A Level *Playing-Field:* Perceptibility and Inflection in English Compounds

Robert Kirchner and Elena Nicoladis (U. Alberta)

Abstract

To explain why English compounds generally avoid internal inflectional suffixation (e.g. *key-chain* rather than *keys-chain*), linguists have often invoked the Level Ordering Hypothesis (Siegel 1979), i.e. that particular types of morphology, in this case inflectional suffixation, are derivationally ordered after compounding. However, a broad range of counterexamples and conceptual objections to Level Ordering have emerged. We propose an alternative account, based on the observation that certain English inflectional suffixes are more perceptible than others (*-ing* > *-s* > *-ed*), and that these suffixes are less crucial to lexical access and recovery of meaning than corresponding root-final segments. This proposal was tested in perception and production experiments. In the perception experiment, compounds with a nonsense word as modifier (e.g. *dacks van, dacked van*) were auditorily presented to 20 native English speakers, who were asked to spell what they heard. The participants omitted significantly more *-ed* than *-s* or *-ing*. In the production experiment, we asked 22 native English speakers to read these compounds. The speakers dropped significantly more *-ed* than *-s* or *-ing*. Furthermore, they dropped more of these sounds when they were spelled as affixes than as part of the root (e.g. *dacked van* vs. *dact van*. These results suggest that English speakers' avoidance or inclusion of inflection in compounds is based not on Level Ordering, but on perceptibility as well as the status of the consonant as an affix. We further present a formal analysis capturing these factors in terms of Steriade's (1999) Licensing-by-Cue proposal.

1. Introduction.

1.1. <u>The Issue</u>.

In English, inflectional suffixes rarely occur within compound words, e.g. *keychain,* not *keys-chain,* despite its canonical use for holding several keys. This observation has previously been attributed to the derivational mechanism of **Level Ordering** (Siegel 1979). The Extended Level Ordering Hypothesis, particularly as elaborated in the theory of Lexical Phonology, assumes something like the following organization of the grammar:

