Compound Formation is Constrained by Morphology:

A reply to Seidenberg, MacDonald & Haskell

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Abstract

Why do compounds containing regular plurals, such as *rats-infested,* sound so much worse than corresponding compounds containing irregular plurals, such as *mice-infested*? Berent and Pinker (2007) reported five experiments showing that this theoretically important effect hinges on the morphological structure of the plurals, not their phonological properties, as had been claimed by Haskell, MacDonald, & Seidenberg (2003). In this note we reply to a critique by these authors. We show that the connectionist model they invoke to explain the data has nothing to do with compounding but exploits fortuitous properties of adjectives, and that our experimental results disconfirm explicit predictions the authors had made. We also present new analyses which answer the authors' methodological objections. We conclude that the interaction of compounding with regularity is a robust effect, unconfounded with phonology or semantics.

English-speakers prefer compounds containing irregular plurals, such as *mice-infested*, to compounds containing regular plurals, such as *rats-infested* (e.g., Gordon, 1985; Alegre & Gordon, 1996; Senghas, Kim, Pinker, & Collins, 2005). The theory that language consists of an interaction between a memorized lexicon and combinatorial grammatical operations (which we call the Words & Rules theory; Pinker, 1991, 1999; Pinker & Ullman, 2002b) attributes this phenomenon to the different morphological structure of irregular and regular plurals. Irregular plurals are represented as memorized roots, regular plurals as compositionally structured words. The relevant compounding operation concatenates a root (or stem) nonhead (such as *mouse* or *mice*) with the nominal head (such as *infested*).

Haskell, MacDonald and Seidenberg (2003) offered an alternative explanation: that regular plurals have a phonological form that is atypical of "modifiers," a category, they suggest, which encompasses both adjectives in phrases and the nonheads in compounds. Haskell et al. showed that a connectionist network trained to discriminate adjectives from nonadjectives ended up also dispreferring regular plurals compared to irregular ones. They suggested that speakers' dislike of compounds containing regular plurals can be explained by the speakers' histories of exposure to nominal modifiers in English, whose typical phonological and semantic properties differ from those of regular plurals. Their conclusion is that language ability consists of a sensitivity to the phonological and semantic properties of words, with no need for morphological structure or combinatorial operations.

In a recent series of experiments, we (Berent & Pinker, 2007) showed that the plurals-in-compounds effect is not, in fact, an epiphenomenon of the phonology of

regular plurals. Our Experiment 1 showed that people prefer compounds containing phonologically unfamiliar novel irregular plurals (as in *leevk-eater*) to compounds containing phonologically familiar regular plurals (as in *loonks-eater*). Our Experiments 2 and 3 showed that people have no trace of a dislike for compounds containing nonheads that are phonologically identical to regular plurals, such as *hose-collector*, whether they are compared with phonological controls, such as *hoes-collector*, or with semantic controls, such as *pipe-collector*. Our Experiments 4 and 5 showed that even when both the semantic and phonology of irregular and regular plurals are identical, as in *gleex-container* (based on irregular *gloox-gleex*) versus *gleeks-container* (based on regular *gleek-gleeks*), people reliably dislike compounds containing the regular plural.

Seidenberg, MacDonald, and Haskell (2007) claim these experiments are either not relevant to their hypothesis or are compromised by methodological problems. In this reply, we show that neither criticism is warranted.

1. The Theories of Language at Issue

Seidenberg et al. mischaracterize the two theoretical propositions at issue in our disagreement. First, we are not disputing their claim that language use reflects "multiple probabilistic constraints"; we are disputing their claim that these constraints are exclusively phonological and semantic, and must exclude all grammatical properties, such as morphological structure (see Pinker & Ullman, 2002a). Second, as we made clear in the original article, we are not defending Kiparsky's (1973) specific theory of level-ordered morphological and phonological rules; we are defending only the hypothesis that regular and irregular forms differ in their mentally represented morphological structure, rather than just in their phonology and semantics. More generally, the "rules" in "Words

& Rules" refers to grammatical operations over variables, including those in unification and constraint-based approaches (Prince & Smolensky, 1993/2004; Smolensky & Legendre, 2006; Pinker & Jackendoff, 2005).

