German Inflection: The Exception That Proves the Rule

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Language is often explained as the product of generative rules and a memorized lexicon. For example, most English verbs take a regular past tense suffix (e.g., asked), which is applied to new verbs (faxed, wagged), suggesting the mental rule “add -ed to a Verb.” Irregular verbs (break—broke, go—went) would be listed in memory. Alternatively, a pattern associator memory (such as a connectionist network) might record all past tense forms and generalize to new ones by similarity; irregular and regular patterns would differ only because of their different numbers of verbs. We present evidence that mental rules are indispensable. A rule concatenates a suffix to a symbol for verbs, so it does not require

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access to memorized verbs or their sound patterns, but applies as the "default," whenever memory access fails. We find 21 such circumstances for regular past tense formation, including novel, unusual-sounding, and rootless and headless derived words; in every case, people inflect them regularly (explaining quirks like flew out, sabre-tooths, walk-men). Contrary to the connectionist account, these effects are not due to regular words constituting a large majority of vocabulary. The German participle -t applies to a much smaller percentage of verbs than its English counterpart, and the German plural -s applies to a small minority of nouns. But the affixes behave in the language like their English counterparts, as defaults. We corroborate this effect in two experiments eliciting ratings of participle and plural forms of novel German words. Thus default suffixation is not due to numerous regular words reinforcing a pattern in associative memory. Because default cases do not occupy a cohesive similarity space, but do correspond to the range of a symbol, they are evidence for a memory-independent, symbol-concatenating mental operation. © 1985 Academic Press, Inc.

In 1980, Allen Newell singled out one discovery as the central contribution of cognitive science (Newell, 1980; see also Newell & Simon, 1981; Fodor, 1968). According to the Physical Symbol System Hypothesis, intelligence is the product of mechanically implemented rules manipulating symbolic representations or data structures. Human language has always been a paradigm case of a rule system. Chomsky (1957, 1965) pointed out that all normal humans can produce and understand an infinite number of novel sentences, including sentences whose words have no associations with familiar meanings or with each other, like Colorless green ideas sleep furiously. This ability can be explained on the theory that people have memorized a finite list of simple words in a mental dictionary, and combine them using a finite list of rules in a mental grammar. The rules specify the arrangement of abstract symbols like Noun, Verb, Noun Phrase, and Verb Phrase, rather than words or concepts directly. Thus the rules can generate an infinite number of sentences, by specifying, for example, that a Verb Phrase may contain a Verb Phrase (thereby generating I think that he thinks that she thinks that . . .). They also can generate sentences with completely unfamiliar sequences of words, by specifying, for example, that any noun can combine with any verb and adjective, regardless of how familiar or sensible the particular noun and the particular verb are in combination (thereby generating colorless green ideas using the same rules as in strapless black dresses).

Recently, however, one domain of language has been the subject of a debate over the empirical status of rules as mental entities. English inflectional morphology seems like a transparent example of the use of rules and their contrast with memorized lexical items. Nearly all English verbs form their past tense in the same way, by adding the morpheme -ed.1 The past tense of these verbs (e.g., walk—walked, perambulate—perambulated) is said to be "regular." People pro-

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1 There are three pronunciations of this morpheme—the [t], [d], and [id] in walked, jogged, and patted—but they exemplify a predictable phonological alternation that recurs elsewhere in the language and thus appear to be the product of a separate process of phonological adjustment applying to a single underlying morpheme, /d/; see Zwicky (1975) and Pinker and Prince (1988).
ductively extend the regular pattern to new verbs, like *faxed* and *out-Gorbacheved*. Even preschool children, after hearing a novel verb like *rick* in the laboratory, readily create its past tense form *ricked* (Berko, 1958). The predictability and productivity of the pattern suggests that regular past forms are generated, when needed, by a mental rule: "to form the past tense of a verb, add -ed."

English also contains about 180 exceptional or "irregular" verbs that form their past tense in idiosyncratic ways, such as *ring-rang, go-went, and think-thought*. The idiosyncrasy and fixed number of irregular verbs suggests that they are memorized as a list of exceptions. The memory and rule components interact in a simple way: retrieval of an irregular form blocks application of the rule, preventing *breaked*. Children occasionally make "overregularization" errors like *broke*, presumably because they occasionally fail to retrieve the irregular form from memory and thus fail to block the rule (see Marcus, Pinker, Ullman, Holander, Rosen, & Xu, 1992; Marcus, 1995a).

It is crucial to distinguish two very different senses of the notion "rule" and its related concept "regular." One sense is as a purely statistical or descriptive generalization holding of most or all of a kind of phenomenon, like "planets follow elliptical trajectories." In philosophical terminology, one says that the planets "obey the rule" (i.e., merely conform to it) but do not "follow the rule" (i.e., actually consult it). This is not the sense of "rule" that Newell, Fodor, and Chomsky refer to. They posit actual mental operations that manipulate internal symbols. When spellers think to themselves, "*i* before *e* except after *c*," and write a word accordingly, they are actually consulting and following a rule (though following rules need not be conscious). Such psychological rules need not be statistically general; they must apply when invoked, but may be invoked only rarely. Thus one version of the claim that the *-ed* suffix in English is "regular" or "the rule" would just be a claim about vocabulary statistics, validated by opening a dictionary and counting. The most interesting claim is that the rule is a mental operation. The problem is how to test that claim.

Rumelhart and McClelland (1986) have suggested that regularity in the English past tense system (and rules in general) may be a fact about the language but not about language users. They designed a connectionist pattern associator network in which inflection was computed not by rules, but by a network consisting of two connected layers of neuron-like units which corresponded to bits of phonological information in the stem and past tense form, respectively. After extensive training, the model picked up the statistical contingencies between stem sounds and past tense sounds and thereby produced the correct past tense forms of 420 verbs; generalized to many new verbs, regular and irregular; produced overregularizations like *broke* during intermediate stages of training; and had more trouble with the kinds of irregular verbs that children have more trouble with. Rumelhart and McClelland concluded, "We have, we believe, provided a distinct alternative to the view that children learn the rules of English past-tense formation in any explicit sense. We have shown that a reasonable
account of the acquisition of past tense can be provided without recourse to the
notion of a ‘rule’ as anything more than a description of the language” (p. 267).

English inflection is probably not the fairest arena in which to test the psy-
chological status of rules. Unlike phrases and sentences, tensed verbs are of a
fixed length, display no recursion, and involve a combination whose second
member is drawn from a list of three (-s, -ing, -ed). Thus they do not require the
full resources of rule systems. Nonetheless, the English past tense system has
recently been the subject of intense research on the psychological reality of rules
(see Marcus et al., 1992; Plunkett & Marchman, 1993; and Ling & Marinov,
1993, for reviews). The more general debate on symbolic versus connectionist
cognitive architecture (e.g., Fodor & Pylyshyn, 1988; Smolensky, 1988; McClel-
land, 1988) often focuses on English inflection as a test case. Inflection is also
highly informative about the role of rule-based versus prototype- and similarity-
based generalization in human categorization (Bybee & Moder, 1983; Lakoff,

In this paper, we review the aspects of the English past tense system that make
a single pattern associator memory plausible for the computation of inflection:
pattern associators remember and generalize frequent patterns, and irregular
verbs fall into clusters displaying such patterns. We then present a body of
evidence that suggests that a mental rule is indispensible: English speakers gen-
eralize regular inflection under diverse circumstances in which access to memory
fails, held together only by the word’s bearing the symbol ‘‘verb’’ or ‘‘noun.’’
We then note a possible confound: the regular past tense in English is rule-
governed both descriptively (it characterizes the vast majority of verbs) and
psychologically (speakers can generalize the rule to any new word that bears the
mental symbol ‘‘verb’’). Many connectionist pattern associators exploit this
confound, because pattern associators are designed to generalize the most per-
vasive and frequent patterns. German breaks the confound: it has inflections that
are not regular or rule-governed in the descriptive sense (it does not apply to the
vast majority of forms) but are regular and rule-governed in the psychological
sense (speakers generalize it to any new word that bears the mental symbol
‘‘verb’’ or ‘‘noun’’ regardless of its availability from memory). This argues that
a mental rule is used to compute regular inflection and is not an epiphenomenon
of the statistical preponderance of regular words and the ability of pattern asso-
ciators to exploit it.

The larger goal is to call attention to a key capability of physical symbol
systems (including grammars), in contrast to systems that compute by general-
izing from similar instances (including connectionist pattern associators). The
crucial notion is that of a default: an operation that applies not to particular sets
of stored items or to their frequent patterns, but to any item whatsoever, as long
as it does not already have a precomputed output listed for it. Default cases occur
for heterogeneous reasons: an item may be unfamiliar, dissimilar to (and hence
not generalizable from) familiar items, or computationally inaccessible because
of noise in memory or because of the way the data in memory is structured. These circumstances do not define a cohesive similarity space, and hence are not well handled by models whose outputs depend on generalizing by similarity from remembered items or patterns.

In contrast, the ability to have a computation operate on a “symbol,” which embraces all possible instances in a class regardless of their featural decomposition or availability from memory, allows a symbol system to handle a default case naturally. The empirical demonstration of a clear default operation in the computation of inflection, then, has implications beyond those for the particular models proposed thus far. It implies that any model, connectionist or otherwise, will have to implement representations that correspond to symbols, and operations that apply to them.

THE PARTIAL STRUCTURE OF IRREGULAR MORPHOLOGY

The pattern-associator challenge is motivated by an important wrinkle in the classic distinction between rule and memory: English irregular verbs are somewhere in between an idiosyncratic list and a product of freely applying rules. First, most irregular past tense forms share much of their phonological material with their stems (e.g., ring and rang differ only in the vowel). Second, there are far fewer kinds of changes from stem to past than there are irregular verbs (e.g., the i—a alteration in ring—rang is also found in sing—sang, spring—sprang, and drink—drank). Third, irregular verbs displaying a given alteration are “hyper-similar” (Bybee & Slobin, 1982; Pinker & Prince, 1988): the i—a verbs share not only i, but also typical initial and final consonant clusters. These three redundancies suggest that the mental links between stem and past are not completely arbitrary, as a rote list of paired-associate items would be.

Chomsky and Halle (1968) and Halle and Mohanan (1985) propose that irregular forms are produced by minor rules, such as “Lowering Ablaut” for ring—rang. Though such rules explain stem-past similarity (because the rule takes the stem as input and modifies part of it) and pair-pair similarity (because a large number of verbs can share a smaller set of rules), they cannot explain hyper-similarity, because it is difficult to characterize necessary and sufficient conditions from a minor rule. For example, Lowering Ablaut applies to ring, sing, spring, drink, sink, shrink, and stink, suggesting that the trigger for the rule would be “i following an optional consonant cluster and preceding an optional velar nasal.” But such a rule would miss swim and begin (final consonant nasal but not velar) and sit and spit (final consonant neither nasal nor velar) and would false-alarm to bring, think, cling, fling, sling, sting, string, swing, wring, slink, wink, and blink (Bybee & Slobin, 1982; Bybee & Moder, 1983; Pinker & Prince, 1988). For this reason, Halle and Mohanan have each minor rule specifying a rote list of words it applies to. But this leaves the hypersimilarities in the list unexplained.

Moreover, people are sensitive to hypersimilarities and sporadically use them to extend irregular alterations to new verbs. Children occasionally make errors
like trick–truck, bring–brang, and wipe–wope (Bybee & Slobin, 1982; Pinker & Prince, 1988; Xu & Pinker, in press), usually with verbs that are similar to the corresponding irregulars. Adult subjects, when inflecting a novel verb like spling, sometimes produce splang or splung (Bybee & Moder, 1983; Prasada & Pinker, 1993). This tendency reflects the degree of hypersimilarity: people are more likely to inflect spling as splung than nist as nust. Some English irregulars must have come into the language by this route: caught, knelt, quit, and snuck are relatively recent additions, and alternative forms like heat–het and bring–brung are found in nonstandard dialects (Pinker & Prince, 1988). Existing irregulars that are low in frequency but hypersimilar to more common irregulars, like slink–slunk or thrive–throve, often feel neither exactly right nor clearly wrong to native speakers (Pinker & Prince, 1988; Ullman, 1993).

One solution is to enrich the notion of memory. Say the memory structure for words to which the alternations are linked is not just a list of atomic items, but also a list of the phonological patterns they contain, and that the links are not all-or-none but of graded strength. That is, i → a is joined not just to a representation of the words ring and spring, but to a representation of -ing- and -ri-, which are shared by ring, drink, spring, bring, and so on. Though the link between word and alternation ordinarily suffices to retrieve the alternation and generate the correct past tense form, this is more likely when the link is reinforced by links to the words’ various patterns. And when a word itself is not linked to an alternation but one of its phonological components is (because other words containing that component are so linked), the word is prone to being irregularized. Thus lists of irregulars will be remembered more reliably when they are hypersimilar, and new, similar irregulars can be added when word-specific memory fails or, in the case of novel forms like spling, does not exist.

A system in which not only X is linked to Y, but the features of X are linked to the features of Y, may be called an associative memory, and connectionist pattern associators are a systematic implementation. For example, Rumelhart and McClelland’s (1986) pattern associator consists of an input layer representing the stem, an output layer representing the past form, and weighted connections between every input unit and every output unit. Each node corresponds to a sequence of phonological features, such as a high vowel between two stop consonants, or a back vowel followed by a word-final nasal consonant. The model learned irregular past forms, successfully generalized them to novel irregular stems, and learned different kinds of irregulars in ways resembling children, by capitalizing on the hypersimilar patterns in the irregulars.

As a more realistic model of memory, networks like the Rumelhart–McClelland model can easily be incorporated into theories invoking minor rules. The verbs to which, say, the i–a rule applies would be stored in a pattern associator. Pinker and Prince (1988, 1992) go further to propose that such networks can also model the alternations themselves; no irregular rule would be
needed. The pattern associator would pair *sing* with *sang*, not *sing* with *i*-a; the *i*-a alternation is merely the strongest of a large ensemble of connections between stem components and past components. This proposal, while differing from that of Halle and Mohanan, is consistent with those of many other generative linguists. Jackendoff (1975), Aronoff (1976), Lieber (1980), Perlmutter (1988), and Spencer (1990) argue that semiregular patterns like those found among irregulars are the product not of real rules in the sense of mental operations, but of "redundancy rules": common patterns reinforced by similar items in memory. Pinker and Prince (1992) note that redundancy rules do just what pattern associators do, and hence the latter are a good model of the former. This treatment of the irregulars is also compatible with the schema theories of Bybee (Bybee & Slobin, 1982; Bybee & Moder, 1983; Bybee, 1993) and Köpcke (1988, 1993), which specify several templates for the typical sound patterns of past tense forms, plus the typical properties of the verbs each template is associated with. Thus there is a broad consensus that pattern associator memories have a role in irregular inflection.

The current controversy is about what to do with regular forms, which most linguists attribute to a rule. If a pattern-associator memory is already needed to link *sing* to *sang* and generalize *sling* to *sling*, why not use it to link *walk* to *walked* and generalize from *wug* to *wugged*, eliminating an "add -ed" rule? This is what Rumelhart and McClelland argued for: irregulars belong to classes of different sizes displaying different degrees of systematicity; regular verbs simply constitute a much larger, more systematic class of the same kind. Regulars and the various subclasses of irregulars would simply carve up the space of English verb sounds among them, one region associated with *-ang*, another with *-ound*, and many large regions associated with *-ed*.

The appeal of this proposal is that the memory mechanism uncontroversially needed to capture irregular patterns serves for regular verbs as well. Moreover, we would not have to try to explain how children learn a regular rule or classify verbs as regular or irregular. We will refer to this proposal as the Pattern Associator hypothesis.

Note that while the hypothesis happens to be embraced by most connectionists working on language, it is not inherent to connectionism. There could be separate connectionist subnetworks for irregular and regular mappings, the latter representing all verbs by a single "verb" node rather than a set of nodes for the verb's phonological and semantic features; this subnetwork would be gated to apply if the subnetwork for irregular mappings failed to produce an output. Such a model could be said to implement a symbolic default rule and an associative lexicon, as we argue for here. Thus the discussions in this paper are not directed at connectionism itself, just at the Pattern Associator hypothesis defended by most connectionist theorists, and at similar hypotheses that would explain all linguistic productivity as generalization by similarity.
PART 1: EVIDENCE FROM ENGLISH

If the Pattern Associator hypothesis has economy on its side, what evidence would show that generalizations of the regular pattern are performed by a symbol-concatenation rule? The hallmark of a symbol is that it can uniformly represent an entire class of individuals, suppressing the distinctions among them. Moreover, the class can be open-ended; possible members of the class are represented identically to existing ones. In the case of the past tense rule, the fact that the rule concatenates the suffix -ed to “V,” a symbol standing for the verb stem, predicts that the regular suffix can be productively attached to any verb, whether familiar or unfamiliar, similar or dissimilar to remembered regular verbs. The only exception would be when memory already contains an irregular form listed for a given verb stem; the system blocks application of the general rule to the stem (versions of this principle, called the Uniqueness, Blocking, and Elsewhere principles, are reviewed in Marcus et al., 1992). Furthermore, if memory has a pattern-associator component, then any verb that is sufficiently similar to stored irregulars, not just the irregulars themselves, should evoke irregular alternations and hence tend to suppress regular suffixation. But aside from this competition, regular suffixation should be omnipotent, applying to any word bearing the “Verb” symbol. This would offer the crucial empirical contrast to irregular alternations, which are linked to specific memorized verbs and their patterns.\(^2\)

In this section, we present evidence for regular suffixation by rule in English: in a diverse set of circumstances in which access to a memorized past tense form or pattern is prevented, held together only by the fact that a word bears the symbol “Verb” or “Noun,” people readily supply the regular suffix. There are at least 21 such circumstances, falling into several classes corresponding to ways in which access to information in associative memory can fail: there may be no memory entry (or similar entry) at all; there may be competing entries; the grammatical mechanisms that allow information in memory entries to be passed to the word may be systematically disabled; the person’s memory system may not be functioning properly. But despite such lack of memory access, generally revealed by a failure to apply an irregular form, the word is not left inflectionless: the regular rule, applying to the all-embracing, exemplar-independent symbol “Verb” (or “Noun”), succeeds in adding the regular suffix. (The arguments to be presented are independent of whether people in fact store common regular past tense forms in memory; whether they do or not, use of the regular affix does not depend on stored forms.) The circumstances are listed in Table 1.

Lack of Entry or Similar Entries in Memory

1. The verb has no past tense entry in memory. The fact that children (Berko,
TABLE 1
Circumstances in Which Memory Patterns Are Not Accessed and Regular Inflection Is Applied

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<td>Overregularizations</td>
<td><em>comed</em>, <em>breaked</em></td>
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<td>Overregularizations</td>
<td><em>comed</em>, <em>breaked</em></td>
</tr>
</tbody>
</table>

1958) and adults supply regular past tense forms for novel verbs (e.g., *snarf*, *wug*) is the traditional rationale for a rule, though the generalization abilities of pattern associators have rendered it inconclusive by itself.