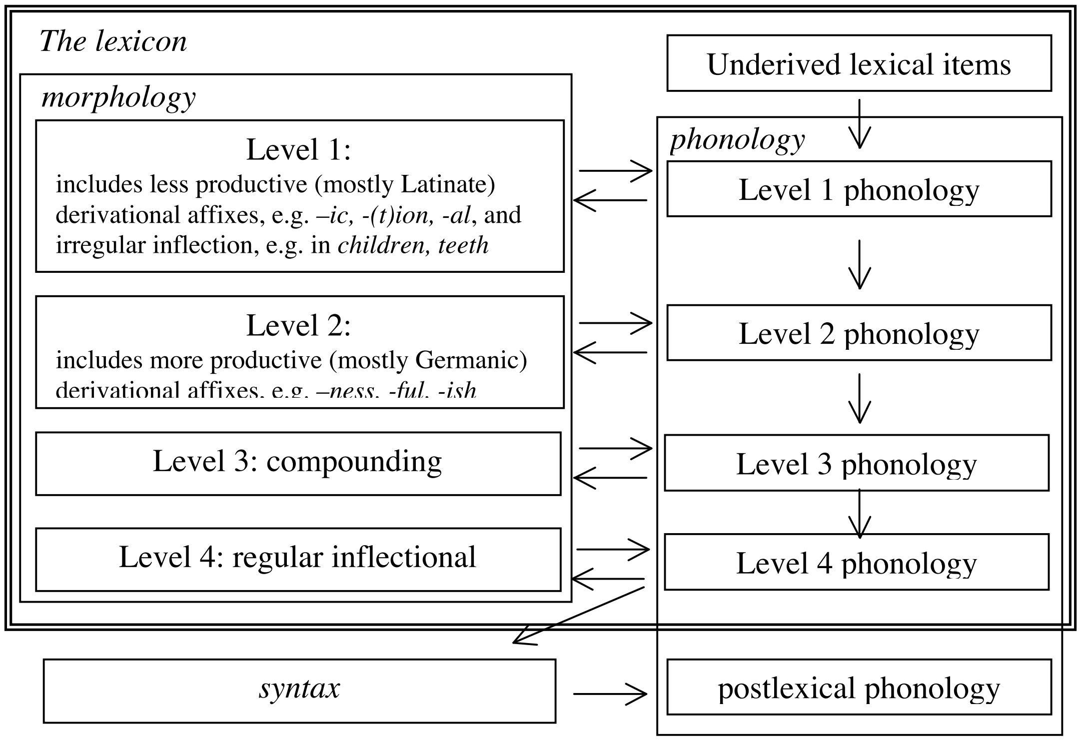


Figure 1: Level ordering of English morphology, phonology, and syntax, in Lexical Phonology (after Kiparsky 1982, Mohanan 1986).

By this account, a compound such as *keychain* is formed by first combining the roots, *key* and *chain*; inflectional affixes are added later in the derivation, at which point the root *key* is no longer accessible to plural suffixation.

Despite its once-widespread deployment in Generative theories of morphology and phonology, however, the Level-Ordering Hypothesis is now embarrassed by numerous classes of counterexamples, while theories of morphology and phonology have generally moved away from derivational devices, in favour of more declarative, constraint-based approaches. Indeed, Level Ordering's viability has been in doubt since Fabb (1988) demonstrated that it is neither necessary nor sufficient for an account of ordering of English derivational affixes, thereby refuting Siegel's (1979) original motivation for Level Ordering. The time is therefore ripe for a reexamination of generalizations previously attributed to Level Ordering, particularly the avoidance of inflection within compounds. In this paper, we argue that avoidance of inflection within compounds is a more nuanced phenomenon than Level Ordering predicts. We then develop a more accurate account, appealing to Optimality Theory (Prince and Smolensky 1993), specifically Steriade's (1999) perceptually-based approach to phonotactics (Licensing by Cue).

1.2. Empirical Problems of Level Ordering.

As a threshold matter, it must be recognized that avoidance of inflection within compounds is not a cross-linguistic generalization, but a generalization about English (and arguably certain other languages, e.g. German, Clahsen, 1995).[1] In Turkish, by contrast, a variety of inflectional suffixes can appear within compounds (Spencer, 1991; see also Lardiere, 1995):

(1)	el-i açık	vurd-um duymaz	Türk Dil-i Dergi-si
	his-hand open	I-hit it-doesn't-feel	Turk his-language its-journal
	'generous'	'thick-skinned'	'Turkish Language Journal'

The literature is in fact unclear as to the extent to which Level Ordering is supposed to be universal. It generally seems to be assumed that the architecture is part of Universal Grammar, although some aspects of Figure 1, such as the particular set of Level 1 affixes for English, and the phonological rules which apply to them, obviously must be language-specific. But no consensus has emerged from this research program as to (a) how learners determine which level particular morphological operations or phonological rules belong to in their target language, (b) what universal properties each level must have (e.g. cyclic vs. non-cyclic rule application), nor even (c) the number of levels.

[1] We leave for future research the typological question of whether the English or the Turkish pattern is more common cross-linguistically.

Without a coherent position on these basic issues, claims of universality for Level Ordering may be largely meaningless. On the other hand, if Level Ordering is merely language-specific, the hypothesis faces the non-trivial problem of explaining how learners of English morphology acquire this derivational architecture (Gordon, 1985).

Furthermore, to the extent that Level Ordering categorically rules out inflection within compounds, its predictions are demonstrably false, even for English. The progressive/gerundive suffix *-ing* occurs quite freely within compounds, e.g. *playing field*, *hummingbird*, *washing machine, rolling pin*. The possessive, -'*s*, can also occur e.g. in *writer's cramp, menswear, foolscap, cat's paw*. The plural suffix occurs compound-internally in some forms, e.g. *systems analyst, glasses case*, *arms control, sales manager, clothespin, sports car,* though the plural nouns in these cases typically receive a plurale tantum reading, distinct from the normal meaning of the singular form (Gordon, 1985). Even the past tense suffix *-ed* occurs in certain compounds, e.g. *scorched-earth, corned beef*. To handle such violations of Level Ordering, Mohanan (1986) proposes a derivational "loop," allowing forms to cycle back from Level 4 (inflectional affixation) to the Level 3 (compounding). Some researchers have argued that this kind of loop allows for differentiation of meaning, for example the difference between *a red rat eater* (an eater of rats who is red) and *a red rats eater* (an eater of red rats; see Alegre and Gordon, 1995). Nevertheless, allowing optional loops renders Level Ordering, at least as applied to the present topic, empirically vacuous.[2]

