsonim/rtsonot* went on a honeymoon.

6. mazon

   In the Deli, one can find a variety of *mzonot/mzonim* and drinks.

   The French Jazz singer Paul Mazon and his wife, the pianist Marie, arrived to the country for a concert tour. The *mzonot/mzonim* will perform in an open concert in Gan Ha'paamon in Jerusalem.

7. Maon

   Na?amat organization opened three *m?onot/m?onim* for young children in the Tel Aviv area.

   Yossi Ma?on and his wife were last seen in a fancy Tel Aviv restaurant. The *m?onot/m?onim* raised a toast and looked happy.

8. makom

   To my great surprise, I found several free *mkomin/mkomot* to park my vehicle.

   The couple Edna and Joseph Makom are well known scientists. To date, the *mkomim/mkomot* published hundreds of papers in common.

9. Karon

   The locomotor is connected to four *Kronot/kronim.*

   During my visit to Hungary, I became very friendly with the Karon family. The *kronot/kronim* are wonderful hosts, and I will never forget their generosity.

10. malon

   The *mlonim/mlonot* strip on Tel Aviv beach prevents the winds from reaching the city.

   The French scientists Jean and Marie Malon won the Nobel prize. The *mlonim/mlonot* discovered a gene controlling cell division.

11. Gilayon

   I bought in the store four *glyonot/glyonim* and three pens.

   The children of the Gilayon family are known for their musical talent. The *glyonot/glyonim* established a musical trio that was enthusiastically hailed by the press.

12. zikaron

   The first day at school is one of my first *zkronim/zkronot.*

   The children of the Zikaron family excel at math. Recently, the *zkronim/zkronot* have won the youth tournament of the North.

13. kishlaon

   After three successive *kshlonot/kshlonim* in the driving test, I decided to move to biking.

   Despite their name, Michal and Yossi Kishalon are excellent students. The *kshlonot/kshlonim* skipped two classes and began their studies at the university at the age of 16.

14. ?ikaron

   My parents are known for their strong moral *?kronim/kronot.*

   Even though Yossi and Michal ?ikaron live upstairs, I have not met them yet. The *?kronim/kronot* leave their home early in the morning and come back after midnight.

15. shitfaon

   The sudden rains caused *shtfonot/shtfonim* in the Negev.

   Alon and Rina Shitafon live in the Galilee. About a year earlier, the *shtfonot/shtfonim* lived in Tel Aviv, but they had to leave due to the high cost of rent.

16. Dika?on

   Patients suffering from depression undergo prolonged *dk?onim/dk?onot.*

   Despite their serious surname, the members of the Dikaon family are quite naughty. Last year the *dk?onim/dk?onot* were suspended from school five times.

REFERENCES

Alegre, M., & Gordon, P. (1996). Red rats eater exposes recursion in children's word formation. *Cognition, 60,* 65–82.

Aronoff, M. (1994). *Morphology by itself.* Cambridge: MIT Press.

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

Bat-El, O. (1996). Selecting the best of the worst: The grammar of Hebrew blends. *Phonology, 13,* 283–328.

Benua, L. (1997). Transderivational identity: Phonological relations between words. Doctoral dissertation, University of Massachusetts, Amherst. (Available as ROA-235 on http://ruccs. rutgers.edu/roa.html)

Berent, I., Pinker, S., & Shimron, J. (1999). Default nominal inflection in Hebrew: Evidence for mental variables. *Cognition, 72,* 1–44.

Bolozky, S. (1978). Some aspects of modern Hebrew phonology. In R. A. Berman (Ed.), *Modern Hebrew Structure* (11–67). Tel Aviv: Universities Publishing Projects.

Bybee, J. (1985). *Morphology: A study of the relation between meaning and form.* Philadelphia: Benjamins.

Bybee, J., & Moder, C. (1983). Morphological classes as natural categories. *Language, 59,* 251–270.

Chomsky, N., & Halle, M. (1968). *The sound pattern of English.* New York: Harper and Row.

Clahsen, H., & Almazen, M. (1998). Syntax and morphology in Williams syndrome. *Cognition, 68,* 167–198.

Daugherty, K., & Seidenberg, M. (1992). *Rules or connections? The past tense revisited.* Proceedings of the 14th Annual Conference of Cognitive Science Society, Hillsdale, NJ.

Gordon, P. (1985). Level ordering in lexical development. *Cognition, 21,* 73–93.

Gordon, P., & Alegre, M. (1999). Is there a dual system for regular inflections? *Brain and Languages, 68*(1), 212–218, doi: 10.1006/brln.1999.2082.

Goshen, M., Livne, Z., & Shafan, S. (1970). *Hadikduk ha'Ivri hashimushi.* (Hebrew grammar). Jerusalem: Shoken.

Hare, M., Elman, J., & Daugherty, K. (1995). Default generalization in connectionist networks. *Language & Cognitive Processes, 10,* 601–630.

Kempley, S. T., & Morton, J. (1982). The effects of priming with regular and irregular related words in auditory word recognition. *British Journal of Psychology, 73,* 441–454.

Kim, J., Marcus, G., Pinker, S., Hollander, M., & Coppola, M. (1994). Sensitivity of children's inflection to grammatical structure. *Journal of Child Language, 21,* 179–209.

Kim, J., Pinker, S., Prince, A., & Prasada, S. (1991). Why no mere mortal has ever flown out to center field. *Cognitive Science, 15,* 173–218.