2. **The verb has a weak past tense entry in memory.** Since memory strength depends on frequency of encounter, if inflection is dependent on retrieval of
words from memory, lower-frequency past tense forms should be less natural-sounding and harder to produce than high-frequency ones, holding similarity constant. Pinker and Prince (1988) pointed out that this is true for irregulars but not regulars: rare bade, slunk, and stridden sound stilted relative to their stems; rare infarcted, eked, and stunted do not. Low-frequency regular past tense forms are not rated worse (Ullman, 1993; Pinker, 1991) nor produced more slowly (Prasada, Pinker, & Snyder, 1990; Seidenberg & Bruck, 1990; Daugherty & Seidenberg, 1992) than high-frequency ones.3

3. The verb has no similar entries in memory. If memory has a pattern-associator component, lacking a past tense entry is not fatal; a past form may be assembled for similar verbs. Such analogizing is essential for generating novel irregular forms: people can inflect spling as splung, but only because of its similarity to string, sling, etc.: nist and vin do not yield nust and vun (Bybee & Moder, 1983). In contrast, people reliably supply, and give high ratings to, regular past forms for verbs that do not resemble any existing regular verb, such as ploamph and krilg (Prasada & Pinker, 1993).

Competing Entries or Similar Entries in Memory

4. The verb has a competing entry in memory. In associative memories, alternative mappings compete for patterns of input features: if a verb’s sound is linked to one kind of past tense form, it will tend to be linked to that form across all instances unless trained otherwise. But the regular form can overcome this competition, and apply to verbs whose sounds are reliably linked to an irregular form. There are several homophone sets in English where one verb takes an irregular form and the other takes a regular form; this would be impossible if both forms were generated as associations to the phonology of their stems, which are identical (Pinker & Prince, 1988). Examples include lie—lay (recline) and lie—lied (prevaricate), hang—hung (suspend) and hang—hanged (execute, in the standard dialect), fit—fit (intransitive) and fit—fitted (transitive), and meet—met and mete—meted. Note that it is the fact that the homophones are simply different words, not that they differ along some particular dimension of meaning, that allows for differences in inflection: lied differs from lay but the semantic distinctions between prevaricating and reclining do not correlate with a difference between regular and irregular inflection anywhere else in the language. This suggests that it is representations of wordhood (e.g., lexical entries) not representations of

3 Stemberger and MacWhinney (1986) claimed that people make more speech errors for low-frequency regularly inflected forms, but the comparison confounded the frequency (hence familiarity) of the verb itself with the frequency of its past tense form. Burani, Salmaso, and Caramazza (1984) found an unconfounded effect of the frequency of regular inflected words on lexical decision time in Italian, but regular inflection in Italian can be applied only when one knows which conjugational class a verb belongs in, an unpredictable, hence stored, datum that could have caused the frequency effect. Sereno and Jongman (1992) did, however, report an unconfounded effect of inflected-form frequency on lexical decision time in English.
meaning (e.g., nodes for semantic features), that are linked to irregular inflection (see Pinker & Prince, 1988, pp. 113–114; Kim et al., 1991, pp. 177–179, and 1994, pp. 178, 202–204).

5. The verb has competing similar entries in memory. Because of the associative nature of memory, families of similar listed entries should pull a new entry toward its associated pattern. But the omnipotent regular past tense process can escape this attraction: blink is inflected as blinked, not blank or blanked, despite competing drink, stink, slink, and so on. Indeed, in every irregular territory in phonological space, there are interloping regulars: jutted next to cut, shut; needed next to bled, bred; seeped next to slept, wept; glowed next to grew, blew, and so on (Pinker & Prince, 1988).

Note that this does not imply that regular verbs are not subject to attraction from competing irregular patterns. Regulars similar to irregulars are produced more slowly (Daugherty & Seidenberg, 1992) and are subject to frequency effects (Ullman, 1993), in contrast with regulars that do not resemble irregulars. Indeed such effects are inevitable given that a verb cannot be recognized as being regular until after it has been checked against memorized irregulars and found to be absent; any similarity to irregulars in an associative memory will yield a weak false-positive match signal. The point is that the regular form generally prevails for verbs rhyming with irregulars despite this pull.

The Entry Is Not a Canonical Root

Words are not represented in the mental dictionary as haphazard collections of information, but are generally in a standard format that can be called a "canonical root": an "address" or distinct identity as a word in the language; a part-of-speech category; subcategory features (e.g., transitive or intransitive for verbs, count or mass for nouns); a semantic representation; and a phonological representation. The phonological representation must conform to a canonical template for words in the language (McCarthy & Prince, in press) and is arbitrarily paired with the word's meaning (de Saussure, 1960).

Complex words may be formed out of roots by processes of "derivation" or "word formation" (e.g., unmicrowaveability, Nixon-defender), but it is the roots that are the most basic units of lexical memory storage. Crucially, information about irregular forms (e.g., "my past tense form is stuck") consists of a link to a lexical root, not just to any kind of object that can function as a word. This fact gives rise to a number of other cases where information about inflectional form cannot be taken from memory.

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4 Wordhood and semantics are often not properly distinguished. For example, Hoefner's (1992) pattern associator model is described as having "semantic representations" for words. But in fact they were arbitrary patterns randomly assigned to individual words, and did not encode the meaning of a word or the semantic similarity among words. Thus they are simply 84-bit indexes for lexical entries.
6. The word lacks a canonical root in memory. To fill lexical gaps, people sometimes use sounds that are outside the system of canonical roots. One example is onomatopoetic words, which are conceived of as not standard-format arbitrary phonological objects but as renderings of the sounds in the world they refer to.\(^5\) Onomatopoetic verbs and nouns need past tense and plural forms, but have no canonical roots, and hence cannot tap into the system of roots and their linked irregular forms that encourage irregular analogizing. Thus despite the fact that all English verb roots ending in -ing are irregular (Pinker & Prince, 1988), which should make analogy especially strong, onomatopoetic verbs ending in -ing are regular, as are other seemingly analogizable onomatopoetic forms: dinged/*dang/*dong, pinged/*pang/*pung, zinged/*zang/*zung, peeped/*pept, beeped/*bept.

7. The word is mentioned rather than used. Another kind of sound that is used as a word but that lacks a canonical root is a quotation. A quotation bears no necessary resemblance to canonical words in the language, but reflects a stretch of sound someone else has said, as in Elmer shouted "Dwat!" Of course, they may happen to be real words, as in He uses "trivial" too often, but that is a special case, not necessary to the use of a quotative construction. As with onomatopoetic forms, quoted nouns fail to access associative memory system for genuine roots. Information about stored plurals, including irregular plurals, is not tapped, but the regular applies: While checking for sexist writing, I found three "man"s/*men" on page 1.

8. The word is based on a name. In modern English, proper names are opaque stretches of sound. Some happen to be homophonous with roots (e.g., Baker, Green), because they began as mnemonic descriptors, but this is now conceived of as coincidental; a person could also bear the name Dweezil or Bftspkl. As in onomatopoecia and quotations, they are mentally represented as stretches of sound, not canonical roots, and hence do not evoke homophonous or similar canonical roots. Thus people regularize them: We're having Julia and her husband, the Childs/*Children, for dinner; Why hasn't the literary world seen any more Thomas Manns?

9. The word is an unassimilated borrowing. Other words lacking roots are foreign borrowings like latke and capuccino, which are recognizably not canonical English words but sounds taken from other languages. Despite their independence from a system of memorized roots, borrowed nouns easily receive regular inflection, as in latkes and cappucinos. Such regularization bypasses similar irregular forms: despite widespread stem voicing in thief–thieves, leaf–leaves, shelf–shelves, life–lives, etc., nouns originally borrowed from French or German take regular plural forms: beefs/*beves; chiefs/*chieves; gulfs/*gulves;

\(^5\) Of course onomatopoetic forms are usually conventional and consistent with the phonological constraints of the language, but these constraints may be violated (e.g., no word in English has the sequence found in oink), and crucially, speakers perceive onomatopoecia as representing language-external sounds.
GERMAN INFLECTION

*fifes*/fives (Curme, 1935). Similarly, virtually all French and Latin loan verbs are regular (Pinker & Prince, 1988). Presumably this is because Latinate verbs are typically polysyllabic, with stress on the second syllable, and the canonical template in English is a monosyllable or a disyllable with initial stress (McCarthy & Prince, in press; Pinker, 1989). Noncanonical borrowed verbs, even if similar to existing clusters of irregulars, are all regular: *derided*/derode (cf. *ride/rode, stride/ strode); *succumbed*/succame (cf. came).

Of course, many borrowings may get assimilated into canonical words in the language. For example, French loans like promise have taken canonical English stress and are treated identically to the native vocabulary (Pinker, 1989; McCarthy & Prince, 1990, in press.) The few Latinate borrowings that have been given irregular pasts like *cost, quit, and catch, are clearly assimilable to the English template. Presumably, whether speakers assimilate a loan word depends on the ease of distorting the word’s sound into the canonical template and on metalinguistic factors such as their awareness of the loan status and familiarity with the donor language. So unassimilated borrowings should resemble onomatopoeia, quotations, and names in being sounds that do not have a canonical lexical entry, whereas assimilated borrowings should be no different from any other root in the language.

10. The word is formed by distorting a root. Words perceived not to be roots but distortions or truncations of roots should not tap into memory for roots; the regular applies. Thus we get synched (from synchronize), not sanch. Similarly, some dictionaries list *man. as a truncation of manual; if commonly used, it seems likely that the plural would be formed as mans, not men.

11. The word is formed by artificial means. Acronyms are not roots, but are formed by an artificial method from the orthographic rendering of roots. Nonetheless they undergo regular suffixation, as in PCs and TVs. Indeed even if the acronym matches a stored irregular past form, the form is unusable, and regular suffixation would apply. If a container with a mixture of Oxygen and Xenon were referred to with the acronym OX, presumably it would not be pluralized as OXen.

The Root Cannot Be Marked for the Inflectional Feature

12. The word is derived from a root of a different grammatical category, which is incapable of bearing the inflectional feature. A denominal verb is a verb that is sensed by speakers to be based on a noun. Denominal verbs have regular past tense forms, even when homophonous with an irregular verb, as in *ringed/ *ranged the city with artillery ("formed a ring around") and *spitted/*spat the pig ("put on a spit"). See Kiparsky (1982) and Kim et al. (1991, 1994), for more examples, documentation of sources, and experimental data showing that college students, non-college-educated adults, and 4- to 8-year-old children reliably regularize denominal verbs.

The explanation is that a noun root like ring cannot have an irregular past tense associated with it because the notion of "past tense" makes no sense for a noun
and hence cannot be listed with its root. The regular rule, being the default, is fully available—indeed, is the only way—to inflect such derived verbs. Similar considerations predict regular inflection for deadjectival verbs (*righted/rote the boat "set it right"). Likewise, nouns can take the regular plural suffix whenever they are derived from other grammatical categories (e.g., *ifs, *ands, or *butts), even when there is a competing irregular sound pattern: to obtain surreptitious smokes and loafed/*loaves ("interludes of loafing"); a quotation from Curme, 1935, p. 114).

Features Cannot Percolate from Root to Whole Word (Exocentrism or Headlessness)

The regularization of rootless irregular-sounding words is part of a more general phenomenon. People’s grammatical systems contain a mechanism, “percolation,” by which the information stored with a root is passed on to a complex word containing that root (Williams, 1981; Selkirk, 1982; Kim et al., 1994; Pinker & Prince, 1992). In the constituent structure reflecting a word’s derivation from more basic morphemes, one of these morphemes is generally the head of the word, and its properties percolate up to characterize the whole word. In English and many other languages, the head of the phrase is the rightmost element, so the heads form a chain of category labels on the right periphery of a word-structure tree:

(1) 
  X
  X
  X

The head of overeat is the verb eat, so overeating is a kind of eating, and it is a verb (as represented by the topmost node), because eat is a verb. Similarly, a workman is a singular noun, and it refers to a kind of man, not a kind of work.

(2) 
  V
  N
  prefix
  over
  eat
  work
  man

The difference between a verb root that is homophonous with another verb root (#4) and a denominal that is homophonous with a verb root (#12) is that a homophonous root, as a separate word, is eligible to have a regular form, but whether it does have one is an accident; a pair of homophonous roots could both be irregular, as in rang the bell versus wrung out the shirt. But a denominal homophone must take the regular form.
Crucially, the percolation conduit from head to top node applies to all the information stored with the head: syntactic category, meaning, grammatical features (gender, animacy, etc.), and, for irregular words, the irregular form. Thus the past tense of *overeat* is *overate*, and the plural of *workman* is *workmen*. This is also why irregularity is preserved in novel forms like *out-sang*, *overshot*, *re-did*, *sawteeth*, *repairmen*, and *supervives*.

But some words are headless, or "exocentric": they differ in some property from their rightmost element, requiring that the usual pipeline of information percolation from head to top node be blocked. Denominal verbs, for example, are necessarily headless, as in *to ring the city*.

(3)

\[
\begin{array}{c}
\text{V} \\
\text{N} \\
\text{ring}
\end{array}
\]

Since the whole word, represented by its topmost label, is a verb, but the element it is made out of, *ring*, is a noun, it must be headless—if the noun *a ring* were its head, *to ring* would have to be a noun, too, which it is not. Though we have just noted that the noun *ring* cannot be listed with a past tense form for semantic reasons, even if it could be, the denominal verb *to ring* could not inherit it, for without a head and its associated data pipeline, the stored form *rang* could not bubble up to attach to the whole word. Thus even if a word has a root that *does* bear the relevant features in memory, if the word is headless, the features remain confined with the root, and are unavailable for application to the whole word.\(^7\) This gives rise to several other regularization circumstances.

13. The information stored with an irregular root is unavailable because derivation via a different category makes the word headless. Consider the baseball term *to fly out*, meaning "to hit a fly." The noun it comes from, *a fly*, is itself based on the simple verb root *to fly* ("to move while airborne"). Therefore *to fly out* does have a verb root, which has the irregular past *flew*, but the derivation that created the verb (*to fly out*) from the noun (*a fly*) yields an exocentric structure, as does the derivation that created the noun from the root verb *fly*.

\(^7\) Another way of capturing this phenomenon is to posit that no verb is truly headless. When a verb is derived from a noun, it is headed by a phonologically empty derivational suffix, which would be categorized as a verb and hence would determine the category of the whole word in a fashion parallel to that of other derived words (Wunderlich, 1986; Olsen, 1990; Neeleman & Schipper, 1992; Brinkmann, 1994; Pesetsky, in press).
Therefore, access to the memorized fly–flew connection is blocked, and the common past tense form is flied. Similar examples include The doctor casted his leg ("put a cast on," ultimately from the verb to cast but only via the noun a cast), and Vera costed out the budget ("ascertain the costs of," from the verb to cost but only via the noun the cost).\footnote{The complex structure of these seemingly simple verbs makes them liable to misanalysis by some speakers, who may short-circuit the derivation and assume that the derived verb is directly based on the root. Such speakers are predicted to retain the irregular form, explaining apparent counterexamples to the regularization phenomenon, such as the occasionally heard flew out. See Kim et al. (1991) for experimental documentation.}

For similar reasons, nouns derived from verbs are exocentric and thus form regular plurals, even if homophonous with, and ultimately derived, from that noun. For example, the denominal verb to wolf means "to gobble like a wolf." Like many verbs, it can be nominalized, referring to an instance of wолfin.

(5) N N V N wolf

With a couple of quick wolves/*wolves, Arnold consumed his entire lunch.
I hope we’ll have time for a couple of quick fishes/*fish.
Can you take a couple of leaves/*leaves through this magazine?

14. Derivation via a name blocks the percolation of information from the root entry. As mentioned (\#8), pluralized surnames like the Childs regularize because a surname is not a canonical root. But even names that do have canonical roots regularize. For example, the name Mickey Mouse is based on the noun root mouse
with irregular plural *mice*, but when the name is converted into the eponymous noun *a Mickey Mouse* ("simpleton"), the irregular is unavailable, and the regular steps in: *I'm sick of dealing with the Mickey Mouses/*Mickey Mice in Administration. Eponyms can also come from dolls (*Batmans*), theatrical roles (*the best of the Mack the Knifes*), and titles (*Christopher Reeve starred in all three Supermans*). In addition, brand names (*Renault Elfs; Spectrums*) and sports franchises (*the Toronto Maple Leafs/*Leaves; the Florida Marlins/*Marlin*) can be derived from irregular noun roots and then converted back into nouns, which form regular plurals (see Kim et al., 1994, for documentation of the effect in children).\(^8\)

The effect is a consequence of the fact that names are not common nouns, and therefore must be represented as a different kind of lexical category from N. Say a stretch of sound that functions as a word but lacks a canonical root (names, borrowings, onomatopoeia, quotations, acronyms, truncations) bears a nonspecific symbol "X" as its category label in the mental dictionary. When the rootless name is converted to a noun referring to the generic object that is pluralized, the new noun is exocentric, as in 7(a). When the name had originally been based on a noun root, the new to-be-pluralized noun based on that name is doubly exocentric, as in 7b:

\[(7)\]

```
 a. N       b. N
      X       X
     X       X
   N   N   N

Julia Child  Child (s)  elf  Elf  Elf (s)
```

The structure is percolation-proof; links to irregular forms like *elves* are trapped in the entry and the regular applies.\(^9\)

\(^8\) Occasionally product names are given irregular forms like *Vaxen* (Vax computers) and *Macintees*, but these are widely recognized as self-conscious wordplay, an oft-noted characteristic of the hacker culture from which these examples originated (Raymond, 1992).

\(^9\) The *Minnesota Timberwolves* fail to show the effect seen for the Maple Leafs and Marlins; perhaps this is because team nicknames can be taken directly from plurals when semantically appropriate (i.e., the entire team is being identified with a pack of wolves), inheriting any irregularity, just as nicknames can come from mass nouns like the *Miami Heat*. In contrast, when a name is clearly based on the singular, it does regularize, as in the navy planes called *Sea Wolves*. Similarly, for the Leafs, the team is not being identified with foliage, but each player is identified with Canada's national symbol, the Maple Leaf.

\(^9\) On semantic grounds, too, the structures must be exocentric, for the eponym *a Mickey Mouse* is not a kind of mouse in the same way that *a workman* is a kind of *man*. Moreover eponyms are
15. The semantic interpretation of a compound precludes using the features of the root. The headlessness account also explains seemingly unrelated cases where there is no category change. A low-life is not a kind of life, but a kind of person, namely one who leads a low life. This is a "bahuvrihi" compound, one that characterizes an object as having, rather than being, the referent of its rightmost morpheine. Recall that if the head-to-top-node pipeline is blocked for one kind of information, nothing else passes through automatically. Therefore there is no way for the irregularity of a headless word to percolate up: If low-life cannot get its referent from life, it cannot get its plural from life either. Memory for stored past tense forms, in this case an irregular one, is unavailable, but the regular rule steps in by default; hence low-lifes, not *low-lives. Other examples are still lifes, bigfoots (monsters), flatfoots (policemen), tenderfoots (cub scouts), loudmouths (blowhards), saber-tooths (cats), and sweet tooths (taste for sugar).