[2] Alternatively, it is possible to dismiss some of these counterexamples by assuming that the *–ing* or *-ed* occurring within compounds is a derivational suffix, homophonous with but distinct from inflectional *–ing, -ed*. But in the absence of some independent diagnostic of the inflectional vs. derivational status of *–ing* or *–ed* within particular words, this assumption likewise renders the Level Ordering claim vacuous.

Although the claim of no inflection within compounds is untenable in its absolute form, there is, nevertheless, a strong tendency for avoidance of some inflections, which requires explanation. Moreover, not all inflectional affixes are equal in preservation: a hierarchy of compound-internal inflection acceptability appears, *-ing* > *-s* > *-ed*, based on the authors' intuitions as native speakers of English,[3] as well as the experiments in §§3, 4. Asymmetric loss of inflectional suffixes within compounds is also demonstrable diachronically, e.g. retention of *-ing* in *washing machine,* variable loss of *-s* in *scissor(s) kick,* and firmly established loss of *-ed* in *iced cream* > *ice cream, popped corn* > *popcorn*. The Level-Ordering analysis (with or without the 'Loop') treats all these inflectional suffixes as derivationally equivalent; thus it cannot account for these asymmetries.

A further problem is the behaviour of irregularly inflected forms, e.g. *teeth*, *children*. Under standard Level Ordering assumptions for English (see e.g. Kiparsky 1982, 1985; Mohanan 1986), irregular inflection is assigned to the very first stratum of the morphology. Since irregular inflection thus precedes compounding, the Level Ordering account predicts that irregular inflection can occur freely within compounds. Although we find a few compounds with internal irregular inflection, such as *teethmarks*, and there is experimental evidence indicating that speakers, particularly children, are more likely to produce novel compounds containing an irregular plural than a regular one (Gordon, 1985; Nicoladis, 2003), irregular plurals are also largely avoided within compounds by adults. Thus, a brush for the teeth is a *toothbrush (*teethbrush)*, and the

[3] We attempted to verify these intuitions by consulting CELEX, the English corpus most readily available to us; however, the set of identifiable compounds (i.e. structurally tagged as such) within this corpus appears to be only a non-representative fragment of those occurring in English: it omits, for example, most of the examples with internal –*s* (or –'*s*) cited above. We leave a more thorough corpus-based study of this question for future research.

supervision of children is *childcare (*children care)*: the behaviour of these compounds with irregular plural inflection seems to nearly parallel the regular cases such as *keychain*. Furthermore, Seidenberg, Haskell, and MacDonald (1999) have argued that the inclusion of irregular plurals is a nuanced phenomenon as well, with speakers preferring to avoid irregular plurals that sound like regular plurals (like *mice*) while preserving irregular plurals that do not sound like regular plurals (like *feet*).