2. The Specific Phenomena at Issue

Seidenberg et al. sometimes conflate two phenomena that affect plurals in compounds. One is that people generally prefer singular to plural nonheads (Haskell et al., 2003; Senghas et al., 2005): they like *mouse-eater* better than *mice-eater*. The standard explanation is that singular forms can be semantically unmarked for number, rather than always indicating singularity. This explanation is fully compatible with the Words & Rules account, and is independently motivated by experiments on the processing of the semantics of singular forms (Berent, Pinker, Tzelgov, Bibi, & Goldfarb, 2005).

The second phenomenon is that when people *are* forced to consider compounds containing plurals, they dislike ones with regulars (e.g., *rats-eater*) relative to ones with irregulars (e.g., *mice-eater*). Our disagreement concerns the second phenomenon. It is thus unfortunate that Seidenberg et al. characterize our experiments as "attempting to provide evidence that the grammatical distinction between singular and plural modifiers is relevant rather than phonology" (p. 289).

There is a third phenomenon, which consists of a qualification of the second one. Two subtypes of irregular plurals are also disliked, to varying degrees, in compounds: bifurcate pluralia tantum plurals (e.g., *trousers*), and plurals with regressive voicing (e.g., *loaves*). Haskell et al., and Seidenberg et al. attribute the dislike to their phonology (ending in *z*), though we point out that they also have the morphological structure of

regular plurals (stem + suffix). We will not discuss this specific phenomenon further, since our data on unambiguous regular plurals establish that morphological effects cannot be reduced to phonological ones.

3. Which is the More Relevant Measure of Phonological Typicality: Similarity to Adjectives, or Phonological Well-Formedness?

Our Experiment 1 contrasted nonwords like *ploon*, which conform to English phonology and hence are phonologically frequent, with nonwords like *ptoon*, which are phonologically illicit and hence are unattested in EnglishParticipants rated the singular and plural forms of these novel nouns in isolation and inside compounds, and we varied whether the plurals were regular (e.g., *ploon-ploons, ptoon-ptoons*) or irregular (e.g., *ploon-pleen, ptoon-pteen*). The acceptability of a plural-containing compound depended only on whether the nonhead was regular or irregular, not on whether its phonology was typical or atypical. Indeed, phonological frequency did not statistically interact with regularity, and people rated compounds with phonologically typical regular plurals (e.g., *ploons-eater*) as sounding far worse than compounds with phonologically atypical irregular plurals (e.g., *pteen-eater*).

Seidenberg et al. present several objections. The first is methodological: that our phonological manipulation was too weak to have an effect. Seidenberg et al. interpret our reporting of bigram frequency differences between the illicit and licit nouns (which we provided as a quantitative corroboration of the legality manipulation) as the primary basis of that manipulation. They then noted that the word recognition literature contains many reports of null effects of bigram frequency.

These null effects, however, are in response to small differences between words that are all attested in the language, for example, that between *boat* (summed bigram frequency of 81 per million) and *step* (summed bigram frequency of 28). Our manipulation, in contrast, differentiated onset- and coda-clusters that are either attested (hence with frequencies far above zero) or unattested (with frequencies of zero). Unlike the small effects of bigram frequency among attested forms, effects of cluster legality are well established (e.g., Hallé, Segui, Frauenfelder, & Meunier, 1998; Massaro & Cohen, 1983;Moreton, 2002; Pitt, 1998). Moreover, the illegality of our onset clusters does not stem from an accidental gap in the English lexicon—onset clusters as in *ptoon* are universally ill-formed relative to onsets as in *ploon* because of the sonority profile of their onsets (Clements, 1990; Smolensky, 2006), and people are sensitive to this grammatical distinction even when comparing onset clusters that are all unattested in their native language (Berent, Steriade, Lennertz, & Vaknin, 2007; Berent, Lennertz, Jun, Moreno, & Smolensky, 2008)

In any case, Seidenberg et al's a priori arguments are moot: when our participants rated these nouns *outside* of compounds, they were highly sensitive to the manipulation, rating the illicit forms as significantly less acceptable than the licit ones (mean rating of 2.9 versus 4.3 on a 7-point scale). People's insensitivity to the phonological frequency of nonheads in compounds therefore cannot be due to the weakness of the legality manipulation. Nor can their indifference be an artifact of our rating methodology (in which participants compared matched pairs like *ptoon-container* and *ptoons-container*, a procedure that could reduce sensitivity to properties manipulated across pairs), since the participants evinced a strong and significant difference between the compounds

containing regular and irregular plurals (which, like our phonological legality manipulation, was manipulated across pairs). Our interpretation of Experiment 1 thus rests not on a null effect but on a positive one— that regular plural nonheads are disliked relative to irregular plurals, irrespective of their phonological frequency.