Similarly, the now-generic product name walkman commonly receives the plural walkmans (Newsweek, 8/7/1989). The word is not a recognizable kind of English compound, but an example of the pseudo-English common in Japanese products and advertising. Its structure, obscure to an English speaker, is hard to analyze as referring to a kind of man: hence it is treated as exocentric and regularized for the same reasons that bahuvrihi compounds are. See Kim et al. (1994) for data showing that children tend to regularize exocentric compounds.

16. The word is formed from a phrase, in which a root is inaccessible. Occasionally people coin a noun from a verb phrase to refer to a total that has the function specified by the VP. Again the structure is headless, and the following hypothetical product names would presumably be regularized: bag-a-leaves, protect-a-childs (car seats), shear-a-sheeps (razors).

\[(8)\]

\[
\begin{array}{c}
\text{N} \\
\text{VP} \\
\text{V} \quad \text{NP} \\
\text{bag} \quad \text{a} \quad \text{leaf}
\end{array}
\]

**Memory Failures**

In any case in which a person's memory retrieval mechanism fails to deliver a stored irregular form but that person's grammatical system is functioning, a regularized version of that form should be available.

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exocentric for three reasons. In English a proper name behaves syntactically like an entire noun phrase, not like a common noun (*the Donald; *a Gary; *I'm going to see happy Fred), so the name must be made into a NP before being converted back into a noun.
17. Childhood overregularizations. Children have not heard past tense forms as often as adults and so are expected to have less reliably accessed memory entries for them, especially the lower-frequency ones. Nonetheless they succeed in marking them for tense, in overregularization errors like holded (Marcus et al., 1992).

18. Speech errors. Normal adult memory is not perfect, either, and indeed, overregularizations occur as adult speech errors (Fromkin, 1971; Stemberger, 1985).

19. Alzheimer’s Disease. Alzheimer’s patients characteristically have word-finding problems, a part of their general memory impairment, but often have relatively preserved grammatical abilities. As predicted, they produce regular pasts more easily than irregular pasts and often overregularize the irregulars (Ullman, Corkin, Pinker, Coppola, Locascio, & Growdon, 1993).

20. Williams Syndrome. This is an unusual form of retardation involving relatively spared linguistic abilities, including excellent grammar, but deviant word retrieval, involving a reduction of the normal tendency to favor high-frequency words. The syndrome can be accompanied by high rates of overregularization errors (Bellugi et al., 1989; Pinker, 1991; Bromberg, Ullman, Marcus, & Kelly, & Coppola, 1994).

21. Anomia. Ullman et al. (1993) report a case study of an anomic patient (defined by severe word-finding problems) who had more trouble inflecting irregular verbs than regular or nonce verbs, and frequently overregularized the irregulars. A case study of a patient with agrammatic aphasia (difficulties with grammar but less severe difficulties in word retrieval) showed the opposite difference on the task.

Though there are many different circumstances in which information from stored roots is suppressed but regular affixation applies, it is important to note that the regular is not merely used whenever a form is novel, unusual, extended, or abstract. Lexical information about inflectional form can be passed to novel words in a number of circumstances, summarized in Table 2: (1) when a new word is perceived as a lexical root, and is similar enough to other roots that their associated inflected forms can transfer to it (e.g., spling–splung); (2) when a new

<table>
<thead>
<tr>
<th>Root in head position</th>
<th>Irregular-sounding words</th>
<th>Prefixes verbs</th>
<th>Endocentric compounds</th>
<th>Metaphors</th>
<th>Light verbs</th>
<th>Root in nonhead position</th>
<th>Lexical compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Simple root</td>
<td>splang, sprunk</td>
<td>out-sang, re-broke</td>
<td>sawteeth, workmen</td>
<td>(chess) men, (intellectual) children</td>
<td>blew him off, took a leak</td>
<td>mice-infested, teethmarks</td>
<td></td>
</tr>
</tbody>
</table>
word is formed by prefixation of an irregular verb, leaving the verb in head position, as in overate, out-sang, overshot, re-did, re-broke, overshrank, under-flew, and unhung; (3) when a compound is created with an existing irregular in the rightmost, head position, as in workmen, repairmen, coalmen, superwomen, muskoxen, and milkteeth; (4) when a word is used metaphorically or in some extended sense, as in men (chess pieces), leaves (of a book), and Freud's intellectual children, oilmice (Chinese peasants who scavenge oil from unguarded wells), sawteeth, snowmen, metrical feet, three feet long, and so on; (5) when a word is used in an idiom or collocation, particularly common with "light verbs" such as cut a deal, took a leak, caught a cold, blew him off, put him down, came off well, went nuts, and so on.

There is another especially interesting circumstance in which irregular forms may be used, because of their status as memorized roots, but regular inflected forms may not. Kiparsky (1982) has noted that irregular plurals easily appear inside compounds as the left-hand (non-head) member, as in mice-infested, men-bashing, teethmarks, and oxen-yoke whereas otherwise similar regular plurals do not (*rats-infested, *guys-bashing, *clawsmarks, *horses-yoke). This effect has been documented in 3- to 5-year-old children by Gordon (1985) and in adults by Senghas, Kim, Pinker, and Collins (1991). The explanation is that this lexical compounding process takes two stems from the mental dictionary and joins them together. Irregular forms are stems in the mental dictionary, and can be used in compounds, just like any other word. But regular forms are complex products of a rule, formed outside of the mental dictionary, too late in the chain of processes for inclusion in the compounding operation.12

In fact, the respective circumstances in which regular and irregular inflection can apply are not predicted by some global function of similarity, but are predicted in precise ways by the theory of rule application—all from a simple set of postulates, required independently of the facts about regular/irregular interactions reviewed above. The theory states only that (a) lexical information is stored in the form of canonical roots in the mental lexicon; (b) memory is associative, so that similar roots reinforce each other by overlap and foster analogies to similar new roots; (c) information stored with a root can apply to a word containing that root only if the root is the head of the word; (d) the mental grammar contains symbol concatenation operations which can apply to any instance of a syntactic category unless there is a competing form passed on from lexical memory. All the facts

12 By "stem" we mean a canonical uninflected word that may have been formed from a root by processes of derivational word formation (see, Selkirk, 1982; Aronoff & Sridhar, 1983). Thus dancer, which can appear inside compounds like dancer-lover, is a stem formed from the root dance. Conversely, even if people do store high-frequency regular forms like rats in memory, since the forms are not stems, they cannot easily appear in compounds. There are counterexamples, such as enemies list and chemical weapons attack, which appear to be due to a second process that can insert an entire phrase as the first member of a compound (this would automatically embrace regularly inflected forms); see Alegre and Gordon (1994) and Senghas et al. (1994) for experimental evidence.
about regular and irregular generalizations (21 circumstances in which the regular form is generalized, and 5 where irregular forms are generalized) fall out of this theory, on the assumption that irregular forms are lexically stored information and regular forms are rule products. In all and only the circumstances in which a word is sensed not to be headed by a stored irregular root (or irregular-sounding root)—that is, by default—the word is given a regular inflected form.

Another way of putting it is that the regularization circumstances do not define a cohesive similarity space. They not only fill the complexly shaped, high-dimensional interstitial space between existing clusters of irregulars (#3), but also, for rootless and headless words (#6–16), leap out of phonological space altogether and apply uniformly to several cases defined by their morphological structure, and furthermore, apply in circumstances of memory failure (#17–21) defined not by any properties of words but by the person’s developmental and neurological state. A post-memory processor that operates on a symbol such as “verb,” in contrast, embraces all these cases.

Note that we are not denying that various connectionist pattern associators might be designed and trained to handle one or more of these regularization phenomena. The crucial point is that a symbol-processor handles them all, without design features or training sequences tailored to any of the phenomena. The symbolic rule theory gives a single explanation to the hegemony of the regular form in circumstances that would otherwise seem to have nothing in common: nonexistent roots (wug), unusual roots (ploamph), headless words of a variety of kinds (flied out, low-lifes, Mickey Mouses), and rootless words (pinged, synched), without making the incorrect prediction that any form of novelty whatsoever triggers regularization. What these diverse words have in common is being instances of the same symbol. There need be no special mechanism that ensures that an unusual-sounding root like ploamph gets its suffix, with separate ad hoc mechanisms ensuring that common-sounding nonroots like ping, common-sounding headless roots like flied out, and all the rest get that suffix, too. Rather, they all earn -ed simply by virtue of all bearing the symbol V. We emphasize this to underscore the fact that people’s use of regular inflection in all of these circumstances falls automatically out of the nature of the underlying process. It is not a collection of unrelated contingencies acquired one at a time from hearing the relevant uses in speech and writing (which, in any case, would beg the question of why previous speakers of the language applied a single suffix to all of those cases to begin with). This unification of disparate phenomena is the reason that a symbol-concatenation operation, of the kind needed for syntax, is mandated for regular inflection.

Attempts to Get Pattern Associators to Generalize English Regular Inflection

These phenomena pose a challenge for associationist theories: to account for the diverse circumstances in which regular inflection can be applied productively. As mentioned, in the future connectionist models might implement a
symbol-processing path and hence handle the regularization phenomena. But the dominant trend in connectionist modeling is to try to account for the phenomena with an architecture consisting of a single pattern associator.

The Rumelhart-McClelland model was designed to display two of the phenomena: regular inflection of novel words like \emph{wug} (Table 1: \#1), and children’s overregularizations like \emph{breaked} (Table 1: \#17). Pinker and Prince (1988), Marcus et al. (1992), and Marcus (in press) have provided evidence that its explanation for children’s overregularization is incorrect. Presumably the model can also regularly inflect low-frequency words, a third circumstance (Table 1: \#2), since it can regularly inflect novel (zero-frequency) words.

The model does poorly, however, when attempting to inflect novel unusual-sounding verbs like \emph{ploumph} (Table 1: \#3) (Pinker & Prince, 1988; Prasada & Pinker, 1993). It does not reliably apply regular inflection to novel forms resembling irregulars (Table 1: \#5) (Prasada & Pinker, 1993), but since this difference from humans is only quantitative, its ultimate significance is uncertain.\footnote{The model can inflect some existing regular words rhyming with irregulars (e.g., \emph{needed}). This ability, however, may have come from a quirk of the implementation. Rumelhart and McClelland represented each word by activating not only its appropriate phonological feature nodes, but an additional set of nodes that represented distortions of the actual word. They referred to this scheme as “blurring.” But curiously, each word received the same set of blurred features on every presentation, so it was not like random noise. But many of the nodes in the model do not correspond to any phonological sequence in English, so consistent “blurring” is a way of recruiting these otherwise useless nodes as surrogates for a verb’s idiosyncratic lexical entry. Similar verbs—indeed, even homophones—with different past tense forms could then be distinguished by the connections to these nodes.} Effects of the analogue of memory failure in neurological impairments (Table 1: \#19) are uncertain, but Marchman (1993) shows that a model similar to the Rumelhart-McClelland model that is “lesioned” by eliminating connections shows selective decrements in its ability to apply regular inflection, the opposite of the pattern found in Alzheimer’s Disease patients. And because the model’s input representation consists entirely of phonological information, it is incapable in principle of regularizing words whose phonological representations are the same as those of familiar irregular words: homophones of irregulars (Table 1: \#4), derived words with roots of different categories (Table 1: \#12), headless words (Table 1: \#13–16), and rootless words (Table 1: \#6–11).

There have been many suggestions from connectionist theorists on how to deal with these problems. The most common attributes these problems to the model’s input representation, “Wickelfeatures” and its two-layer architecture, lacking a hidden layer of nodes (e.g., McClelland, 1988; Plunkett & Marchman, 1991, 1993; MacWhinney & Leinbach, 1991; Seidenberg, 1992). But these factors appear to be irrelevant. Egedi and Sproat (Sproat, 1992) performed the only focused comparison of two-layer and three-layer networks for inflection, comparing the Rumelhart–McClelland model to a version with a hidden layer and an
improved input representation and output process, trained on the same items. The new model behaved virtually identically to Rumelhart and McClelland’s: it failed to provide regular inflected forms for novel unusual-sounding words and failed to overregularize except with the same unrealistic input regime that the original model needed (see also Marcus, 1995a). And of course, adding a hidden layer cannot help a model with headless and rootless words; if a model fails to represent nonphonological information such as derivational structure, it is incapable in principle of discriminating homophones.

A second technological response is to add separate hardware features to cope with particular regularization failures. This was the approach taken by MacWhinney and Leinbach (1991) (see Prasada & Pinker, 1993). First, irregular phonological patterns (generally rhymes) support analogization, but nonetheless regular affixation can apply to words displaying such patterns, (Table 1: #5, e.g., blinked). Thus the MacWhinney–Leinbach model contained two redundant phonological representations for words in the input, one for the rhyme, allowing the analogies, one for the whole word, allowing the regular exceptions. Second, irregulars are largely idiosyncratic in form, but regular inflection predictably adds a suffix to a preserved stem (Table 1, #3). Thus the model had a second pathway which connected every input directly to its counterpart in the output, supplementing the pattern-associator network (see Prasada & Pinker, 1993, pp. 41–43). Third, some homophones verb pairs can have different past tense forms (Table 1, #4). Thus the model had extra nodes for the semantic features that are necessary to distinguish such homophones, such as features specific to the meaning of ring and specific to the meaning of wring.

But such efforts address the engineering question of what one can do to a connectionist network to get it to reproduce the facts of inflection, rather than the psychological question of how the facts of inflection fall out of the design of language mechanisms. MacWhinney and Leinbach did not motivate their design features except as fixes to Pinker and Prince’s (1988) individual criticisms. For example, they examined the handful of pairs of English words that by historical accident are homophonous with different past forms (like wring and ring), and built in innate features for just such pairs (not for all words; Kim et al., 1994). Moreover, the suggestion that the semantic features used as cues to discriminate homophones (Table 1: #4) can also be used to regularize headless and rootless words like fly out (Table 1: #6–16) is empirically inaccurate: neither specific semantic features, nor degree of semantic unusualness, systematically make an irregular verb regularize (see Table 2 and data from Kim et al., 1991). It is the more abstract notions of headlessness and rootlessness, for which semantic information is a cue, that is the reliable predictor. That is, people may ascertain that a word, like a denominal or a “has-a” compound, is headless using a combination of its meaning, the arrangements of its parts, and the parts’ relation to other words in the lexicon, but the meaning itself is not sufficient to trigger regularization, whereas headlessness per se is sufficient. Finally, the fact that
people immediately regularize headless and rootless words even in exotic circumstances like inflected quotations and truncations shows that the phenomenon has to be an automatic consequence of how regularization is computed, not a set of specific contingencies trained by exposure to regularized words from each circumstance (Kim et al., 1994).

Another augmented network was implemented by Daugherty, MacDonald, Peterson, and Seidenberg (1994). They added input nodes representing the degree of semantic distance of the verb from a homophonic noun. But these nodes do not represent the semantics of the verb itself, as one would expect if the full, standard representation of the verb was being fed into the inflection-learning device. Rather, the semantic nodes explicitly encoded the verb's relation to the noun that heads it—that is, they were an approximate implementation of morphological structure, the kind of information Kim et al. argued for. Daugherty et al. motivated this representation with reference to a suggestion by Harris (1993) that speakers regularize denominals to enhance communication (presumably to disambiguate homophones), but as Kim et al. (1994) point out, the evidence runs against the hypothesis: there are hundreds of pairs of ambiguous verbs with irregular verb roots (e.g., *blew away* = "wafted; assassinated; impressed"), and they do not regularize, and the vast majority of verbs with noun roots are not ambiguous (e.g., *grandstanded*), and they do regularize. A final problem is that Daugherty et al. had to train their model on regular past tenses of denominal verbs homophonous with irregulars (about 5% of the training exemplars). But such verbs, though scientifically interesting test cases, are used extremely rarely, and speakers cannot depend on having heard them regularized (Kim et al., 1994). More generally, the *heterogeneity* and *rarity* of the circumstances triggering regularization cast doubt on any approach that would simply add on mechanisms, and devise training sequences, specific to each circumstance. A symbolic rule automatically embraces all the default cases, and a convincing pattern associator model should do the same.

*The Type Frequency Hypothesis*

Are there any more general principles by which pattern associator models might duplicate the wide-ranging productivity of regular inflection, other than by implementing a symbol-processing path? The main one that has been proposed is type frequency: the number (and, thus, in general, the variety) of words with regular inflection. ("Type frequency" refers to the number of different words in a class, each counted once; "token frequency" refers to the number of occurrences of a word.) In addition to the various properties distinguishing regular and irregular suffixation listed in Tables 1 and 2, there is one more: the regular form applies to the majority of nouns and verbs in English, irregular forms to the minority. This was the original reason that the *-ed* suffix is called "regular" for English, in the purely descriptive or statistical sense. Since connectionist pattern associators are designed to pick up on input-output statistics, this is the sense in
which they acquire -ed suffixation as a "regular" operation. The extent to which a standard pattern associator generalizes the regular suffix depends on the frequency of the affix in the vocabulary sample it is trained on.

Connectionist modelers have been explicit about this point. Rumelhart and McClelland (1986, pp. 230–231) note,

> Because of the predominance of the regular form in the input, the network learns the regular pattern...

They modeled the onset of overregularization in children by exploiting this fact: the model overregularized when, after first being trained on a small set of verbs, 20% of them regular, it was suddenly trained on a much larger set of words, 80% of them regular. Bybee (1991), in proposing a kind of connectionist model for inflection, claims

> All types of morphological patterns can be acquired by the same process—the storage of items, the creation of connections among them, and the formation of patterns that range over sets of connections. The differences among [inflectional classes] are due largely to the number of distinct lexical items involved—a big class is more productive and forms a stronger schema than a small class. A large class has a high type frequency, that is, the number of different words containing the suffix or pattern is high (pp. 86–87).

Plunkett and Marchman (1991, 1993) demonstrated that varying the ratio of regular and irregular items greatly changes the performance of their network model. For example, they found in their 1991 simulations that increasing the number of irregular types has the consequence that "performance on the regulars deteriorates. This result can be partially, but not totally, predicted from changes in relative class size (p. 67)" and in their 1993 simulations that "generalization is virtually absent when regulars contribute less than 50% of the items overall" (p. 55). Like Rumelhart and McClelland, they had to model overregularization by changing their model's diet from one lean in regulars to one rich in regulars (Plunkett & Marchman, 1993; Marcus, 1995a). Similarly, in the Daugherty and Seidenberg (1992) model, reducing the number of regular types substantially weakened the model's ability to generalize the regular pattern to novel words. But in a training regime in which regular verbs were a large majority, the model duplicated people's ability to produce regular inflected forms for low token frequency verbs needing no more time than for verbs with high token frequencies (Prasada, Pinker, & Snyder, 1990; Seidenberg & Bruck, 1990). Seidenberg (1992, p. 113) speculates,

> One of the important tests of future models of the past tense will be to determine if they generalize in appropriate ways. I myself doubt whether this will be a serious problem, assuming the model is trained in a way that faithfully reflects facts about the distribution of regular and irregular past tenses in the language. The system is overwhelmingly regular, and the weights will come to reflect this fact, making it likely that the regular past tense will be attached to almost any novel input.