Some proponents of Level Ordering have argued that this architecture is unlearned, and constrains compounding as soon as speakers produce novel compounds (Gordon, 1985), although recent evidence has challenged that argument. The evidence for Level Ordering being unlearned comes from English-speaking and German-speaking preschool children who avoid using regular plurals within compounds but allow irregular plurals (Gordon, 1985; see also Clahsen, 1995). Children allow irregular plurals even though their experience with compounds with irregular plurals is infrequent to non-existent. This holds true both for novel synthetic compounds in the form X-eater (Gordon, 1985) and novel noun-noun compounds (Nicoladis, 2003) for monolingual children. However, other studies have shown that novel English compounds created by bilingual children (Nicoladis, in press), second-language learning preadolescents (Murphy, 2001) and second-language learning adults (Lardiere,1995) allow regular plurals on the non-head. Furthermore, English-speaking children often go through a phase of producing ungrammatical compounds like *a break-bottles*, to refer to a single machine breaking multiple bottles, in which regular plurals are allowed on the non-head *bottles*[4] (Nicoladis and Murphy, 2004). This finding is problematic for Level Ordering, since the plural suffix in such cases marks the number not of the compound as a whole, but of its non-head constituent, *bottles*, which is ostensibly inaccessible to plural suffixation once the compound is formed. These studies demonstrate that learners are not necessarily constrained by Level Ordering when they first begin to produce compounds. Rather, these results suggest that English speakers tend to avoid regular plurals in non-head position of compounds if the non-head is to the left of the head. That is, English-speaking children are more likely to avoid regular plurals in the first noun of noun-noun compounds (Nicoladis, 2003) and the X of X-eater compounds (Gordon, 1985) than they are in the non-head noun of ungrammatical compounds like *a break-bottles* (Nicoladis and Murphy, 2004). That is, English speakers may simply avoid word-internal *-s* (Hayes, Murphy, Davey, Smith, and Peters, 2002; Seidenberg et al., 1999).

The Level Ordering Hypothesis is beset with similar problems in other domains as well. For example, the assumption that compounding precedes syntax is difficult to reconcile with the observation that syntactically regular constituents, including grammatical function words, can be found within compounds: e.g. *off-the-wall behaviour, Mom-and-apple-pie values, a real you-won't-have-Dick-Nixon-to-kick-around-any-more farewell speech.* Such a reconciliation can only be achieved by assuming that phrases such as *Mom and apple pie* can be stored as atomic lexical entries, independent of their component morphemes (e.g. Di Sciullo and Williams 1987). But in the Generative framework in which Level Ordering is couched, linguistic regularity is attributed exclusively to the grammatical rule system, which assembles well-formed

[4] There are some exocentric compounds extant in English (like *pickpocket* and *daredevil*) but they are not considered productive. Curiously, Marchand (1960) notes at least one exocentric compound of this form with a regular plural in a non-head constituent: *sawbones*.

expressions from listed elements; and lexical listing is reserved for the "lawless" (as Di Sciullo and Williams themselves put it), i.e. the purely arbitrary and unpredictable elements of language. Di Sciullo and Williams' move must be distinguished from the less controversial view of, e.g. Mohanan 1986, allowing lexical listing of regularly derived forms: in such cases, the derivational architecture in Figure 1 is understood as a checking mechanism; these listed items are well-formed just in case they are structured *as if* generated by the Level-Ordered rule system. For Di Sciullo and Williams, however, such listing allows items to *circumvent* the predictions of Level-Ordering and other grammatical restrictions. This raises the question of why this lexical listing option is not likewise available for **keyschain* or **popped-corn,* rendering Level Ordering empirically vacuous as it applies to inflection within compounds.

1.3. The move away from derivation.

In addition to these empirical deficiencies, both general and specific – perhaps partly because of them – linguistic theory has seen a general abandonment of derivational devices in favour of parallel, declarative analyses of many phenomena. One such alternative is the framework of Optimality Theory ('OT', Prince and Smolensky 1993),[5] now widely adopted particularly in phonology. In OT, the basic formal device is a set of universal, violable constraints, applying in parallel.[6] Analyses are typically presented by

[5] A partial alternative explanation to the Level Ordering account of inflection and compounding has been put forward in a connectionist framework. Seidenberg et al. (1999) have argued that irregular plurals are avoided if they sound like regular plurals (e.g., *mice* sounds like a regular plural so speakers are more likely to change *mice* to *mouse* than *feet* to *foot*). While this argument addresses why some irregular plurals are more acceptable within compounds than others, it does not address the question of why some morphemes (like *-ing*) are used freely in compounds, some appear occasionally (like plural –s and possessive –'s) and some appear virtually never (like –ed).

[6] Some OT analyses (e.g. Boersma 1998, Kiparsky 2000) have retained Lexical Phonology's multi-stratal architecture, but the general thrust of OT is decidedly declarative and parallel: most OT proponents have therefore rejected serial devices such as multi-stratal grammars.

showing a set of output candidates, with the relevant constraints, and the violations incurred by each candidate.