Seidenberg et al's theoretical objection is that phonological frequency in the language is irrelevant to their original hypothesis that speakers' dislike of regular plurals reflects their experience with compounds in the language. They argue that only the phonological properties of nonheads *in compounds*, not the phonological properties of English words in general, is relevant. Yet as we pointed out, the phonological forms of our illicit forms are less frequent in compounds than the phonological forms of regular plurals, since phonologically illicit nonheads are never attested in compounds, whereas many nouns that sound like regular plurals (e.g., *rose garden*), together with some exceptions that actually are regular plurals (e.g., *publications catalogue*), do occur.

We agree with Seidenberg et al. that ultimately the best test of their hypothesis would come from an analysis of the phonological properties of nonheads in English compounds, representing the input to a speaker during language acquisition. They claim to have done so, and to have modeled a sensitivity to such properties in a connectionist network. But as we noted in Berent & Pinker (2007), this claim is misleading. Haskell et al. analyzed the phonological properties of English adjectives, not the nonhead elements in English compounds. By referring loosely to both kinds of elements as "modifiers," they gave the impression that their analysis was relevant to the statistical properties of compounds. This allowed them to capitalize on a fortuitous fact about the English lexicon: that it almost entirely lacks common adjectives ending in *z* or in unvoiced *s*-final

consonant clusters. Since these are the phonological signatures of regular plurals, a model that learns what adjectives sound like will, coincidentally, disprefer regular plurals.

But as noted, the adjectives in noun phrases (such as *large* in *large room*) and nonheads in compounds (such as *rat* in *rat-infested*) behave completely differently in numerous linguistic phenomena (semantic, syntactic, and phonological), and no viable model of language acquisition could collapse their properties. Indeed, if Seidenberg et al. really thought that learners generalize over a single category of "modifiers" embracing adjectives and the nonheads in compounds, it is not clear why they exclude possessives such as *Bill's* in *Bill's dog*. Possessives, of course, are phonologically identical to plurals, so a model that learned the phonological properties of "modifiers," collapsing over grammatical differences, would have to accept plurals in compounds—contrary to the phenomenon at hand.

Note, too, that Haskell et al's network was not a model of compound recognition, but a model trained to discriminate the phonological properties of adjectives and nonadjectives after a regimen of supervised learning. During such training, connectionist networks learn to zero in on the input properties that discriminate one category from another, and learn to ignore the properties that fail to discriminate them. And this is why Seidenberg et al. were able to claim that their model was insensitive to the difference between our licit and illicit materials. Since the difference between phonologically licit and illicit words is not diagnostic of the difference between adjectives and nonadjectives (all the adjectives, and all the nonadjectives, in the model's training set were licit), it is completely predictable that their trained discrimination network would be insensitive to the licitness difference. But people are not insensitive to

the difference: as mentioned, our participants did rate the illicit nouns as worse when they are presented outside of compounds (which is exactly the circumstance in which Haskell's model was given the forms). They were just insensitive to the difference when the nouns were placed inside compounds.

A similar explanation shows why Seidenberg et al.'s new simulation, which discriminated plurals from nonplurals, failed to distinguish licit and illicit materials. The model was trained to find the phonological properties that distinguish singulars and plurals, which of course pertain only to the presence of *s* or *z* at the end of codas. The phonological properties typical of nonheads are not diagnostic of the singular-plural distinction, and so the model learned to ignore them.

More generally, it is unclear how either simulation of supervised discrimination learning is relevant to real people acquiring language. People are exposed to compounds in the language, and if Haskell et al. are correct, spontaneously become sensitive to the phonological properties in a kind of unsupervised learning. They do not hear labeled positive and negative examples of nonheads and make an effort to discriminate them.

4. Singular Nouns that Sound Like Regular Plurals.

Our Experiments 2 and 3 tested a clear prediction from Haskell et al.:

> "One way to address this question would be to look at words for which phonological and morphological cues conflict, e.g., *box*, which is a singular noun but sounds like a regular plural. The phonological constraint should cause such words to be somewhat less acceptable as modifiers than other singulars" (p. 143).

This is exactly what we did, and the prediction was falsified. Compounds containing nonheads that merely sound like regular plurals (*hose-collector*) are no less acceptable than those containing singular controls (e.g., *pipe-collector* or *hoe-collector*).