The type frequency hypothesis is grounded in general principles governing
how pattern-associator models work. High type frequency leads to generalization in these models for several reasons. Generalization occurs when a new item is represented on some of the nodes belonging to previously encountered words that have been paired with a particular output during training. Thus when many words have been paired with a particular output, the connections between their overlapping nodes and the output are strengthened many times, so a new word represented on those nodes has a higher probability of evoking that output. Furthermore, the more words that have been paired with a single output, the more different nodes, on average, will be linked with strong weights to that output (depending on how diverse the words in the training set are), so the more likely it will be that some new item will overlap with some previous one and exploit its connections. Finally, the thresholds of the nodes representing the output will be lowered when it is frequently trained, making such responses more likely across the board. For these reasons, a suitably configured and suitably trained pattern associator might in principle be able to inflect unusual-sounding words like *ploamph*, owing to their diffuse similarity to the large and widely spaced set of regular training exemplars.

At present, there is no actual evidence for this possibility, and several factors that can mitigate against it. Since in a pattern associator the same set of nodes has to represent the inflectional class of the verb (i.e., irregular versus regular) and the phonological composition of the verb, from which the stem portion of the past form is recovered, the representations of the input have to be quite fine-grained. This defines a high-dimensional input space, where new verbs' representations can fall into nooks and crannies that do not overlap previously-trained verbs and hence cannot co-opt their connections (Prasada & Pinker, 1993). Moreover, the presence of irregulars in the training set—generally with very high token frequencies (Rumelhart & McClelland, 1986; Bybee, 1985; Pinker & Prince, 1988)—means that many nodes will have to be inhibited from producing the regular output, competing with the regular mapping. That is, many of the nodes representing a new form like *ploamph* will inhibit the regular output because they have been trained to inhibit it for *go, blow, grow,* and so on.

And by itself, type frequency does nothing to help the models' problems with regularization of irregular sounding homophones, headless and rootless words, and so on, because the necessary morphological and lexical distinctions are not even represented and so the model is color-blind to them. If nodes representing semantic features, or even individual lexical distinctness, are added to the input representation as a way of approximating such information, generalization to unusual sounding words might be further curbed, as the model could learn to associate the regular ending with frequent word nodes or semantic nodes, absorbing connection strengths that would otherwise go to general patterns of phonological nodes.

Still, the important role of type frequency might allow one to give the benefit of the doubt to future pattern associator models. There might be an input repre-
sentation and network configuration that, when processing a realistic input mixture (with thousands of regular words, most of low token frequency, and a few irregulars, most of high token frequency), could generalize freely to novel, unusual-sounding, low-frequency, and most irregular-sounding words. Furthermore, if a modeler employed some input representation representing a word’s root status and morphological structure, the model might be able to exploit hidden nodes that represent all of non-irregular phonological space (if they developed in learning unusual-sounding words), and develop other hidden nodes that inhibited all the irregular regions, and use them together to select the regular suffix as the default across all the phonological and morphological circumstances that call for it, without having to be trained on each one.

Is there any way of testing the type frequency hypothesis directly, rather than speculating about what future models might do? Pinker and Prince (1988), Marcus et al. (1992), and Marcus (in press) did one kind of test: they found that the onset and degree of children’s overregularization errors were not predicted by increases in the number, or the proportion, of regular words in the parental input or the child’s own vocabulary, contrary to the predictions of Rumelhart and McClelland (1986) and Plunkett and Marchman (1993). Here we describe a more general test.

PART 2: EVIDENCE FROM GERMAN

The type frequency hypothesis exploits a correlation: the inflectional form that serves as the default in generalization is also the majority form in English. The hypothesis assumes a causal relation: frequency in the input to a pattern associator causes greater tendency to generalize. As in many correlations, a causal arrow in the opposite direction can be equally or more plausible. The language that provides the input to the child cannot be treated as an environmental given. It is itself the product of generations of learners and could reflect, rather than shape, their generalization tendencies. In particular, English words may be mostly regular because they are the product of a default generalization process—a rule—rather than vice versa.

Recall that regular suffixation is used for borrowings and derivations from other categories. These happen to be two of the major ways in which a language’s vocabulary can grow. If a language started off with a rule for a regular inflection, that rule would automatically get first dibs on these new arrivals, regardless of how many or few words originally underwent regular inflection. If for historical reasons, such as foreign invasions, ecclesiastical and scholastic influences, and trade with neighbors, a language experienced most of its vocabulary growth by borrowings, and also allowed easy conversion of words from one category to another—both true of English—then its regular vocabulary could shift from being in the minority to being in the majority, with no change in the psychology of its speakers. Thus under the rule theory, majority status and default status are psychologically independent. If they correlate, it could be because there were
historical events that put rule-generated forms in the majority. The crucial prediction, then, is that there should be languages in which the default inflection is not in the majority. The pattern-associator alternative predicts that that should not be possible.

In this paper we introduce cross-linguistic evidence from Modern Standard German (High German) which offers such a test. At first glance, the complexity of German seems like a connectionist’s dream. Mark Twain wrote (1880/1979, p. 187):

A person who has not studied German can form no idea of what a perplexing language it is. Surely there is not another language that is so slip-shod and systemless, and so slippery and elusive to the grasp. One is washed about in it, hither and thither, in the most helpless way; and when at last he thinks he has captured a rule which offers firm ground to take a rest amid the general rage and turmoil of the ten parts of speech, he turns over the page and reads, “Let the pupil make careful note of the following exceptions.” He runs his eye down and finds that there are more exceptions to the rule than instances of it.

Indeed, proponents of pattern associators sometimes point to German plural formation as an ideal test of the Type Frequency Hypothesis. Bybee (1991, pp. 86–87), for example, writes that

there are many cases of morphological systems in which no one pattern represents the regular pattern. For instance, German Plural formation interacting with the gender system offers several strong patterns and not just one rule. For this reason Köpcke (1988) argues that the situation is best handled by [associative] schemas.

Similarly, MacWhinney and Leinbach (1991:137), discussing Pinker and Prince (1988), claim that

This contrast between the regular pattern as a formal rule and the minor patterns as fuzzy families of memorized exceptions involves a number of questionable assumptions. Perhaps the most serious problem with this view is the claim that all phonological markings have some preeminent regular pattern. Consider a system such as the marking of plurality on the German noun. German plurals can be formed using -en, -er, -s, -e or -en as endings, along with possible vowel ablauting. None of these five possible suffixes is statistically predominant (Köpcke, 1988); none can be characterized as being “the regular ending.” In a situation such as this, there is simply no regular pattern at all. Are we to draw some sharp line between English and German speakers by claiming that only the former evidence “rule-governed” behavior?

Note that this argument has nothing to do with psychology: MacWhinney and Leinbach are using “regular rule” in the descriptive sense of “majority pattern,” rather than the psychological sense of “freely generalizable,” and then argue against regular rules on the basis that German has no majority pattern (see Seidenberg, 1992, pp. 33–34, for another example of this misunderstanding of linguistic rules as purely descriptive devices). The empirical question is whether the lack of a majority pattern means that German has no rule in the psychological sense of a symbol-manipulation operation that can act as the default generaliza-
tion. This requires looking at the generalization patterns of speakers, not just counting the types in the language.

We will examine two inflectional systems in German which differ from their English counterparts in the balance of regular and irregular patterns. We show that the participle suffix -t, which is less predominant in German than its counterpart -ed in English, and the very infrequent plural suffix -s, serve as important test cases: despite their low type frequency compared to English, they are generalised in heterogeneous default circumstances, just like their counterparts.

Experiment 1: Participles

The structure of the German verb paradigm is illustrated in (9). Each verb has three forms: an infinitive, a preterite, and a participle, which we list in that order (e.g., *kaufen*-kaufte*-gekauft*). Infinitives consist of a stem and the infinitival suffix -(e)n. Preterites or simple pasts are uncommon in informal speech; we do not examine them in this paper. Participles are composed of three elements. The prefix ge- occurs when the stem has primary stress on the first syllable (which is true of most German verbs). Because ge- prefixation is independent of the choice of stem pattern and suffix, we will not consider it further (for detailed analysis see Wiese, in press, Section 4.1). The second element is the verb root, which sometimes involves changes from the infinitive (most notably ablaut, i.e., vowel change). The third is the suffix -t or -n.14

(9)

Weak verbs:

*kaufen*-kaufte*-gekauft* "to buy—bought—(has) bought"
*diskutieren*-diskutierte*-diskutierte* "to discuss—discussed—(has) discussed"

Strong verbs:

*gehen*-ging*-gegangen* "to go—went—(has) gone"
*vertrieben*-vertrieb*-vertrieben* "to expel—expelled—(has) expelled"

Mixed verbs:

*rennen*-rannte*-gerannt* "to run—ran—(has) run"
*bringen*-brachte*-gebracht* "to bring—brought—(has) brought"

There are three classes of German verbs. In weak verbs, the participle is formed by adding -t to the unchanged stem (along with ge- where applicable). Because the participle form of weak verbs is perfectly predictable, we will refer to weak verbs as "regular." The participles of strong verbs are different in two

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14 For many German verbs, the verbal stem is the combination of a prefix and a root. For some "separable prefix" verbs, in the preterite (but not the participle), the prefix stands as a separate independent word. For these verbs, the prefixes are always stressed. In the class of "inseparable prefix verbs," the verb never appears independently of the prefix, and the prefix is always unstressed (except for the prefix mif— where the prefix varies).
ways: the stem generally changes, and -en is suffixed instead of -t. Finally, there is a small group of high-frequency "mixed" verbs whose preterite and participle forms undergo stem changes (as in strong verbs) but which take the same regular suffixation seen in weak verbs (-te in the past tense and -t in participles). They are similar to "weak irregular" verbs in English like sleep-slept and tell-told.

The stem changes in the strong and mixed verbs resemble (and are historically related to) the stem changes in English irregular verbs. First, in nearly every case, the participle stem shares some phonological content with the infinitive stem, e.g., gehen-ging-gegangen; singen-sang-gesungen, and schreiben-schrieb-geschrieben. Second, irregular verbs tend to come in clusters. For example, singen-sang-gesungen resembles sinken-sank-gesunken and trinken-trank-getrunken; sehen-sah-gesehen resembles lesen-las-gelesen and geben-gab-gegeben. These stem-past and pair-pair similarities suggest that the stems of German strong participles are not just a memorized list of isolates. The stem changes, however, cannot easily be described by rules with necessary and sufficient conditions. For example, the singen group has exceptions like beginnen-begann-begonnen, and the sehen group has exceptions like gehen-ging-gegangen. Furthermore, German speakers sometimes have graded judgments about the preterite and participle forms of certain verbs, like fragen, which admits of preterites frug or fragte, and stecken, which has stak and steckte. These facts suggest that stems are stored in some kind of associative memory, as in English, which can encourage generalization of the strong patterns to similar new forms.

Wiese (in press) and Wunderlich (1992) have argued that the -t of the weak verb is generated by default, just like the English -ed; it is the product of a rule that adds -t to any verb that lacks a strong form in memory, leaving its stem unchanged. Most of the criteria we have used for English apply to the German weak suffix. For example, German speakers would use the -t suffix to form the participle of low-frequency verbs like lüten "to weld" (Table 1: #2) and of novel verbs like faben (Table 1: #1), even of novel verbs that do not rhyme with any existing ones, such as ritken, tuden, teinten, quossen, and wauden (Table 1: #3). The weak suffix can also apply to verbs that are homophones with strong verbs (Table 1: #4). For example, strong-participled mahlen-gemahlen "to grind" is homophonous with weak malen-gemalt "to paint"; strong schaffen-geschaffen "to create" is homophonous with schaffen-geschafft "to work." Furthermore, -t may be used with verbs that rhyme with strong verbs (Table 1: #5). For example, strong-participled stehlen-stahl-gestohlen "to steal" rhymes with the weak fehlen "to miss"; strong saufen-soff-gesoffen "to drink (booze)"

15 There is a group of strong verbs (which take -en) in which the participle stem does not change but the preterite stem does, e.g., sehen-sah-gesehen.
rhymes with weak *kaufen* "buy" and *raufen* "wrestle"; strong *blasen–geblasen* "blow" rhymes with weak *rasen–gerasi* "rage."

Furthermore, because the weak suffix is the default, it applies to words with no available listed past root, such as onomatopoeic verbs (Table 1: #6) like *brummen* "growl," *flüstern* "whisper," and *klatschen* "clap." It also applies to verbs that are derived from other categories and thus cannot have listed inflected roots. Indeed existing denominal verbs in German (Table 1: #12) are all suffixed with *-t,* e.g., *frühstücke–gefrühstückt* from *Frühstück* "breakfast," *baggern–gebaggert* "to dredge" (from *Bagger* "excavator"), *angeln–geangelt* "to fish," *haus–gehaft* "to house." This is also true of verbs derived from adjectives, such as *kürzen–gekürzt* "shorten" from *kurz* "short," *säubern–gesäubert* "to clean" from *sauber* "clean," and many others. The effect occurs not just with existing denominal verbs, but with novel ones: for example, the participle of *gorbotschowen,* "to Gorbachev," must be *gegorbotschowt.* Furthermore, the effect occurs with verbs formed from nouns formed from irregular verbs, that is, verbs that have irregular roots but do not have them in a head position from which the regular form can percolate (Table 1: #13). For example, the irregular verb *halten–hielt–gehalten* "to hold" can be converted into the noun *Halt* "a hold" which can be used in the compound *Haushalt* "household." The compound can then be turned back into a verb ("to housekeep"), but the irregular forms are unavailable and the regular suffixes apply: *haushalten–haushaltete–gehaushaltet.*

Furthermore, German speakers are prone to overapplying the *-t* suffix to strong verbs. Overregularization errors in adult speech (Table 1: #18) have been reported by Meringer and Mayer (1895), Meringer (1908), and MacKay (1970). Clahsen and Rothweiler (1992) presented evidence on overregularization in German children (Table 1: #17). In a longitudinal study of 22 children (19 were language-impaired, but they behaved similarly to the unimpaired children), they found that the children systematically overapplied *-t* (at rates comparable to those of English-speaking children; Marcus et al., 1992), but not *-en:* they found 94 instances of overapplied *-t* (e.g., *ausgetrinkt* for *ausgetrunken*), but only 4 instances of overapplied *-n* (e.g., *geschlachtet* for *geschlachtet*), despite approximately equal numbers of opportunities. Furthermore, there were no examples of a participle in which an irregular stem pattern was extended to a weak verb, (e.g., *gesogen* instead of *gesagt*). The only stem errors they found were in 68 cases where the infinitival stem was used in the participle (i.e., the regular pattern), rather than the correct irregular ablauted stem. Similar results came from a participle elicitation experiment (Weyerts & Clahsen, 1995) in which 70 normal children from 3:10 to 8:10 generalized *-t* to novel verbs more than 80% of the time, even when the novel verbs rhymed with existing irregulars.

In sum, by the same tests that establish that *-ed* is the default past tense suffix in English, *-t* is the default in German, whereas suffixation of *-n*, together with particular vowel-changes, depends on word-specific idiosyncratic information
which must be stored in memory (Wunderlich, 1992; Wiese, in press). For similar reasons, the mixed verbs or their stems must be stored.

Comparison with English: Statistics

It has long been noted that English has a larger ratio of weak to strong verbs than is found in the other Germanic languages. However, how one quantifies this difference and whether the difference amounts to the weak verbs being in the minority of German, depends on unsettled assumptions about the mental representations of verbs fed into the inflection-learning process (see Marcus et al., 1992, Ch. 5).

Rumelhart and McClelland (1986) wrote:

The [simulation] run was intended to capture approximately the experience with past tenses of a young child picking up English from everyday conversation. . . . Although the child would be hearing present and past tenses of all kinds of verbs throughout development, we assume that he or she is only able to learn past tenses for verbs already mastered fairly well in the present tense. This is because the real learning environment does not, in fact, present the child with present-tense/past-tense pairs. Rather, it presents the child with past-tense words in sentences occurring in real-world context. The child would therefore have to generate the appropriate present tense form internally with the aid of the entire sentence and context, and this, we suppose, requires that the child already know the present tense of the word. (Rumelhart and McClelland, 1987, p. 222)

This entails that learning is driven by tokens: every time a parent uses a past tense form of a verb the child knows, a learning episode takes place, so more frequently used verbs should be processed more often. But Rumelhart and McClelland did not run their simulation according to their assumptions about learning: they fed each verb to the model once per epoch, regardless of its frequency. Presumably they did so because even in English, regular verbs constitute a minority of tokens (35–45%; see Marcus et al., 1992, and below), which would not lead to proper generalization of the regular suffix (Pinker & Prince, 1988; Plunkett & Marchman, 1993). By feeding the model types rather than tokens, regular verbs could be in the majority (though the psychological assumption that inflection learning is fed by entries from the mental lexicon is inconsistent with the common claim that connectionist models render lexical entries unnecessary). In any case, regardless of what Rumelhart and McClelland did, type frequency must be the measure with which German and English are compared, or else not even English would support the connectionists’ frequency-based hypothesis about generalization.

The total number of types in a language, however, is not countable, because it depends on how many specialized and archaic literatures one samples. Nor is it psychologically relevant: the existence of an obscure jargon verb in a scientific journal cannot affect the reader of a fishing magazine or vice versa, and neither verb can affect someone who reads neither.

Working on the assumption that the relatively common verbs are the basis for
inflection learning, Clahsen and Rothweiler (1992) examined a constant number of relatively common verb types. In Ruoff’s (1981) sample of 500,000 tokens of spoken German, there are 105,939 verb tokens. The 1000 most frequent types account for 96% of the tokens. Table 3 shows the relevant comparison for the 1000 most frequent verb types, and the comparable estimates from English, based on Francis and Kucera (1982)’s Brown Corpus of a million words from written sources. (All frequencies are for the verbs’ lemmas, that is, the sum of all of their inflectional forms, not the frequencies of the participle forms alone.) In both languages, the mean token frequency of regular verbs is far lower than of irregular verbs (Table 1: ≠2). Crucially, whereas in the English sample regular types are in an 86% majority, in the German sample regular types are in a 45% minority. (Mixed verbs belong with irregulars, both for commensurability with English in which “mixed” forms like told and slept are considered irregular, and because their idiosyncratic vowel-change must be memorized which makes them

<p>| TABLE 3 |</p>
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<tr>
<td>German</td>
</tr>
<tr>
<td>Strong (irregular)</td>
</tr>
<tr>
<td>Meier</td>
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<tr>
<td>Type frequency</td>
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<tr>
<td>Ruoff: 1000 most frequent verbs</td>
</tr>
<tr>
<td>Type frequency</td>
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<tr>
<td>Token frequency</td>
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<td>Mean token freq.</td>
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<tr>
<td>CELEX: All verbs</td>
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<tr>
<td>Type frequency</td>
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<td>Token frequency</td>
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<td>Mean token freq.</td>
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<tr>
<td>CELEX: All monomorphemic verbs</td>
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<tr>
<td>Type frequency</td>
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<tr>
<td>Token frequency</td>
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<tr>
<td>Mean token freq.</td>
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</table>

| English                                  |
| Irregular                                | Regular          |
| Type frequency                           | 14% (136)        | 86% (864)      |
| Token frequency                          | 60% (93,083)     | 40% (63,158)   |
| Mean token freq.                         | 684.4/million    | 73.1/million   |
| Francis & Kucera: All verbs              |                  |                |
| Type frequency                           | 5% (223)         | 95% (3943)     |
| Token frequency                          | 55% (93,587)     | 45% (77,359)   |
| Mean token freq.                         | 419.7/million    | 19.6/million   |
behave linguistically like the irregulars. But even adding the mixed verbs to the regular set does not bring the total proportion into the majority.) The ratio of regular to irregular tokens is also greater in German than in English. Similar estimates come from Meier’s (1964) data on the 1200 most frequent word forms in German, which included 34 participles: 68% were strong, 23% weak, and 9% mixed.