Lieber, R. (1980). On the organization of the lexicon. Doctoral dissertation, Department of Linguistics and Philosophy, MIT, Cambridge. Distributed by the Indiana University Linguistics Club.

MacWhinney, B., & Leinbach, J. (1991). Implementations are not conceptualizations: Revising the verb learning model. *Cognition, 40,* 121–171.

Marchman, V. (1997). Children's productivity in the English past tense: The role of frequency, phonology, and neighborhood structure. *Cognitive Science, 21*(3), 283–305.

Marcus, G. (1998). Rethinking eliminative connectionism. *Cognitive Psychology, 37,* 243–282, doi: 10.1006/cogp.1998.0694.

Marcus, G. (2001). *The algebraic mind: Integrating connectionism and cognitive science.* Cambridge: MIT Press.

Marcus, G., Brinkmann, U., Clahsen, H., Wiese, R., & Pinker, S. (1995). German inflection: The exception that proves the rule. *Cognitive Psychology, 29,* 189–256, doi: 10.1006/cogp.1995.1015.

Marcus, G. F., Pinker, S., Ullman, M., Hollander, M., Rosen, T. J., & Xu, F. (1992). Over-regularization in language acquisition. *Monographs of the Society for Research in Child Development, 57*(4), 181.

Marslen-Wilson, W. D., & Tyler, L. K. (1997). Dissociating types of mental computation. *Nature, 387,* 592–594.

McCarthy, J., & Prince, A. (1990). Foot and word in prosodic morphology: The Arabic broken plural. *Natural Language & Linguistic Theory, 8,* 209–283.

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

McCarthy, J., & Prince, A. (1995b). *Faithfulness and reduplicative identity.* ROA-60, http://ruccs.rutgers.edu/roa.html

Orsolini, M., & Marslen-Wilson, W. (1997). Universals in morphological representation: Evidence from Italian. *Language & Cognitive Processes, 12*(1), 1–48.

Pastizzo, M. J., & Feldman, L. B. (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. (1991). Rules of language. *Science, 253,* 530–535.

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

Pinker, S., & Prince, A. (1988). On language and connectionism: Analysis of parallel distributed processing model of language acquisition. *Cognition, 28,* 73–193.

Plunkett, K., & Juola, P. (1999). A connectionist model of English past tense and plural morphology. *Cognitive Science, 23*(4), 463–490.

Plunkett, K., & Marchman, V. (1991). U-shaped learning and frequency effects in a multi-layered perceptron: Implications for child language acquisition. *Cognition, 38,* 43–102.

Plunkett, K., & Marchman, V. (1993). From rote learning to system building. *Cognition, 48,* 21–69.

Plunkett, K., & Nakisa, C. (1997). A connectionist model of Arabic plural system. *Language & Cognitive Processes, 12,* 807–836.

Prasada, S., & Pinker, S. (1993). Generalization of regular and irregular morphological patters. *Language & Cognitive Processes, 8,* 1–56.

Prince, A., & Smolensky, P. (1997). Optimality: From neural networks to Universal Grammar. *Science, 275,* 1604–1610.

Rueckl, J., Mikolinski, M., Raveh, M., Miner, C., & Mars, F. (1997). Morphological priming, fragment completion, and connectionist networks. *Journal of Memory & Language, 36,* 382–405, doi: 10.1006/jmla.1996.2489.

Rumelhart, D. E., & McClelland, J. L. (1986). On learning past tense of English verbs: Implicit rules or parallel distributed processing? In J. L. McClelland, D. E. Rumelhart, & T. P. R. Group (Eds.), *Parallel distributed processing: Explorations in the microstructure of cognition* (Vol. 2 Psychological and biological models, 216–271). Cambridge MA: MIT Press.

Senghas, A., Kim, J. J., Pinker, S., & Collins, C. (1991). *Plurals-inside-compounds: Morphological constraints and their implications for acquisition.* Paper presented at the Sixteenth Annual Boston University Conference on Language Development, October 18–20, Boston, MA.

Sonnenstuhl, I., Eisenbeiss, S., & Clahsen, H. (1999). Morphological priming in the German mental lexicon. *Cognition, 72*(3), 203–237.

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

Stemberger, J. P. (1995). Phonological and lexical constraints on morphological processing. In L. B. Feldman (Ed.), *Morphological aspects of language processing* (247–267). Hillsdale, NJ.

Stemberger, J. P. (1998). Morphology in language production with special reference to connectionism. In A. Spencer and A. M. Zwicky (Eds.), *The Handbook of Morphology* (428–452). Oxford: Blackwell.

Ullman, M. (1999). Acceptability ratings for regular and irregular past tense forms: Evidence for a dual-system model of language from word frequency and phonological neighborhood effects. *Language & Cognitive Processes, 14,* 47–67.

Ullman, M., Bergida, R., & O'Craven, K. M. (1997). Distinct fMRI activation for regular and irregular past tense. *NeuroImage, 5,* S549.

Ullman, M., T., & Gopnik, M. (1999). Inflectional morphology in a family with inherited specific language impairment. *Applied Psycholinguistics, 20*(1), 51–117.

Ussishkin, A. (in press). The inadequacy of the consonantal root: Modern Hebrew denominal verbs and output-output correspondence. *Phonology, 16*(3).