Seidenberg et al. ignore their own prior prediction and now claim that such compounds should be perfectly acceptable, because "the language does not provide another way of expressing the intended concept without violating other constraints that create worse expressions" (p. 298). That is because the alternative expression would either contain a homophone of another word (*hose* → *hoe*) or a nonword (e.g., *blaze* → *blay*).

But the hypothesis that grammatical forms are completely acceptable whenever there is no alternative is falsified by numerous phenomena, including the presence of morphological gaps in English and many other languages, and the very phenomenon under consideration here. There is no alternative way of expressing "an eater of more than one rat" in English, yet people dislike *rats-eater*, whereas they show no such dislike of *mice-eater* as "an eater of more than one mouse."

This claim is also at odds with their own theory, which posits a continuum of judgments reflecting an aggregation of multiple, probabilistic constraints. Even if one constraint (the absence of an alternative form) would militate in favor of a form, the other constraint (phonological resemblance to typical nonheads) should militate against it, and the quantitative effect of that second constraint would be detectable in the ratings (as they themselves had previously predicted).[1] Note also that the proposed mechanism, which

[1] Seidenberg et al. attribute an erasure of phonological frequency to constraint-based approaches in general, but research in Optimality Theory has shown that low-ranked

would check for the availability of homophones and for the lexicality of modified forms, is not a feature of any of their computational models, but is brought in to explain this recalcitrant datum. Indeed, the computational model described in their Study 7 disliked regular-sounding forms such as *gunitions* as modifiers even though the removal of the *–s* would alter the meaning of the input, just as it would for *hose* in our experiments.

Seidenberg et al. devote most of their criticism of Experiments 2 and 3 to our parenthetical remark that English speakers never strip the *s* from such nonheads (producing, say, *fokhole*) the way they do with regular plurals (e.g., producing *rat-infested* instead of *rats-infested*). They reject the possibility that any reasonable model would truncate a word into a nonword. Yet people do something like this in compounds like *scissor-blade, pantleg,* and *trouser-press*. And it cannot be taken for granted that distributed connectionist models lacking lexical entries preserve the form of a word; stem distortions in such models are not at all uncommon (Pinker & Prince, 1988; Marcus, 1998; Sproat, 1992). In any case, the crucial phenomenon is not whether people truncate -s-final nonheads, but whether they disprefer them at all, as Seidenberg et al. had predicted.

5. Compounds containing Regular and Irregular Plurals that are Perfectly Matched

Our final experiments compared compounds containing a constant phonological form (e.g., /brix/) presented either as a regular plural (e.g., of /brik/) or as an irregular plural (e.g., of /bruk/). Because people might dislike /brix/ for reasons unrelated to its morphological structure, these experiments also measured the acceptability of these forms outside compounds. Whether presented in writing (Experiment 4) or auditorily

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well-formedness constraints continue to exert their effect, a phenomenon known as *the emergence of the unmarked* (e.g., McCarthy, 2002, p. 129).

(Experiment 5), the compounds containing regular plurals were rated significantly lower than those containing irregular plurals, despite the fact that the two forms were identical phonologically and semantically.

Seidenberg et al. begin their criticism of these experiments by claiming that a theory which invokes grammatical processing cannot explain why phonologically unusual singular forms should be rated poorly, nor why speakers' ratings of singular and plural alternatives might affect one another. But as mentioned in section (2), the possibility of multiple graded constraints is not at issue.

Seidenberg et al. do, however, use these effects to make a valid methodological criticism, which we agree requires additional data to rule out. Our ratings show that singular forms like *breek* (the base for regular *breeks*) are preferred to singular forms like *broox* (the base for irregular *breex*). Seidenberg et al. note that this difference could taint the evaluation of compounds containing their plural counterparts: the well-formedness of *breek* could taint the regular plural *breeks* when they are rated together, whereas the ill-formedness of *broox* could elevate the irregular plural *breex* when they are rated together. The dislike for regular plurals in compounds would, in these experiments, be an artifact of their suffering in comparison with the relatively good-sounding singular counterpart. In support of the possibility of such a contrast effect, Seidenberg et al. note that such a tradeoff was found in our Experiment 1, in which a singular form like *loovk* was rated lower when contrasted with a relatively well-formed irregular plural nonhead (e.g., *leevk*), compared to when it was contrasted with an ill-formed regular plural nonhead (e.g., *loovks*). Seidenberg et al. colleagues take the capacity of the plural to taint the singular as evidence that singulars may also taint plurals.