However, one must bracket the estimates of German and English speakers’ experience by examining larger samples, because regular verbs in both languages are lower in frequency, so larger samples will shift the balance in the direction of the regulars. Table 3 also presents data from the German CELEX database, which consists of approximately 381,000 distinct inflected forms of 50,000 word types (lemmas), covering about 83% of the “Mannheim” corpora. These corpora contain nearly 6,000,000 tokens, most from written text of a variety of discourse types (e.g., literature, newspapers, science, as well as 600,000 from speech), including a large number of words that appear in German dictionaries but were not attested in the written texts (and hence are listed with token frequencies of zero). English data come from the full Brown corpus, which is a fifth of the size of German CELEX and hence biases the comparison in favor of German in terms of the percentage of regular types. In these larger samples (see Table 3), there is still a difference between the proportion of verb types that are regular—95% of English types versus 78% of German types—though the proportion in German is no longer in the minority.

One additional complication in the comparison is that in German, many verbs have a common stem but are distinguished by having different separable prefixes and different meanings such as *ankommen, aufkommen, and bekommen*. Bybee (1993) suggests that because the prefixes can be separated from the stems in finite constructions, they are analogous to sets of English verb-particle combinations such as *give up* and *give out*. She argues that counting them separately inflates the number of irregular verbs in German, presumably because irregular roots are more likely to be found in sets of separable-prefix verbs than regular roots are. When the roots (“grundverben”) shared by separable-prefix verbs are tallied individually, about 83% of the 1000 most frequent roots are weak; a similar percentage applies to all the roots in Ruoff, and to all the monomorphic verbs in CELEX. English, as expected, has an even higher proportion of regulars among its verb roots: 91% of the 843 verb roots we counted by hand in 6123 verb lemmas in English CELEX. (This is a conservative estimate, because we defined the verb roots broadly using morphological, not semantic criteria, so

---

16 The database can be obtained by contacting celex@mpi.nl.

17 “Doublet” verbs having both regular and irregular forms were counted with the irregulars in both languages; they are few enough in number that the proportions are unchanged regardless of how they are counted. Note that the CELEX database contains many errors and is frequently updated, so exact numbers cannot be taken too seriously.
that include, preclude, conclude, and many other sets of regular verbs were counted as a single root.)

But note that this method of counting assumes that learners analyze verbs into their morphological structure, so that the inflection learning mechanism is fed individual roots (regardless of how many separable-prefix verbs each one appears in), rather than the verb types themselves. This assumption runs against the standard connectionist hypothesis that pattern associators obviate the need for morphological analysis. Moreover, Bybee’s claim is questionable: traditionally, separable-prefix verbs have been treated as distinct verbs (analogous to come, become, overcome in English) because their meanings are not semantically predictable from the meanings of their stem and their prefix, they are orthographically and phonologically rendered like single verbs, and in the participle forms, which we are concerned with here, the prefix is never separated from the stem. Moreover, Claassen (1982), Poeppel and Wexler (1993), and Broihier et al. (1994) have found that German children (at an age in which they are generalizing -t) do not separate the prefix in these verbs and appear to treat them as unanalyzed items.

In sum, the dominance of the regular pattern among English verb types is not seen to the same extent in German verb types, and may be in the minority in samples relevant to learners. Because of several uncertainties both in how to count the verbs, and in precisely what proportion of a pattern associator’s input must be regular for a regular pattern to be treated as the default, the comparison between English and German participles must be interpreted with caution.

Much of the data we have discussed consists of grammatical phenomena that either have entrenched themselves in the two languages or represent widespread patterns of judgments and generalizations. For English, several of these phenomena have been corroborated in experiments eliciting graded judgments of native speakers (Kim et al., 1991; Bybee & Moder, 1983; Prasada & Pinker, 1993; Senghas et al., 1991). In Experiment 1 we seek similar corroboration for one of the key grammatical phenomena among German speakers: that they use the weak suffix in the default circumstance of a verb being derived from a noun, even if it is homophonous with a strong verb. If they do, it would further confirm that generalization of a suffix in default circumstances occurs in speakers of languages other than English, and does not depend on a frequency ratio as high as is found in English.

**Method**

**Subjects.** Thirty-two adult native speakers of German from northern Germany were paid for their participation.

**Procedure.** Subjects were given a paper-and-pencil test containing 19 test items and 16 filler items, randomly ordered. Each test item consisted of a context paragraph which used a word either as a noun or a verb, and test sentences in which the word was used as the root of a prefixed verb in its participle form. Thus the subjects should have interpreted the test verb either as a denominal verb, when the first mention had been a noun, or as a verb root. The roots were presented in contexts that involved a
semantic extension of their usual senses. This was done to rule out the possibility, suggested by Lakoff (1987; see Kim et al., 1991), that mere semantic extendedness, rather than headlessness or rootlessness, encourages regularization (for example, the past tense of fly out would be regular because its meaning is not a central sense of to fly."

Each test item contained two sentences, one with each form of the participle: a regular formed with the -t suffix and no stem change, and an irregular formed with a stem change and the -en suffix. Here are two items with English translations (the test participles are rendered as rough English analogues). A full list of the materials can be found in Appendix I.

Extended: (From pfiefen "to whistle")

Die schöne Ilse glaubt, mit ihrem Pfeifen Karriere beim Film machen zu können. Wenn sie beim Vorstellungsgespräch gefragt wird, was sie kann, fängt sie keineswegs an, aus Goethes Faust zu zitieren. Nein, nein, Ilse beginnt zu pfiefen.

["Pretty Ilse thinks she’ll have a career in the movies by her whistling. When asked at the audition what she can do, she doesn’t start reciting Goethe’s Faust at all. No, Ilse starts to whistle."

Mittlerweile hat sie schon sieben fassungslose Regisseure bepfiffen.

Mittlerweile hat sie schon sieben fassungslose Regisseure bepfiffen.

["Meanwhile, she has already be-whistled/be-whistled seven speechless directors."

Denominal: (From Pfeife "pipe")

Die kleinen dreieckigen Pfiefen fuer Yuppies sind bei der Kundschaft gut angekommen.

Täglich muß Tabakhändler Meier die Regale auffüllen, auf denen die Pfiefen ausgestellt werden. Morgens ist daher immer seine erste Sorge:

["The little triangular pipes for yuppies are a success with the customers. Everyday the tobaccoist, Meier, has to fill the cabinets on which the pipes are exhibited. Therefore, his first concern every morning is:"

Sind die Regale auch schon bepfiffen?

Sind die Regale auch schon bepfiffen?

["Have the cabinets already been pippen/piped?"]

Subjects were asked to rate each test sentence on a 7-point scale, with 7 = "totally natural" and 1 = "totally unnatural." In the instructions, the scale was explained using grammatical and ungrammatical examples that did not involve denominals. As in Kim et al. (1991), subjects were instructed to pay attention to the context sentences, to rate the two test sentences independently (i.e., they were shown, with the help of non-denominal examples, that a verb can have regular and irregular forms that are both natural, or both unnatural), to base their ratings on what sounds most natural to their ears as opposed to what they would guess "sophisticated" usage would consist of, and not to treat the items as examples of jokes, puns, or wordplay.

Each denominal verb had a homophonous counterpart of an extended verb root with the same prefix. Fifteen verbs had inseparable prefixes (verspinnen, verblasen, verbacken, verbergen, verklingen, verscheren, verschlingen, vertragen, verwiegen, begraben, beschneien, bereiben, besitzen, befiegen, bepfiefen). The remaining 4 had separable prefixes (ausliegen, ausweichen, abreisen, abringen). A subject saw a given verb either as a semantically extended verb root or as a denominal verb. There were four counterbalanced versions of the questionnaire, such that each subject saw about half the verbs as denominal verbs, and half the verbs as semantically extended roots. Each subject received half of the test sentences with the regular participle before the irregular participle, and the other half with the irregular participle before the regular participle; the ordering was reversed for half the subjects.

The 16 filler items contained an existing regular or irregular verb, used in a standard sense, half with separable prefixes and half with inseparable prefixes. Their ratings were not analyzed.
Results and Discussion

Figure 1 presents the mean ratings of regular and irregular participle forms of the denominal and extended verbs (means for individual items are in Appendix 1). As predicted, subjects judged regularly inflected participles as better than irregularly inflected participles when the verb was denominal (means 3.3 vs 2.1), but preferred irregularly inflected participles when the verb was merely extended (means 5.1 vs 2.0). (The low ratings for both inflected versions of the denominal reflects the awkwardness and novelty of the derived verb itself.) The interaction is statistically significant with subjects as the error term, $F(1,28) = 105.83$, $p < .001$, and with items as the error term, $F(1,18) = 88.69; p < .001$. Sixteen of 19 denominal items were judged as better in the regular versions (2 items were given the same mean ratings, and one was judged better as an irregular), and 18 of 19 extended items were judged as better in the irregular versions (the nineteenth was judged as better as a regular).

Thus in German, as in English, denominal verbs are judged as better when regularly inflected, even when homophousous with verb roots that take irregularly inflected participles. Moreover, mere novelty or extendedness, unlike denominal derivation, is not enough to reverse the usual preference for the strong participle forms of these irregular roots. The results show that when inflecting verbs, German speakers take into account the morphological structure of verbs, and use the -t suffix as the default way of forming past participles. Verb inflection processes in English and German are qualitatively similar despite quantitative differences in the balance between the number of regular and irregular verbs in the languages’ vocabularies, with German regular verbs falling well short of the

![Fig. 1. Mean ratings of regular (-t) and irregular (-en) participle forms of novel German verbs that were presented either as semantic extensions of existing German verb roots (Extended) or as derived from German nouns (Denominal).](image-url)
95% proportion found in English corpora, and forming a minority of the commonly used verbs.

**Experiment 2: German Plurals**

Though the German participle system allows some comparison to English, the default suffix in the participle system still applies to half or more of German verbs. And though all the irregular verbs take the suffix -en, there are a number of ablaut (stem vowel change) patterns among them, so no single irregular pattern across the whole word is as frequent as -t suffixation (though this heterogeneity is even more marked in English, and was mitigated in Experiment 1 by presenting novel participles with the ablaut pattern most highly associated with the test item). Thus the German plural system could provide an even stronger test of the type frequency hypothesis, because no single plural form applies to a large percentage of nouns.

German has five plural suffixes, -(e)n, -s, -e, -er, and zero, three of which also allow umlauting of the stem vowel (Table 4). We will ignore umlaut, because it seems to be governed by an independent phonological rule of fronting which applies under specific morphological conditions (Wiese, 1987, 1994). For similar reasons, we ignore the allomorphy between -en and -n (Wiese, in press: Section 4.3.1). Orthographic -e in suffixes represents stressless schwa.

To varying degrees, the use of these forms with specific nouns is arbitrary. There are no known systematic correlations between the type of plural form a noun takes and semantics of its root, with the possible exception of some minor patterning according to animacy among some nouns. There are some correlations between plural form and the gender and morphophonology of the root, though like the English past tense forms, they defy simple summary. Descriptive grammars of German list typical plural forms for various kinds of nouns, but, as Twain noted (Twain, 1880/1979; see also Köpcke, 1988; Mugdan, 1977), long lists of
exceptions as well. The most systematic attempt to account for plural noun formation in German through descriptive (non-generative, nonpsychological) rules led to ten rules and fifteen lists of exceptions (Mugdan, 1977:87ff), which we reproduce in Appendix 2.

For example, masculine and neuter nouns ending with final schwa syllables such as -er and -el usually form the plural with zero, but plural forms such as Bauern "farmers," Vetter "cousins," Muskeln "muscles," and Pantoffeln "slippers" exist as well. Even families of rhyming words exhibit exceptions, like, Kind-Kindere, Rind-Rinder, but Wind-Winde.18

The -s plural suffix is in a decided minority in the German language, and unlike the case of particles, this conclusion comes both from samples of commonly encountered nouns and from very large samples. We present measures from three sources. First, Janda (1990) examined a corpus of 600,000 words in taped interviews (Pfeffer, 1964). He found that of the 200 most common nouns (with token frequencies from 100 to 2500 per million), 42% have plurals with -(e)n, 35% with -e, 12% with zero, 10% with -er, and only 1% (Autos and Hobbies, 115th and 134th in token frequency) with -s. Another five nouns take -s as an alternative, nonstandard plural form (such as Jung-s rather than Jung-e "boys"), raising the estimate to 3.5%

Second, Janda analyzed a standardized list of crosslinguistically common words (the "Swadesh list," often used in historical linguistics to measure language change). He found that -s was the least common suffix, not appearing at all in the list of 87 nouns. The other suffixes were ranked as follows: -e, 39%; -en, 28%; zero, 17%; -er, 11% (the other 5% allow no plural form).

Third, we conducted our own analyses of CELEX, which contains about 24,906 noun lemmas with plural forms listed in dictionaries or corpora, of which 16,958 types were attested at least once in the textual database (the other types appeared only in dictionaries, and hence had frequencies of 0).19 Only 4% of

18 Derivationally suffixed words have completely predictable plural forms. For example, words suffixed with -ung takes the -e plural; words suffixed with -er, -ler, and -ner require zero, and the majority of the feminine derivational suffixes such as -e, -schaft, -heit, -keit, and -ung form the plural with -(e)n. The obvious explanation is that the derivational suffixes themselves are just like words, some with their own irregular plural forms; these suffixes may then serve as the heads of the complex words they are part of (see Lieber, 1980; Williams, 1981; Selkirk, 1982; but also Anderson, 1992). This account might also explain the only truly exceptionless regularity between German stems and their plurals, that feminine nouns ending in -e form the plural with -n. Wiese (1986) suggests that the -e is a meaningless derivational suffix and hence selects its own plural form, which is inherited by any stem that hosts it.

19 We exclude names and pronouns to avoid an artifact in mean token frequencies. To maximize sample size, our tables present frequencies of lemmas, not plural forms alone; we assume that different kinds of nouns are used in the plural at about the same rate. But the names and pronouns in CELEX wildly violate this assumption: their lemmas can be extremely high in frequency, but they are used in the plural only in exotic circumstances. For example, the pronoun Sie "you" occurred 3476 times in the singular, and once in the -s plural, presumably as a quotation (comparable to mes
these types take plurals with -s, accounting for 2% of the 928,148 noun tokens. The percentage of types remains the same if one includes the nonattested nouns: 4% (946) of types in the entire list are regular.

The estimates are summarized in Table 5. Each measure has drawbacks; Janda’s are from a relatively small corpus, and the CELEX estimates are based largely on automated analyses and are still riddled with errors. The proportions from CELEX are higher than in Janda’s estimates because nouns taking -s are lower in token frequency (cf. Table 1: #2) and thus will be less well represented in smaller lists. Nonetheless they are clearly in a minority even in this very large sample. Note, too, that unlike the case of participles, no assumption about learners’ morphological analysis can put the regular suffix into the majority. When the monomorphemic noun types in the CELEX corpora are tallied separately, nouns

and yous in English). It would have been highly misleading to average the token frequency of 3477 from this unusual case with the much lower token frequencies (both singular and plural) of all the other -s-taking nouns. Similarly, there were 32 names listed as having -s plural in CELEX, most with token frequencies of 0 or 1, but a few, like Europa and Berlin, with token frequencies in the hundreds, so the mean token frequency of noun lemmas that can take -s would have been misleadingly inflated by including them. Note that only the mean token frequencies are affected; the percentages of types and of tokens change only minimally.

### Table 5

<table>
<thead>
<tr>
<th></th>
<th>Non-s-plural</th>
<th>-s-Plural</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>German</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type frequency</td>
<td>99% (198)</td>
<td>1% (2)</td>
</tr>
<tr>
<td><strong>Swadesh</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type frequency</td>
<td>100% (87)</td>
<td>0% (0)</td>
</tr>
<tr>
<td><strong>CELEX: Nouns attested in corpora</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type frequency</td>
<td>96% (16,294)</td>
<td>4% (664)</td>
</tr>
<tr>
<td>Token frequency</td>
<td>98% (905,428)</td>
<td>2% (22,720)</td>
</tr>
<tr>
<td>Mean token frequency</td>
<td>11.1/million</td>
<td>6.8/million</td>
</tr>
<tr>
<td><strong>CELEX: All nouns</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type frequency</td>
<td>96% (23,960)</td>
<td>4% (946)</td>
</tr>
<tr>
<td>Token frequency</td>
<td>98% (905,428)</td>
<td>2% (22,720)</td>
</tr>
<tr>
<td>Mean token frequency</td>
<td>7.5/million</td>
<td>4.8/million</td>
</tr>
<tr>
<td><strong>CELEX: Monomorphic nouns attested in corpora</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type frequency</td>
<td>91% (2,139)</td>
<td>9% (208)</td>
</tr>
<tr>
<td>Token frequency</td>
<td>97% (334,446)</td>
<td>3% (8,701)</td>
</tr>
<tr>
<td>Mean token frequency</td>
<td>31.2/million</td>
<td>8.3/million</td>
</tr>
<tr>
<td><strong>English</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type frequency</td>
<td>2% (161)</td>
<td>98% (6,590)</td>
</tr>
<tr>
<td>Token frequency</td>
<td>3% (6,554)</td>
<td>97% (191,301)</td>
</tr>
<tr>
<td>Mean token frequency</td>
<td>40.7/million</td>
<td>29.0/million</td>
</tr>
</tbody>
</table>
taking 
$s$ consist of 9% of the 2,347 types and 3% of the 343,147 tokens. Therefore we can be confident that the frequency of 
$s$ as measured by types is less than 10%, and by tokens, less than 5%, regardless of how they are counted. English nouns taking 
$s$ plurals, in contrast, constitute 98% of the pluralizable noun types and 97% of pluralizable noun tokens in Francis and Kucera (1982), according to our hand counts. (The mean token frequency differences between regular and irregular nouns are less extreme than one might expect because of the many specialized Greek and Latin nouns that admit of irregular plural forms, like 
*alga* and *bronchus*.)