(2)

Input: /an-ba/	*HETERORGANIC CLUSTER	PRESERVE (nasal)	PRESERVE (coronal)
anba	*		
☞ amba			*
aba		*	*

In (2), the first candidate [anba] is identical to the input, and in particular it preserves the features [nasal] and [coronal] of the input ('faithfulness' constraints); but it violates the high-ranked *HETERORGANIC CLUSTER, a constraint expressing the markedness of heterorganic clusters relative to single consonants or homorganic clusters. The last candidate, [aba], satisfies the markedness constraint, but violates both faithfulness constraints. The optimal form is therefore [amba], which violates only the low-ranked PRESERVE(coronal). This ranking thus captures a phonotactic generalization of languages such as Japanese, which prohibit heterorganic clusters (e.g. /jom+ta/ → [jonda]) ('read-PAST'). Conversely, in a grammar where *HETERORGANIC CLUSTER is low-ranked, /an-ba/ would surface as [anba]. With different rankings, and inclusion of other markedness or faithfulness constraints, yet further outcomes are possible. In sum, OT is a framework in which phonological systems are expressed in terms of tradeoffs among potentially conflicting universal constraints; and phonological computation is a single-step mapping from input to output, by selection of the optimal candidate.

This is not to say that the Level Ordering account is wrong merely because it is no longer 'in fashion.' However, to the extent that Level Ordering's plausibility was bolstered by the apparent conceptual necessity of a broad range of derivational devices throughout morphological and phonological theory, its plausibility is now undermined by the development of alternative – in many cases, arguably superior – modes of analysis.

2. Assumptions and predictions.

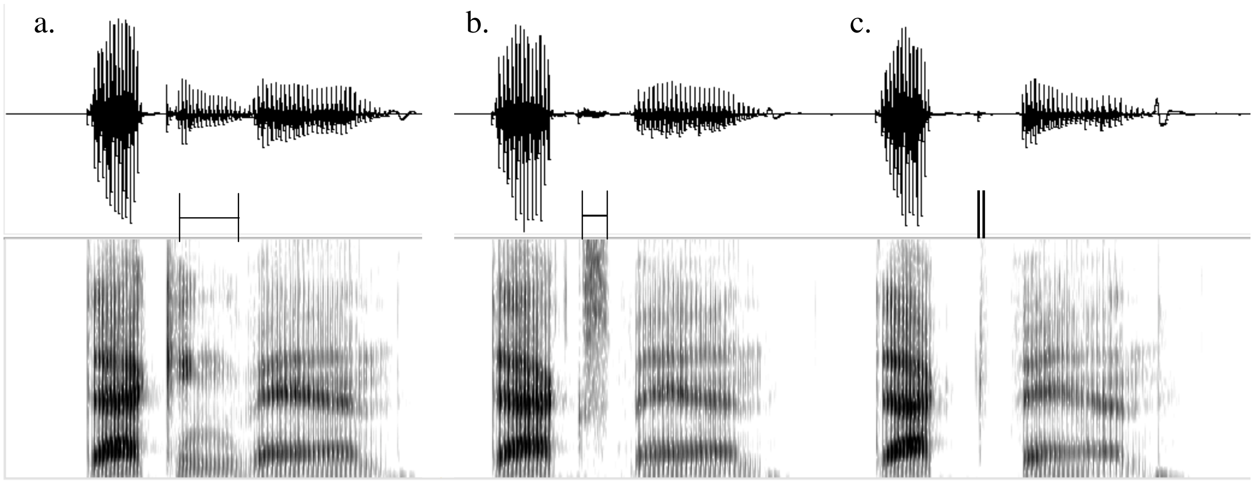
2.1. Perceptual salience.