Here we report two tests of whether the greater acceptability of the regular singular forms can explain people's greater dislike of the regular plurals. In the first analysis, we chose subsets of the regular and irregular nouns that were matched on their mean acceptability as singulars inside the compounds. Any dislike for the compounds containing their plural counterparts would have to be attributable to regularity per se, not acceptability of the singular. The results are presented in Table 1. As in the original paper, the ratings of the compounds with plurals are corrected for the ratings of the same plural in isolation. For the data from Experiment 5, the singulars are corrected in this way as well.

Insert Table 1 about here

In both cases, the compounds containing regulars are rated significantly worse than the compounds containing irregulars (for Experiment 4, $t_{items}(10) = 9.66$, $p < .0001$; for Experiment 5, $t_{items}(18) = 2.22$, $p < .04$).[2] . This analysis shows that the usual dislike of regular plurals in compounds, replicated in these studies with perfectly controlled phonological properties, is not a contrast effect triggered by comparisons with the compounds containing their singulars.

Our second analysis also capitalizes on the fact that there is considerable variation in the acceptability of the singular nouns in each class, allowing us to test whether such variation in general (including the difference between our regular and irregular items) is the cause of the difference in their acceptability as plurals inside compounds. We

[2] Because in the original design items were counterbalanced across subjects, the subsets of items selected here are unbalanced over subjects, and do not permit statistical tests with subjects as the error term.

performed a regression analysis on the mean ratings of all the plural compounds (corrected for goodness outside the compounds, as in the original studies), with two predictors: whether the plural is regular or irregular, and the mean rating of the corresponding compounds containing the singulars. If the regularity difference is a contrast effect arising from differences among the singulars, then it should go away when the effects of the singular ratings are statistically held constant. These analyses showed that in fact the unconfounded effects of regularity account for a significant proportion of the variance in compound ratings (20.9% in Experiment 4, $F_{change}(1, 37)=16.00$, $p<.001$; 15.3% in Experiment 5, $F_{change}(1, 37)=7.48$, $p<.01$). By way of comparison, the unconfounded effects of ratings of the singular forms when regularity is held constant accounted for only 0.1% of the variance in Experiment 4 ($F_{change}<1$) and a nonsignificant 5.6% of the variance in Experiment 6 ($F_{change}(1, 37)=2.72$, $p<.11$). The analyses confirm that the dislike of regular plurals in compounds replicated in these experiments is not attributable to a contrast effect with their singular counterparts.

6. Conclusions

The dislike of compounds containing regular plurals (e.g., *rats-infested*) and the greater acceptability of similar compounds containing irregular plurals (e.g., *mice-infested*) has been discussed in the linguistics and psycholinguistics literature, and brought to bear on several important theoretical issues, for more than 25 years (Kiparsky, 1982). Seidenberg, Haskell, and MacDonald, arguing from a theoretical framework that rejects the possibility that morphological regularity can have any causal role in language processing, have tried to show that the effect is an epiphenomenon of phonological

differences between regular and irregular forms, which learners become sensitive to during the course of exposure to compounds in the language.

However, in Berent and Pinker (2007), and in the present reply to their objections to that paper, we note that their computational model has nothing to do with compounds or their phonological, semantic, or grammatical properties. Instead it learns to discriminate adjectives from nonadjectives, and their argument for relevance to compounding depends on a conflation of adjectives with compound nonhead in the dubious category they call “modifiers.” It also depends on a questionable characterization of the acquisition of compounds as supervised discrimination learning from labeled inputs.

Moreover, we reported five experiments which show that the relative dislike of regular plurals in compounds does not go away no matter how their phonological and semantic properties are equated or controlled. In this note we confirm that these results are not artifacts of a weak phonological frequency manipulation (Experiment 1), the lack of an alternative way to formulate the compound (Experiments 2 and 3), or a contrast effect triggered by differences in the singular counterparts (Experiments 4 and 5). We conclude that regardless of what the best theory of the interaction between regularity and compounding turns out to be, the effect of morphological regularity is genuine, and is not reducible to phonology or semantics.

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Table 1:
Mean Ratings of Compounds Containing Regular and Irregular Plurals Matched on Ratings of Their Singulars

Experiment 4 (*n* = 6 items per cell)

	singular	plural
regular	5.04	3.61
irregular	5.04	6.22

Experiment 5 (*n* = 10 items per cell)

	singular	plural
regular	6.27	5.69
irregular	6.20	6.71