But among the plural allomorphs, 
$s$ is special in several ways—exactly the ways that make up the default circumstances of inflection. This may have been first pointed out by Van Dam (1940), who called 
$s$ the *Notpluralendung* "emergency plural ending" (also see Wiese, 1986; Bornschein & Butt, 1987; Janda, 1990). First, the use of 
$s$ is morphophonologically free: 
$s$ appears when the phonological environment does not permit any other plural allomorph (Table 1: 
#3). The morphophonological space of German noun plurals varies on several dimensions, including gender, syllable structure, and rhyme structure. Irregular suffixes are restricted to particular regions. For example 
*er* applies predominantly to neuter nouns and never to feminines. But noncanonical words may fit in regions outside of the phonological space in which the only suffix that threads is 
$s$. This is especially obvious in the case of unassimilated borrowings (Table 1: 
#9). For example 
*Café*, which has noncanonical stress, takes the 
$s$ plural, as does unusual-sounding 
*Kiosk*. Köpcke (1988, p. 325) found that of 182 recent German borrowings, about half were formed with 
$s$. However, as in other languages, some historical borrowings can become assimilated into the canonical template for roots; in such cases an irregular can be applied, such as 
*Computer–Firma–Firmen, Manuskript–Manuskripte*.

Furthermore, 
$s$ can even appear with stems that rhyme with existing irregular nouns (Table 1: 
#5). Bornschein and Butt (1987, pp. 142–143; translation ours) argue that

... it is important to state that the 
$s$-plural mainly occurs independent of such factors, i.e., with words whose phonological features in other cases allow other plural markers: 
*Reelinge* "railings," but 
*Ringe* "rings," 
*Scheelks* "cheques" but 
*Elecken* "spots," 
*Labels* but 
*Kabel* "cables," 
*Tiefs* "trousers" but 
*Brieze* "letters," 
*Riffs* "reefs" but 
*Kniffe* "tricks," etc. Thus, the suffix 
$s$ is the only plural that can appear in any part of the morphophonological space.

Moreover, in a wide variety of special grammatical circumstances, 
$s$ trumps the other plurals, regardless of phonology (Bornschein & Butt, 1987). In German, as in English (Table 1: 
#8), pluralized nouns based on names homophonous with irregular nouns generally take regular inflection, hence 
*Manns*/Männer, 
*Wiesen*/Wiesen. This occurs not only with semantically opaque surnames, but with product names (Table 1: 
#14) that have salient canonical roots but are headless. For example, the car model 
*Opel Kadett* would be pluralized as 
*Ka-
despite the fact that the common noun *Kadett* ‘cadet’ forms its plural as *Kadetten* (similarly, we find *Volkswagen Golf* und *Jettas*, based on the names of winds).\(^{20}\) Similarly, eponymous movie or play titles generally take the -s plural: *Faust–Fäuste* ‘fists’ versus *Faust–Fausts* ‘productions of the play *Faust*.’ Furthermore, -s is used as the exclusive plural for onomatopoeic nouns (e.g., *Kuckucks* ‘cuckoo,’ *Wauwau* ‘dogs’; Table 1: #6), quoted nouns (e.g., *Nach Korrekturlesung für sexistische Wortwahl fand ich drei “Mann’s auf Seite 1*; Table 1: #7), and nouns based on other categories like conjunctions (e.g., *wenns and abers* ‘ifs and buts’; Table 1: #12), acronyms (e.g., *GmbH–GmbHs* ‘corporations’; Table 1: #11), and truncations (e.g., *Wessi–Wessis* from *Westdeutsche* ‘West Germans,’ *Sozi–Sozis* from *Sozialist*; Table 1: #10). Similarly, -s is applied to most nouns formed from verb and adjective phrases (Table 1: #16), such as *Rührimosichtans* ‘touch-me-nots,’ literally ‘touch me not at’; *Dreikäsehochs* ‘youngsters, pipsqueaks,’ literally ‘three cheeses high’; *Tunrichtguts* ‘ne’er do wells,’ literally ‘do no good.’

Corroboration of the special status of -s comes from a circumstance in which it cannot occur. In German, as in English, regular plurals are generally excluded from lexical compounds, though plurals with other forms can appear inside them (Table 2: #6). For example, the compounds containing irregular plurals with -e, -en, and -er in the following examples are acceptable, whereas the compounds containing regular plurals with -s are not (see also Clahsen et al., 1993; Wiese, in press. Chapter 5).\(^{21}\)

(10)

Professor-en-kränzchen ‘professors’ circle’
Frauen-laden ‘women’s center’
Schwein-e-stall ‘pigsty’
Gänse-braten ‘roast goose’
Bücher-regal ‘bookshelf’
Sozialist-en-treffen ‘socialists’ meeting’

*Sozis-treffen* ‘socialists’ meeting’ (clipped form of *Sozialist*)
*Auto-s-berg* ‘cars heap’

Finally, some German children overregularize with the -s plural (Table 1: #17). Park (1978) reports that the two Swiss children (2;7–3;7) in his longitudinal study overapplied -s 25% of the time in spontaneous speech. Veit (1986) reports a similar figure, 19%, in his cross-sectional experiments testing 8 southern German children from 3;0 to 6;0. Clahsen, Marcus, and Bartke (1993) elicited

\(^{20}\) Note that *Citroen* *Ente* would be pluralized *Enten*, because the cars look like ducks and thus the plural name may be construed as based directly on the plural noun. Similarly the *Volkswagen Küfer* ‘beetle’ is pluralized as *Käfer*. See Footnote 10.

\(^{21}\) An -s suffix is sometimes permitted in compounds (e.g., the -s in *Wirtschaftskrise* ‘economic crisis’), but only as a linking element (*Fugenelement*), similar to *huntsman* and *grantmanship* in English.
plurals of low-frequency words and found that -s was overregularized in 12.5% of the opportunities, a higher rate than for the other affixes. Children also apply -s to novel words: in 11% of the opportunities in Mgdan’s (1977) study of 25 children from 4:4–9:2, in 24% of the opportunities in Schöler and Kany’s (1989) study of 43 children from 6 to 10 years, and in 15% of the opportunities in their second study, of 57 children from 7 to 15. Though -s is not the most frequently overapplied affix, it is interesting that children overapply it at all, given its rarity among the common German nouns.22

In fact, the only systematic nonparellelism between English and German -s occurs in Bahuvi compounds, which in German inherit the plural form of the rightmost morpheme (e.g., Stillleben “still lifes” from Leben, the zero-plural of Leben “life”; Großmaul-Großmäuler “braggarts,” literally “bigmouths,” from Mauler, the -er plural of Maul “mouth”; Geizhals-Geizhälse “misers,” literally “thrift-necks,” from Halse, the unlaunted -e plural of Hals “neck”). Whereas in English, grammatical information (syntactic category and irregular forms) can percolate through the head-pathway only if semantic information (the referent) does so as well, in German the grammatical information (syntactic category, gender, and irregular forms) always percolate through the head-pathway, even if the semantic information does not. We have no well substantiated explanation for this difference. One possibility is that these compounds historically predate the (relatively late) emergence of -s as the default in German (see the General Discussion), but postdate the much earlier corresponding development in English.23

In sum, the -s plural displays a range of applicability and non-applicability that resembles that of the English -en plural in at least 13 different ways. These properties leads to the characterization of -s as the “default plural” or “emergency plural.” This, we suggest, bespeaks the operation of a rule referring to a symbol for an entire category that applies unless blocked by a competing stored form.

Because these criteria have not been systematically applied in the literature, not all German linguists have treated -s as the default plural. For example Wurzel (1990), while in general an advocate of rules, does not adopt Wiese’s (1986,

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22 Typically -en is overapplied more often than -s (Park, 1978; Veit, 1986; Schaner-Wolles, 1986), but Clahs, Rothweiler, Woest, & Marcus (1992) and Clahsen, Marcus, & Bartke (1993) found that children who tend to overaplay -en also omit it from compounds where the adult language permits it, a signature of a regular default (Table 2: #6). This suggests that such children have temporarily misinterpreted -en as a default.

23 This is consistent with the fact that some of the sporadic exceptions to the other regularization phenomena in German involve archaic irregular plurals. For example, Springinsfelder “whippersnappers,” literally “jump-into-the-field,” is an exception to the regularization of nominalized phrases (#16), but it contains the archaic -e plural of Feld “field” rather than the current -er plural Felder. Similarly, the dictionary-listed plurals for countries like Deutschland “Germanys” and Griechenland “Greeces” not only avoid the predicted -s (#14) but also the contemporary irregular plural of Land, Länder; they retain the archaic Lunde. In any case, many contemporary speakers prefer the predicted forms with -s.
1988) suggestion that -s is the default plural marker in German, but claims instead that a number of inflectional rules operate to give nouns their unmarked plural form (e.g., monosyllabic feminines receive -n, bisyllabic vowel-final nouns receive -s). All the rules have equal status in the grammar. This position is reminiscent of the treatment of descriptive handbooks and dictionaries (e.g., Helbig & Buscha, 1987; Wahrig, 1986), which lists a number of inflectional types for nouns in German and assign each noun to one of the types.

Coming from the other direction, Köpcke (1988) has argued that German plurals are assigned by matching the stem to associative schemas. The schemas capture the similarities among the nouns that take a plural suffix; nothing has a special status as the default. Köpcke asked German adults to pluralize 50 novel noun stems which varied by gender and syllable structure (suffixed, schwa-final, vowel-final, pseudosuffixed, or monosyllabic). He found that each type has a preferred suffix. For instance, feminine schwa-final nouns nearly always took -(e)n, and monosyllabic nouns tended to take -e if neuter or masculine, -(e)n if feminine. But Köpcke’s experiment did not test for inflection in default circumstances. Each noun was presented in isolation, so subjects presumably treated them as roots. Any model that acknowledges that the memory for word roots fosters analogies would predict that novel roots may take the suffix of similar existing roots. To test whether there is a default plural rule in German, one needs to examine circumstances in which access to memory for roots is ruled out.

In Experiment Two, we use a three-factor design to test subjects’ ratings of plurals in heterogeneous circumstances held together only as the default. Subjects rated the nouns in the eight possible German plural forms, which we dichotomize as follows. The -s plural was classified as Regular, and -e and -er as Irregular. Although a case could be made that -en is sometimes generated by a rule that operates on specified subcategories of nouns (e.g., feminine nouns ending in a schwa, which all take -en), we treat it as Irregular, because it clearly is not rule-generated in the case of monosyllabic nouns, the kind of item we use in the experiment (see also Footnote 18).

The novel nouns were either “Rhymes,” words that rhyme with existing German irregular nouns (and that do not rhyme with regular nouns), and “Non-Rhymes,” words that do not rhyme with existing German nouns. This factor tests the hypothesis that novel roots are likely to receive irregular inflection if they are similar to existing words; otherwise, the default inflection is available to inflect them. The morphophonological space of German noun plurals is vast, so we sampled only a small region, monosyllabic nouns. These items should be particularly drawn to the irregular clusters of -e, and to a lesser extent -er, since those suffixes are the ones most commonly used to inflect monosyllables; monosyllables are rarely inflected with -s. Note that this choice works against our hypothesis.

The third factor defined three contexts in which the words were presented. A third were presented as Roots, that is, as normal German words in a neutral
context. All are grammatically eligible for either regular or irregular inflection, and the choice should be determined largely by Rhyme: though all the roots could be analogized to the irregular patterns, since they are all monosyllables, the analogy clearly should be stronger for Rhymes, which should thus take irregular plurals to a greater extent (and regulars to a lesser extent) than Non-Rhymes would.

Another third were presented as Names, a circumstance that should elicit the regular or default plural form, -s. The remaining third were presented in a context that suggested that they were borrowed from a foreign language. Because Borrowings can sometimes be assimilated to root status, especially if their phonological patterns fit the canonical template for the language, the preference for -s might be intermediate between that for roots and that for names, depending on the mixture of assimilable and unassimilable borrowings: items that speakers treat as assimilated should behave like Roots and hence take irregular inflection; items that speakers treat as unassimilated borrowings should take regular inflection. Since assimilability depends in part on phonological familiarity, we might expect the increased preference for -s among borrowings to be stronger for Non-Rhymes, which are both unassimilable and unanalogizable, than for rhymes, which are both assimilable and analogizable.

The predictions of the theory that all inflection is computed in a single pattern associator are different, because pattern associators neither easily generalize low-frequency suffixes, nor unite the different default circumstances (phonological and derivational) as defaults. Associative models that rely solely on phonological information must predict that Root has no effect, since it cannot even be represented in the input. These models predict that -s should be eschewed across the board: driven only by phonological similarity, the models should always prefer the more common -e, -en, and -er plural forms to -s, even for Non-Rhymes, since there is no reason that very rare -s would scoop up the words that have lower similarities to existing irregulars and no similarity to existing regulars. Of course, a hypothetical pattern associator model that somehow represented root and head structure in the input could learn to distinguish among Roots, Names, and Borrowings, because the few -s forms in its input would presumably be headless or rootless. Given the rarity of -s plurals both typewise and tokenwise, though, it is unclear whether it would learn that -s is also more applicable to unusual roots.

Method

Subjects. Forty-eight adult subjects were recruited from Northern Germany.

Procedure. Subjects were given a paper-and-pencil test requiring them to judge plurals of novel words. There were four versions, each containing 24 items. Each item contained a novel singular noun in a context sentence, followed by test sentences containing different plural forms. Subjects were asked to rate each sentence on a scale from 1 “perfectly natural” to 5 “perfectly unnatural.” (These anchors correspond to the grade scores familiar in German schools; in the analysis we subtracted each rating from 6 so higher numbers would correspond to greater naturalness.) The
subjects were asked to rate each item in terms of how "normal" or "good-sounding" as opposed to how "funny" or "wrong" they were. They were told not to pay attention to the orthography of the words, only their sounds, that nouns could have any number of natural or unnatural plural forms, and that there were no right or wrong answers; only their personal evaluations were of interest.

The 24 items (listed in Appendix 3) were divided into 6 combinations of conditions (Rhyme/Non-Rhyme X Root/Name/Borrowing), with 4 novel words appearing in each combination. Rhymes were selected to rhyme with clusters of irregular German nouns (the highest-frequency rhymes and their frequencies in Ruoff (1981) are listed in Appendix 3). For example Pund was used on analogy to Hund-Hunde, Pfand-Pfänden, Grund-Gründen, and so on. Non-rhymes were created using a table from Seiter (1970, p. 417) which contained lists of permissible and non-permissible combinations of German onsets and codas. Possible but nonexisting combinations were selected.

Items were presented as Roots by introducing them as novel but otherwise ordinary German nouns. For example, one lead sentence was

Ich habe einen grünen KACH gegen meine Erkältung genommen.
["I have taken a green KACH for my cold."]

Subjects then were faced with each of the following continuations (nouns whose stems contained an unlauted vowel were tested with only five plural forms):

Aber die weißen KACH sind oft billiger und helfen auch besser.
Aber die weißen KACH sind oft billiger und helfen auch besser.
Aber die weißen KACHE sind oft billiger und helfen auch besser.
Aber die weißen KACHE sind oft billiger und helfen auch besser.
Aber die weißen KACHEN sind oft billiger und helfen auch besser.
Aber die weißen KACHER sind oft billiger und helfen auch besser.
Aber die weißen KÄCHER sind oft billiger und helfen auch besser.
Aber die weißen KACHS sind oft billiger und helfen auch besser.
["But the white KACHES are often cheaper and work better."]

Items were presented as Names by introducing them as the surname of a set of people. For example, one lead sentence was

Mein Freund Hans KACH und seine Frau Helga KACH sind ein bisschen komisch.
["My friends Hans Kach and his wife Helga Kach are a bit strange."]

followed by eight test sentences, one per plural form, like

Die KACH versuchen immer, ihre Schuhe anzuziehen, bevor sie die Socken anhaben.
["The KACHES always try to put on their shoes before they put on their socks."]

Items were presented as Borrowings by introducing them as foreign words from one of six languages (never English) for various objects. An example lead sentence was

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24 We inadvertently selected one item (Bral) which rhymed with the low-frequency word Schal "scarf," which permits either the plural -s or the plural -e. This is unlikely to be a significant problem, because Schal rhymes with five other words, Tul-Taler, Maf-Male, Wahl-Wahlen, and Zahl-Zahlen, all more frequent than Schal.

25 Due to experimenter error, one sentence context for borrowed items, Der Computertladen . . . , appeared twice, with different test words, in every questionnaire.
Die französische "KACH" sieht schwarz am besten aus.  
["The French 'kach' looks best in black."]

Aber eigentlich sehen KACH in jeder Farbe gut aus.  
["But actually KACHS look good in any color."]

Except for personal names, which were unmarked for gender (following the common German pattern), half the items in each questionnaire were masculine, half feminine; across subjects, each item appeared an equal number of times as masculine and as feminine. (We included no neuter nouns, because they pluralize much like masculine nouns. Gender did not interact statistically with the other factors and so we will not discuss it further.) The questionnaires were presented in one of two orders, counterbalanced across subjects; one order was assembled at random, the other was its mirror image. In addition, the questionnaires were counterbalanced across subjects so that each word appeared an equal number of times as a Root, Name, or Borrowing.26

In conducting the analyses, we were maximally charitable to the pattern associator hypothesis by comparing each subject's rating of the -s-suffixed form of a given noun to his or her personal highest rating among all the irregularly-suffixed forms of that noun. For example, if a subject rated Kloze as 4, Kloter, Klöte, Klötter, Klöte as 3, and Kloze as 2, we would use 4 as the rating of the "Irregular" form for that item for that subject. The comparison between best Irregular and -s was treated as a within-subjects factor. Regularity, in the analysis of variance to be presented below. (Alternative measures, such as the mean rating of the irregular forms, would systematically underestimate the strength of irregulars in default contexts and thus help our hypotheses.) The zero-suffix or no-change forms were not analyzed because subjects actually saw these forms in the context sentences, possibly biasing them to rate it higher, and because subjects might interpret the no-change form as reflecting unwillingness to pluralize the noun at all, as opposed to how to pluralize it given that it must be pluralized. In any case, adding back the zero forms has little effect on the results.

<table>
<thead>
<tr>
<th>TABLE 6</th>
<th>Mean Ratings of Plural Forms of Novel Nouns in Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Irregular</td>
</tr>
<tr>
<td>Roots</td>
<td></td>
</tr>
<tr>
<td>Rhyme</td>
<td>4.4</td>
</tr>
<tr>
<td>Nonrhyme</td>
<td>4.1</td>
</tr>
<tr>
<td>Mean</td>
<td>4.3</td>
</tr>
<tr>
<td>Names</td>
<td></td>
</tr>
<tr>
<td>Rhyme</td>
<td>3.1</td>
</tr>
<tr>
<td>Nonrhyme</td>
<td>2.8</td>
</tr>
<tr>
<td>Mean</td>
<td>2.95</td>
</tr>
<tr>
<td>Borrowings</td>
<td></td>
</tr>
<tr>
<td>Rhyme</td>
<td>3.8</td>
</tr>
<tr>
<td>Nonrhyme</td>
<td>3.9</td>
</tr>
<tr>
<td>Mean</td>
<td>3.8</td>
</tr>
<tr>
<td>Mean</td>
<td>3.7</td>
</tr>
</tbody>
</table>

26 A second set of 16 subjects was run on a version of the questionnaire in which the items were paired with conditions in a consistent random assignment, rather than counterbalanced; the results, not presented here, were virtually identical.
Fig. 2. Mean ratings of the regular plural form (-s) and irregular plural form (highest rating for that subject and item among -en, -er, -e, with and without umlaut) of novel German nouns. (a) Comparison between roots that rhyme and do not rhyme with existing irregular nouns. (b) Comparison between roots and names (averaged over rhymes and nonrhymes). (c) Comparisons between roots and borrowings (averaged over rhymes and nonrhymes).
Results and Discussion

Means from all conditions are presented in Table 6, and the relevant interactions are shown in Fig. 2; means for individual items and plural forms are in Appendix 3.

Figure 2a presents the effects of phonological similarity on the inflection of the Roots. Irregular forms were judged as better for nouns that rhymed with existing nouns than for nouns that didn’t (means 4.4 versus 4.1, a difference that is significant by subjects, $F(1,47) = 11.83, p < .001$, and by items, $F(1,22) = 7.67, p < .05$). The decline in the ratings of the irregular items can be explained as a standard associative generalization gradient. The -s-suffixed forms, in contrast, were judged as worse in the Rhyme condition than in the Non-Rhyme condition (3.5 versus 3.8; the difference was significant by subjects, $F(1,47) = 7.69, p < .01$, though not by items, $F(1,22) = 2.09, p = .16$). The interaction between Rhyme/Non-Rhyme and Regularity/Irregularity was significant by subjects, $F(1,47) = 16.04, p < 0.001$, and by items $F(1,22) = 5.47, p < 0.05$. Though overall -s was not related better than the best irregular form, for 7 of the 12 items its average rating was higher than the average ratings of any of the other affixes; this was true of only 2 of the 12 rhyming items. The improvement of -s for non-rhymes illustrates one of its uses as a default operation: to apply to forms that are dissimilar to any existing form (note that in pattern associators, dissimilarity to existing forms is not a sufficient condition for greater generalization of the regular suffix; see Prasada & Pinker, 1993). Presumably because the items were monosyllables, which in German are virtually all irregular, there was still enough of an associative pull to prevent the regular plural forms of the nonrhymes from being rated better overall.

The effects of roothood on regular and irregular inflection are displayed in Fig. 2b, which collapses over rhymes and nonrhymes (the three-way interaction among Rhyme/Non-Rhyme, Root/Name/Borrowing, and Regular/Irregular was nonsignificant; $F < 1$ for subjects and items). As noted, among Roots, irregular plural forms elicited higher ratings than regular plural forms (4.3 versus 3.6, significant by subjects $F(1,47) = 20.20, p < .001$, and by items $F(1,22) = 24.26, p < .001$). In contrast, among Names, the best irregular plural forms were rated worse than the regulars (mean 2.9 versus 4.2; significant by subjects, $F(1,47) = 73.87, p < .001$, and by items, $F(1,22) = 23.79, p < .001$). The interaction between Root/Name and Regular/Irregular is significant by subjects, $F(1,47) = 180.90, p < .001$, and by items, $F(1,22) = 44.34, p < .001$. For 22 of the 24 names, the average rating of the -s plural exceeded the average rating of any other plural form (in contrast to only 10 of the 24 roots). Thus the associatively-driven preference for irregular forms for novel German noun plurals is reversed when the same sounds are analyzed as names converted into nouns.

The effect of treating a word as a foreign borrowing can be seen in Fig. 2c, which compares the Roots (same data as in Fig. 2b) with the Borrowings. When subjects analyze the nouns as borrowings, the preference for irregular forms
again disappears, and subjects now rate the regular and irregular forms as equally good on average (3.8). This is reflected in a significant interaction between Root/Borrowing and Regular/Irregular, $F(1.47) = 23.23, p < .005$ by subjects, $F(1.22) = 40.80, p < .001$, by items. For 20 of the 24 items, the average rating of the -s for exceeded the averages of all the other plural forms. The lower ratings of -s for Borrowings compared to Names may be due to subjects’ ability to treat some of the borrowings as fitting the native German sound pattern and hence to rate them as being like roots. This is consistent with the small but nonsignificant trend in which a preference for the regular plural can be seen among the non-rhymes, which should be more difficult to assimilate to the native German pattern (and also less likely to receive irregular inflection if assimilated).

In sum, German speakers generalize the -s plural and the irregular plural forms in different ways. If a novel noun is learned as a root (and perhaps as a borrowing easily assimilable to roots), its plural can be formed by analogy to the plural forms of similar irregular nouns. The suffix -s is likely to be used elsewhere: for the more unusual-sounding roots, for borrowings, and for names (with both usual and unusual sounds). The heterogeneity of these circumstances suggest that the plural -s suffix applies not as an association separately acquired for each circumstance, but whenever the combination allowing memory-based generalization (similar root in head position) does not apply, that is, elsewhere, as the last resort, emergency, or default. The fact that -s serves as a default even though it is rare argues against the hypothesis that default application of a suffix is an epiphenomenon of its having been experienced with a large number of words. Instead, defaultness appears to be a consequence of the suffixation process accessing a mental symbol for a grammatical category and hence applying to any word that such a symbol refers to unless specifically blocked.

**GENERAL DISCUSSION**

In this paper, we have set stringent criteria for attributing a linguistic process to a mental symbol-processing operation. The mere existence of common patterns, and of productive generalization to novel forms, is not enough: English irregular verbs display both, and these phenomena must be attributed at least in part to the kinds of analogies that similarity-driven associative memories, such as connectionist pattern associators, are prone to making. English regular verbs, in contrast, afford a kind of generalization that is not dependent on analogies to stored patterns. Rather, English regular inflection applies in all and exactly the circumstances where analogies fail, for any reason, whether it be because there are no similar relevant forms to support the analogy, or because access to remembered lexical information is cut off in a word whose derivational structure is designed to prevent the usual transmission of information from the lexicon. We listed 21 heterogeneous circumstances, many quite rare, in which such lexical analogies fail but regular suffixation applies. No existing pattern associator theory can explain this range of generalization, but it coincides with the range of a
symbol for a grammatical category like verb or noun, and hence supports the hypothesis that the mind contains something like such symbols and the rule-like operations manipulating them.

In addition, we have shown that the default application of a linguistic pattern does not depend on the pattern constituting a majority of the learner's experience, the principal suggestion of pattern associator modelers that future models might duplicate such generalizations. In German, associative effects are visible in the generalizability of frequent affixes like the -en participle and the -er, -e, and -en plurals to novel roots, the lexical (nondefault) domain in which such effects are expected. But the -t participle and -s plural, despite lower type frequency than their English counterparts, are applied as defaults, by the same diverse criteria used to show default inflection in English. This pervasive parallelism is summarized in Table 7 (cf. Table 1).


d Alternatives and Explanations

Schema theories. Köpcke (1993; personal communication) and Bybee (1993) have suggested several ways in which a schema theory might handle the data. One is that -s might be attached to one or more specific templates, say, for recent borrowings, for names, or for strange-sounding new words. But this proposal fails to explain why the schemas for these heterogeneous cases, plus, presumably, separate ones for conjunctions, truncations, acronyms, quotations, and other headless and rootless circumstances, all ended up selecting the same affix (and why there are no -s schemas for specific subcategories of headed roots). Note, too, that a "template for strange-sounding" words is problematic, since "strange-sounding" by definition implies matching no specific templates; implementing such a template mechanically would require using something akin to a symbol for the default case. A similar consideration arises in interpreting Bybee's (1993) suggestion that -s might be part of an "open" schema with no conditions attached. Such a schema presupposes exactly what we have been calling a symbol (a representation that imposes no conditions other than nounhood itself), and contrary to Bybee's suggestion, it is not a natural characteristic of pattern associators.

Historical influences. English and German, of course, are historically related sister languages. Perhaps the similarities between the behavior of German -t and English -ed and between German -s and English -s are due to inheritance of the individual constructions from common ancestors in Proto-Germanic, not to a common psychology of generalization of their modern speakers. One problem for this hypothesis is that -s is an innovation in High (Standard) German; there is not a single instance in the Old or Middle periods of the language (Leo Connolly, personal communication, March 2, 1993). A more general problem is that the mode of inheritance—a generation-to-generation relearning of the individual circumstances in which the -t and -s suffixes do and don't apply—is psychologically implausible. Many of the circumstances that trigger regularization, such as
TABLE 7
Circumstances in Which German -s and -t Suffixes Behave Like the English Regular -s and -ed Suffixes

<table>
<thead>
<tr>
<th>Circumstance</th>
<th>Kind of word</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No root entry</td>
<td>Lack of entry or similar entries in memory</td>
<td>gefacht</td>
</tr>
<tr>
<td>2. Weak entry</td>
<td>Novel words</td>
<td>mahnlen-gemahlen/malen-gemalt</td>
</tr>
<tr>
<td>3. No similar entries</td>
<td>Low-frequency words</td>
<td>gelötet</td>
</tr>
<tr>
<td>4. Unusual-sounding words</td>
<td>Unusual-sounding words</td>
<td>gequossst, Fmohnks</td>
</tr>
<tr>
<td>5. Competing root entry</td>
<td>Homophones</td>
<td>mehr</td>
</tr>
<tr>
<td>6. Competing similar root entries</td>
<td>Rhymes</td>
<td>mehr</td>
</tr>
<tr>
<td>7. Rendering of sound</td>
<td>Entry is not a canonical root</td>
<td>mehr</td>
</tr>
<tr>
<td>8. Opaque name</td>
<td>Onomatopoeia</td>
<td>mehr</td>
</tr>
<tr>
<td>9. Foreign language</td>
<td>Quotations</td>
<td>mehr</td>
</tr>
<tr>
<td>10. Distortion of root</td>
<td>Surnames</td>
<td>mehr</td>
</tr>
<tr>
<td>11. Artificial</td>
<td>Unassimilated borrowings</td>
<td>mehr</td>
</tr>
<tr>
<td>12. Artificial</td>
<td>Truncations</td>
<td>mehr</td>
</tr>
<tr>
<td>13. Artificial</td>
<td>Acronyms</td>
<td>mehr</td>
</tr>
<tr>
<td>Root cannot be marked for inflection feature</td>
<td>Denominal verbs</td>
<td>mehr</td>
</tr>
<tr>
<td>Features cannot percolate from root to whole word (exocentrism or headlessness)</td>
<td>Deadjectival verbs</td>
<td>mehr</td>
</tr>
<tr>
<td>14. Derivation via different category</td>
<td>Nominalized conjunctions</td>
<td>mehr</td>
</tr>
<tr>
<td>15. Referent different from root</td>
<td>Denominal normalized verbs</td>
<td>mehr</td>
</tr>
<tr>
<td>16. Lexicalization of a phrase</td>
<td>Denominal normalized verbs</td>
<td>mehr</td>
</tr>
<tr>
<td>Memory failures</td>
<td>Denominal normalized verbs</td>
<td>mehr</td>
</tr>
<tr>
<td>17. Children</td>
<td>Overregularizations</td>
<td>mehr</td>
</tr>
<tr>
<td>18. Normal speech errors</td>
<td>Overregularizations</td>
<td>mehr</td>
</tr>
<tr>
<td>19. Alzheimer’s Disease</td>
<td>Overregularizations</td>
<td>mehr</td>
</tr>
<tr>
<td>20. Williams Syndrome</td>
<td>Overregularizations</td>
<td>mehr</td>
</tr>
<tr>
<td>21. Anomic Aphasia</td>
<td>Overregularizations</td>
<td>mehr</td>
</tr>
</tbody>
</table>

pluralized acronyms or quotations homophonous with irregular nouns, are too contrived and infrequent to have depended on parallel, 2000-year old unbroken chains of speakers of both languages all using such forms in the presence of their children. For example, Kim et al., 1994 looked for exemplars of one of the circumstances, denominal homophones of irregulars, in 7,500 parental utterances addressed to four children, and found none. Furthermore, one of the key tests for
rule-generation, inability of regular plurals to appear inside lexical compounds, could not have been specifically learned from exemplars. Children could not learn not to say rats-eater, for they rarely if ever hear plurals, regular or irregular, inside compounds in their parents’ speech (Gordon, 1985).

Another alternative explanation is that the dominance of -s in German was the result not of vertical inheritance from Proto-Germanic but of lateral borrowings from English and French: plural nouns entered German with their -s suffixes preattached. This is an important fact, but it cannot by itself explain the current default status of -s. As Köpcke (1988:326) notes, other foreign plurals “have made no inroads whatever. Foreign plural markers such as Greek -ta as in Thema-Themata, Hebrew -im as in Cherub-Cherubim, or Italian -i in Tempo-Tempi are limited to the small number of stems with which they were borrowed and almost inevitably have a primary or secondary germanicized plural. Themen, Cherubinen, and Tempos.” The key question is why German speakers generalize the -s ending to nouns from other languages (14 of them, according to Janda, and 5 tested in Experiment 2), and to the other circumstances (names, acronyms, etc.) that are nonexistent in the donor language or too rare to have been borrowed individually.

The effects of history can be understood only in conjunction with the psychology of their present and past speakers. Proto-Indo-European had a set of rule-like ablaut processes for tense which, because of changes in the sounds of verbs, ceased to apply predictably in the daughter languages. Their fossils, the strong verbs, constituted the majority of verbs in Proto-Germanic. But Proto-Germanic developed the weak suffix (the ancestor of -ed and -t) and used it for derived forms and borrowings (Pyles & Algeo, 1982). Many historical linguists believe that it came from the verb do, which helps explain why it has default status: syntactic processes would originally have combined do with any verb or noun; this free generalizability would have been preserved after do had been reanalyzed as an affix incorporated into the verb.

Two peculiarities of the history of English are that it borrowed many of its verbs from French and Latin (perhaps 60%), and that it invented many other verbs by deriving them from nouns without overt affixation (perhaps another 20%; Prasada & Pinker, 1993). Unassimilated borrowings and denominals are two of the nonroot circumstances that require affixation by default—exactly where the weak suffix did, and still does, apply. In German the developments were similar, with many verbs zero-derived from nouns or borrowed from French neighbors and Latin texts, and hence necessarily weak. But in German the expansions were less extreme, perhaps because of the lack of anything like the Norman invasion, and perhaps because German made much greater use of prefixation of strong verbs to expand its verb vocabulary. Regular verbs are in the vast majority in English, and a substantial but smaller proportion in German, because of the historical accidents that defined the chief growth areas for their verb vocabularies over the centuries. The psychological process applying the
regular suffix need not have changed over the millenia as regular verbs grew from minority to majority status.

The history of -s was somewhat different. In Old English, there were at least nine affixes that expressed combinations of case and plural number, including -as, the probable ancestor of the modern regular plural. As word-final vowels became reduced to schwa in Middle English, all the plural affixes but -es and -en shriveled. The statistical victory of -s has been attributed to its fairly high original type frequency, its phonological salience, and its ability to follow both consonants and vowels in phonologically legal word-final clusters. But perhaps the key factor was the presence of -s in plural nouns borrowed from Norman French; this changed the phonological realizations of native -es to the forms we see today (Keyser & O’Neil, 1985) and presumably caused it to be reanalyzed as a default affix that could apply to any noun.

In Old and Middle High German, in contrast, -s was almost completely absent (Low German and Northern colloquial German did retain some plurals using a descendant of the Old Saxon -os suffix). In New High German, plural nouns with -s were borrowed from Low German, Dutch, English, and French, especially in the 18th Century, and by the 19th Century, the affix began to become productive for all borrowings and for other “nominalized indeclinabilia” (Bornschein & Butt, 1987). So the properties of German -s and English -s have converged, but too recently for the novel nouns scooped up by German -s to have become a significant proportion of the nouns in the language. Interestingly, Janda (1990) predicts that “the eventual emergence of -s as the dominant plural-ending of NHG seems extremely likely” (1990, p. 149), a conjecture supported by Köpcke’s analysis of recent loanwords. Perhaps in the future, as German borrows words from the global community, the -s plural will become one of the more frequent affixes. Crucially, although Old English, Modern English, Modern German, and Future German differ in the balance of regular and irregular lexical items in their vocabularies, the speaker of all these languages appear to have similar psychological processes generating the affixes.

The rule-theory predicts type frequency and default generalizability can be dissociated in any language family (though the dissociation will have a finite lifespan whenever vocabulary grows by means other than endocentric derivation, since such growth will increase the proportion of words taking the default). For example, in Modern Arabic the “broken plural” is the most common set of forms, but is limited to various classes of similar canonically-shaped nouns. The “sound-plural,” in contrast, behaves like a default in that it applies indiscriminately to all noncanonical forms, such as proper names, transparently derived nouns such as deverbals and diminutives, noncanonical or unassimilated borrowings, and the names of letters of the alphabet, which are mostly noncanonical (McCarthy & Prince, 1990). These forms together, though, constitute a minority of Arabic nouns. Interestingly, Arabic-speaking children often overregularize the sound plural (Omar, 1973).
**Pattern associators.** There have been four attempts to adapt pattern associators to handle default operations with low type frequency (some responding to an earlier version of this paper). Hare and Elman (1992) describe a hidden-layer model trained on 32 verbs from each of 6 inflectional classes, based loosely on Old English. Five classes had stems with specific patterns of vowels and consonants; the 6th embraced all other vowel–consonant combinations. The input was a verb paired with a code for its inflectional class. The goal was to show that the network could learn to treat the sixth class as a default because of its phonological diversity in the context of the phonological cohesiveness of the irregular subclasses. Unlike earlier models, it could generalize novel words that do not resemble any words in the input to the default class. (Regularization of homophones, headless, and rootless words was not addressed). But the psychological relevance is questionable. Children hear their parents produce past tense forms; they do not hear their parents label verbs with their inflectional classes. Moreover, the model in effect assumes that the human brain is innately hard-wired for six of the inflectional classes of Old English. As Daugherty and Hare (1993) point out (p. 151):

> it is possible, however, that the task facing the Hare and Elman network was overly simple, and this simplicity added to the success of the model. On the input layer, the phonological string that was intended as the basis for generalization was clearly presented to the model in each of the five predictable classes. On the output layer, the model was compelled to accept one of the six categories offered, eliminating the possibility of a no-response or entirely novel response to a test item. By presenting the problem as an overt categorization task, instead of requiring the network to categorize implicitly by producing correctly inflected forms, this model may have achieved a satisfactory result for reasons that would not allow it to be extended to the more detailed data sets required of an actual model of verb production.

Daugherty and Hare used materials similar to Hare and Elman’s to train a more conventional model, with a phonological output representation. They tested its generalization with 11 new verbs whose vowels were not in the training set, and claimed that “... these verbs should be placed in Class V [the default].” On the crucial assumption that generalization to Class V does not require similarity to trained patterns, And, as Table 3 shows, this was overwhelmingly the case.” But whereas verbs in Class V are supposed to have a suffix added to their stems, Daugherty and Hare’s Table 3 shows that the model did so only for 2 of the 11 verbs: it changed the vowel of 6, changed the consonants in 2 more, and failed to add a suffix to one, a 22% success rate.

Goebel and Indefrey (1994) trained a connectionist model on the German plural. But it only generalized the -s plural to items that rhyme with existing words that take the -s plural, which skirts the key challenge that the default plural applies to any memory-independent form, including ones that do not sound like existing regulars and those that do sound like existing irregulars.

Finally, Plunkett (1994) trained a network on an idealized version of the
Arabic plural. He simplified it into five broken plural forms, each with a distinct phonological template, and the sound plural (minority default), with members that did not overlap with any of the broken plural templates. He notes that the simplification was crucial: "Exceptions to the default (in this case the broken plural) must be clustered around sets of identifiable cues (distinct phonological templates) which the network can exploit to motivate a reorganization of the input space to form an internal representation. Without these cues the network will remain subject to the tyranny of similarity in the input space and will be unable to acquire a minority default mapping." Arabic in fact has more broken plural forms, with more overlap, than the inputs used in the simulation; whether more realistic inputs would reduce or eliminate the default generalization is an interesting open question. As noted, such tight clustering is strongly violated in German: there is considerable overlap among different irregular clusters, and many regular forms interpose themselves in those clusters (Table 7: #4 and #5).

We do not rule out the possibility that a connectionist model can handle the full set of facts of regular inflection. We simply note that there is a mismatch between the computational demands of a default operation such as regular inflection, and the capabilities of models that generalize to regions in a similarity space, such as pattern associators. The default, virtually by definition, is not a well-behaved similarity space. But it is a well-behaved class with respect to a symbol-processor: the range of a symbol, minus the specific examples or patterns that are otherwise spoken for. Hence a successful connectionist model is likely to need some implementation of symbols and rules.

Learning Default Affixes

Given that the learning of default affixes in humans does not depend on high frequency, what else could it depend on? It is surely not overtly learned in school or from prescriptive grammars. Bornschein and Butt (1987:135–136; translation ours) provide a historical sketch of learned opinion of the -s plural.

The noun category which forms the plural . . . by adding the morpheme -s, is often seen as being only of peripheral importance. This evaluation is especially found in older publications which categorize the s-plural mainly as being strange or "ignorant" and which advise people against using it. This is not always done as vigorously as in Heinsius (1818) who writes: "There is no s-plural . . .," or Sütterlin (1918) who recommends that one should: "avoid the s-plural completely, or at least use it very carefully and at best only in foreign words."

The situation is parallel in English, where the self-appointed language mavens and guardians of proper style have often resisted the lawful regularization of denominal verbs, a robust grass-roots phenomenon (Kim et al., 1991; Pinker, 1994). This is not surprising: irregular words depend on memorization of forms witnessed in speech and writing, and hence will be most vulnerable in the least literate, and most in need of overt examples from style manuals and "experts" (e.g., familiar grammatical "hobgoblins" like datum–data, criterion–criteria,
and alumnus–alumnae). Regular affixation, because of its memory-independent default applicability, is bound to be seen by nonpsychologically minded grammarians as the "lazy" way of doing inflection, and hence discouraged. Note that the facts of prescriptive injunctions regarding regular and irregular inflection run against a common connectionist assumption that the clear cases where people execute rules can be explained away as the conscious application of pedagogical injunctions (e.g., Smolensky, 1988).

But if children's unconscious language acquisition mechanisms naturally seek examples of rules (e.g., Pinker, 1984), there is ample evidence that an affix like -s is a default, despite its low frequency, for it could reveal its default status to the prepared mind in a number of ways (see Marcus et al., 1992, for discussion). These cues all derive from the principle that irregular forms must be stored as roots and clusters of roots, but regular inflection can apply elsewhere. Hence any form that cannot be listed as a root, such as a pluralized name, tells the child that its affix must be acting as a default. Pluralized examples of onomatopoeia like Kuckucks "cuckoo" and Wauwau "dogs," and of obvious noncanonical borrowings like Café and Kiosk, can serve the same function. Furthermore, when a word has two plurals, one is usually -s, such as Onkel–Onkel "uncle–uncles" and Onkel–Onkels. In addition, an affix which applies in many different parts of morphophonological space is likely to be the default. Examples of the plural -s, unlike the other affixes, are haphazardly sprinkled throughout morphophonological space: to masculine, feminine, and neuter nouns, to words that are part of the canonical stress pattern and to those that aren't, to monosyllables and polysyllables, to both vowel-final and consonant-final stems. In contrast, the irregular affixes show systematic gaps in this table: -er never applies to feminines; zero only applies to nouns ending with a schwa syllable; -en applies mostly to feminines; other affixes do not appear with feminine polysyllables, and so on. We do not know which of these cues to lexical storage versus default affixation children depend on, but given one or two of these cues, the child could assign an affix default status and all of the phenomena in Tables 1 and 2 would fall out.

Are there broader psychological implications? The human mind is notable for its ability to override prototypes based on clusters of similar exemplars in memory. We recognize why 24683 is an odd number, and why Priscilla Presley is a grandmother (Armstrong, Gleitman, & Gleitman, 1983), know that an offspring of raccoons that looks and acts like a skunk is nonetheless not a skunk (Keil, 1989), joke that one cannot be a little bit pregnant, deny a beer to a responsible young man the day before his 21st birthday, and free an obviously guilty suspect on a technicality (Pinker & Prince, 1989). These abilities would seem to depend on categorization based on formal conditions that override stored associations, exactly what a mental rule accomplishes. It is possible that regular rules in language and formal rules in categorization are examples of a kind of basic mental symbol-processing operation that is found in many domains of cognition.

The German plural system, notorious for its irregularity from Mark Twain to
the present, might seem to be an unlikely home for a mental symbol-processing operation. Nonetheless we have shown through a variety of linguistic and psychological measures that it contains a clear default operation that, because of its rarity, cannot be just a very strong pattern in associative memory. In this way, German is the exception that proves the rule.

APPENDIX 1:
ITEMS FROM EXPERIMENT 1

<table>
<thead>
<tr>
<th>Infinitive</th>
<th>Meaning as</th>
<th>Meaning as</th>
<th>Rating as</th>
<th>Rating as</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>denominal</td>
<td>extended verb</td>
<td>Reg</td>
<td>Irreg</td>
</tr>
<tr>
<td>verspinnen</td>
<td>cover with spiders</td>
<td>make something up in a wrong way</td>
<td>3.4</td>
<td>3.4</td>
</tr>
<tr>
<td>besitzen</td>
<td>supply with seats</td>
<td>sit around on</td>
<td>2.9</td>
<td>2.9</td>
</tr>
<tr>
<td>befiegen</td>
<td>put flies onto</td>
<td>windsurf</td>
<td>2.6</td>
<td>2.4</td>
</tr>
<tr>
<td>begraben</td>
<td>cover with graves</td>
<td>dig around thoroughly</td>
<td>2.8</td>
<td>2.8</td>
</tr>
<tr>
<td>verbergen</td>
<td>cover with mountains</td>
<td>recover wrongly</td>
<td>3.1</td>
<td>2.0</td>
</tr>
<tr>
<td>verblasen</td>
<td>cover with blisters</td>
<td>use up by blowing</td>
<td>3.4</td>
<td>1.9</td>
</tr>
<tr>
<td>verklingen</td>
<td>put new knife blade on</td>
<td>play to point of breakdown</td>
<td>4.5</td>
<td>1.7</td>
</tr>
<tr>
<td>ausgeliegt</td>
<td>cover with cots</td>
<td>to finish lying down</td>
<td>2.9</td>
<td>2.1</td>
</tr>
<tr>
<td>bescheinigen</td>
<td>supply with documents</td>
<td>shine onto</td>
<td>2.8</td>
<td>1.6</td>
</tr>
<tr>
<td>bepfiegen</td>
<td>put pipes onto</td>
<td>whistle for someone</td>
<td>3.2</td>
<td>1.6</td>
</tr>
<tr>
<td>bereiben</td>
<td>supply with graters</td>
<td>rub around on</td>
<td>4.2</td>
<td>2.2</td>
</tr>
<tr>
<td>verscheren</td>
<td>cover with scissors</td>
<td>trim in a wrong way</td>
<td>3.3</td>
<td>2.2</td>
</tr>
<tr>
<td>verbacken</td>
<td>cover with buttocks</td>
<td>to use up by baking</td>
<td>3.6</td>
<td>2.3</td>
</tr>
<tr>
<td>abgeringen</td>
<td>put off rings</td>
<td>to get someone to do</td>
<td>3.6</td>
<td>1.9</td>
</tr>
<tr>
<td>abgepreisen</td>
<td>use up all the price labels</td>
<td>praise excessively</td>
<td>4.0</td>
<td>1.3</td>
</tr>
<tr>
<td>verschlingen</td>
<td>put bandage on</td>
<td>gulp</td>
<td>3.2</td>
<td>2.4</td>
</tr>
<tr>
<td>ausgewechsen</td>
<td>supply with new switches</td>
<td>make way</td>
<td>4.1</td>
<td>1.4</td>
</tr>
<tr>
<td>vertragen</td>
<td>cover with stretchers</td>
<td>ruin by carrying too much</td>
<td>2.4</td>
<td>1.8</td>
</tr>
<tr>
<td>verwiegen</td>
<td>cover with cradles</td>
<td>weigh wrongly</td>
<td>2.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Means</td>
<td></td>
<td></td>
<td>3.3</td>
<td>2.1</td>
</tr>
</tbody>
</table>
APPENDIX 2:
A SUMMARY OF THE GERMAN PLURAL SYSTEM (BASED ON MUGDAN, 1977)

List 1 $\rightarrow$ -e + change stem as indicated.
List 2 $\rightarrow$ Change stem and add suffix as indicated

Coda = \( \tilde{\varnothing} \):
- Neuter with prefix ge- $\rightarrow$ 0.
- Other neuter $\rightarrow$ -en.
- Käse $\rightarrow$ 0.
- Other Masculine or Feminine $\rightarrow$ -en.

Coda = non-\( \tilde{\varnothing} \) vowel:
- Feminine with coda = long stressed /e/ or /i/ $\rightarrow$ -en
- Other Feminine $\rightarrow$ -s
- Masculine or Neuter $\rightarrow$ -s.

Coda = \( \tilde{\varnothing} \) + consonant:
- Feminine Mutter, Tochter $\rightarrow$ 0 + umlaut
- Other Feminine $\rightarrow$ -en
- Kloster $\rightarrow$ 0 + umlaut
- Other Neuter $\rightarrow$ 0
- Masculine in List 3 $\rightarrow$ -en
- Masculine in List 4 $\rightarrow$ 0 + umlaut
- Other Masculine $\rightarrow$ 0

Other Consonant-final Codas:
- Feminine in List 5 $\rightarrow$ -s
- Feminine with -sal suffix $\rightarrow$ -e
- Feminine in List 6 $\rightarrow$ -e + umlaut
- Other Feminine $\rightarrow$ -en
- Neuter with -lein suffix $\rightarrow$ 0
- Neuter Fluss $\rightarrow$ -e + umlaut
- Neuter in List 7 $\rightarrow$ -s
- Neuter in List 8 $\rightarrow$ -en
- Neuter in List 9 $\rightarrow$ -er + umlaut
- Other Neuter $\rightarrow$ -e
- Masculine in List 10 $\rightarrow$ -en
- Masculine in List 11 $\rightarrow$ -s
- Masculine in List 12 $\rightarrow$ -er + umlaut
- Masculine animate in List 13 $\rightarrow$ -en
- Masculine animate in List 15 $\rightarrow$ -e + umlaut
- Other Masculine animate $\rightarrow$ -e
- Masculine inanimate in List 14 $\rightarrow$ -en
- Other Masculine inanimate $\rightarrow$ -e

List 1: Character-Charaktere, Klima-Klimate, Lira-Lire
List 2: Numerus-Numeri, Jus-Jura, Fortis-Fortes, Koma-Komata, Cherub-Cherubim
List 3: Brüssel, Bauer, Bayer, Fussel, Friesei, Gesatter, Hammer, Kaffer, Lackel, Muskul, Model, Pantoffel, Pommer (nonstandard) Stachel, Stiefel, Stummel, Stoppel, Treidel, Vetter, Ziegel
APPENDIX 2—Continued


List 5: Ahning, Bar, Brigg, Creme, Flak, Gig, Hall, Kautsch, Lok, Mansell, Ordre, Pak, Persenning, Pipeline, Trum

List 6: Angst, Bank (bench), Brot, Brand, Braun, Faut, -flucht (Aus-), Frucht, Gans, Graft, Hand, Haut, Kraft, -kraut, Kuh, Kunst, Laws, Luft, Lust, Macht, Magd, Maus, Nacht, Naht, Niß, Not, Nuß, Sau, Schlucht, Schnur, Schwulst, Stadt, Sucht, Wand, Wald, Wurst, -zucht (Ab-), Zunft, -nis


List 8: Apokryph, Autograph, Bett, Blag, Chromosom, Eck, Gatt, Gör, Hemd, Herz, Insekt, Ion, Jowel, Leik, Ohr, Quant, Requisit, Spunt, Stage, Statut, Verb, Watt

List 9: Aas, Amt, Bad, Balg, Band, Bein, Biest, Bild, Blatt, Bret, Brot, Buch, Dach, Daus, Ding, Dorf, Ei, Fach, Faß, Feld, Gehalt, Geld, Gemach, Gemüt, Geschlecht, Gesicht, Gespenst, Gewand, Glas, Glied, Grab, Gras, Gut, Haupt, Haus, Holz, Horn, Hospital, Huhn, Kälb, Kind, Kleid, Korn, Kreat, Lamm, Land, Licht, Lid, Lied, Loch, Muhl, Mal, Maul, Mensch, Moos (swamp), Nest, Pfand, Rad, Regiment, Reis, Rind, Roff, Scheit, Schewal, Schild, Schloß, Schwert, Spital/Hospital, Stift, Stück, Tal, Trumm, Tuch, Viele, Volk, Wams, Weib, Weif, Wort, -tum

List 10: Augur, Herr (spoken German), Kontal, Modul, Mogul, Nachbar, Satyr, Trümmer, Ungar

List 11: Anorak, Arrak, Badk, Baobab, Baribal, Bisam, Biston, Blizzard, Block, Bluff, Bob, Boulevard, Browning, Bulldog, Camembert, Champion, Chef, Clan, Clip, Clown, Cod, Cut, Dekor, Dollar, Drain, Drink, Fashin, Flip, Flirt, Footward, Frack, Galopp, Giaur, Gong, Grob, Groom, Harem, Havelock, Jak, Jup, Karneval, Kanon, Keg, Klub, Kognak, Konsum, Kornett, Krepp, Leunant, Lift, Lord, Marriott, Mop, Mufflon, Nabhoh, Park, Pennikon, Portulak, Poquid, Puff (breath), Pimp (shoe), Radar, Raglan, Safe, Schal, Scheck, Scheich, Schok, Seal, Shag, Sheriff, Skunk, Smoking, Snob, Sovjet, Sport, Star, Start, Steward, Stopp, Tank, Tarock, Tattersall, Test, Tic, Tip, Toast, Toboggan, Tomet, Tramp, Trick, Trip, Truck, Trapp, Trust, Tschibuk, Tush, Vamp, Yard

List 12: Balg, Daus, Dorn, Geist, Geschmack, Gott, Handsfott, Klotz, Leib, Mann, Mund, Ort, Rand, Rest, Schoß (Zoll), Ski, Stein, Strauch, Trumm, Wald, Wurst, Wicht, Wiking, Wurn, -tum (irrum, Reichum)

APPENDIX 2—Continued


APPENDIX 3:
ITEMS FROM EXPERIMENT 2

<table>
<thead>
<tr>
<th>Word</th>
<th>Meaning</th>
<th>zero</th>
<th>umlat</th>
<th>-e</th>
<th>uml-e</th>
<th>-en</th>
<th>-er</th>
<th>uml-er</th>
<th>-s</th>
</tr>
</thead>
</table>

Items with Rhymes: (plurals of rhymes, and their Ruoff frequencies, in parentheses)

*Brat* (Ruoff 55, Male 26, Pfähle 11, Wahlen 10, Zahlen 5, Schalls 4)

<table>
<thead>
<tr>
<th>root</th>
<th>Container of food</th>
<th>2.6</th>
<th>1.3</th>
<th>3.9</th>
<th>3.2</th>
<th>2.5</th>
<th>1.9</th>
<th>2.1</th>
<th>3.2</th>
</tr>
</thead>
</table>

*Name* | River           | 2.1 | 1.2 | 4.1 | 2.7 | 1.9 | 1.4 | 1.3 | 3.7 |
|--------|-----------------|-----|-----|-----|-----|-----|-----|-----|-----|

*borrowing* | Japanese camera | 3.6 | 1.1 | 3.6 | 1.9 | 2.1 | 1.4 | 1.5 | 3.8 |
<table>
<thead>
<tr>
<th>Word</th>
<th>Meaning</th>
<th>zero</th>
<th>umlat</th>
<th>-e</th>
<th>uml-e</th>
<th>-en</th>
<th>-er</th>
<th>uml-er</th>
<th>-s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Köch (Dächer 29, Bäcke 27, Fächer 11, Kräcke 6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>root</td>
<td>cold tablet</td>
<td>3.3</td>
<td>1.4</td>
<td>2.7</td>
<td>2.1</td>
<td>2.9</td>
<td>2.1</td>
<td>1.8</td>
<td>3.9</td>
</tr>
<tr>
<td>name</td>
<td>family name</td>
<td>1.9</td>
<td>1.2</td>
<td>1.8</td>
<td>1.3</td>
<td>1.6</td>
<td>2.1</td>
<td>1.7</td>
<td>5.0</td>
</tr>
<tr>
<td>borrowing</td>
<td>French clothing</td>
<td>3.3</td>
<td>1.2</td>
<td>3.5</td>
<td>2.5</td>
<td>2.1</td>
<td>2.4</td>
<td>2.5</td>
<td>3.8</td>
</tr>
<tr>
<td>Klot (Brote 103, Nütte 9, Boute 8, Schrot 5, Todt 4, Kot 1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>root</td>
<td>tool</td>
<td>2.6</td>
<td>1.6</td>
<td>4.2</td>
<td>3.5</td>
<td>2.4</td>
<td>1.7</td>
<td>1.7</td>
<td>4.1</td>
</tr>
<tr>
<td>name</td>
<td>first name</td>
<td>2.6</td>
<td>1.3</td>
<td>2.9</td>
<td>1.9</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
<td>4.4</td>
</tr>
<tr>
<td>borrowing</td>
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APPENDIX 3—Continued

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* Unpluralizable mass noun, not zero plural.

REFERENCES