We begin with the intuition that the inflectional suffix *-ing* may occur quite freely within compounds, *-s* (plural or possessive) much less freely, and *-ed* least of all. We suggest that this asymmetry reflects considerations of relative perceptibility:[7]

- *-ing* is the only English inflectional suffix which includes a vocalic portion, i.e. with relatively high amplitude, periodic energy and clear formant structure (Figure 2a).
- *-s*, by contrast, lacks a strong periodic signal and clear formant structure. Though it contains strident fricative energy (Figure 2b), this energy, being aperiodic, is more easily masked by environmental noise, which is also typically aperiodic.
- *-ed* has the weakest internal cues, namely an interval of silence, indistinguishable per se from a pause (perhaps with some weak voicing during a portion of the stop in the case of the [d] allomorph). If the stop is articulated with an audible release, some place and manner cues are contained in the release burst (Figure 2c). But bursts, like fricatives, are aperiodic, and even more vulnerable to masking due to their shorter

[7] Our perceptibility scale correlates with another scale widely used in phonological theory: the sonority hierarchy (see e.g. Steriade 1982). Acoustic/auditory sonority (i.e. average loudness of a particular sound, Ladefoged 2004) in fact amounts to the same thing as ‘perceptibility’ as used herein, under the general observation that louder sounds are more readily perceived. We decline to appeal to the sonority hierarchy, however, to avoid entanglement in the longstanding question of whether sonority is an acoustic/auditory, articulatory, or abstract phonological property (see Clements 1990). Also, sonority is standardly understood as a property of individual sounds, and thus could not be applied to sequences such as [ɪŋ]. Finally, by appealing to ‘perceptibility,’ rather than sonority, we ground our account of these linguistic patterns straightforwardly in the communicative function of speech, i.e. the hearer's need to be able to recover the speaker's intended meaning from the sound signal.

duration; indeed, in pre-consonantal position (as in *dacke*<u>*d*</u> *van*), English stops frequently are not audibly released at all (Jun, 1995).



[d æ k ɪ ŋ v æ n] [d æ k s v æ n] [d æ k t v æ n]

Figure 2. Waveforms and spectrograms of *dacking van, dacks van and dacked van,* showing portions of the signal containing cues to the inflectional suffixes.

On the basis of these phonetic considerations, among the English inflectional suffixes, we infer the perceptibility hierarchy *-ing* > *-s* > *-ed*.

In its most direct form, our hypothesis is that asymmetric avoidance of certain inflectional suffixes within compounds is attributable to hearers' asymmetric failure to perceive certain inflectional suffixes when learning novel compounds (cf. Ohala 1981 for an account of a range of linguistic patterns in terms of such hearer misperception). That is, when English listeners are presented with a compound such as [dækɪŋ væn], the *-ing* will most likely be perceived. In contrast, when they are presented with [dæks væn], listeners are less likely to detect the *-s* (i.e., to hear [dæk væn] instead) than the *-ing* in [dækɪŋ væn]. And, finally, when presented with [dækt væn], listeners are even less likely to hear the *-ed* (i.e. to hear [dæk væn]) than to hear the *-s* in [dæks væn].[8] This hypothesis is tested in Experiment 1.

Moreover, adopting Jun's (1995) Production Hypothesis (that speakers are more likely to omit or hypo-articulate sounds which, inherently or contextually, lack salient perceptual cues, cf. Steriade 1999, Kohler 1990, Lindblom 1983), we hypothesize that this perceptual asymmetry plays a role in speech production as well. That is, English speakers are least likely to omit the *-ing* in [dækɪŋ væn], somewhat more likely to omit the *–s* in [dæks væn], and most likely to omit the *–ed* in [dækt væn]. A subtler form of the hypothesis is that considerations of perceptibility play a role in the diachronic origin and retention of compounding patterns, though these patterns (including the near-absolute ban on *-ed*, and a weaker dispreference for *-s*) may have become grammaticized as rules, constraints, or emergent schemas (perhaps stochastic in character) governing compound formation in English. But in either case, perceptual salience ought to be related to how often inflections are preserved inside compounds. This hypothesis is tested in Experiment 2.

2.2. <u>Morphological affiliation</u>.

Preservation of sounds within compounds should also be related to whether speakers treat the sound as a separate affix or as part of the root. It is a commonplace observation in phonology, going back at least to Jakobson (1965), that languages asymmetrically target affixes rather than root-internal segments, for a broad range of neutralizing processes. Kawahara (2003) summarizes the evidence: affixes are more

[8] A corollary prediction is that the [əz] and [əd] allomorphs, as in *judge's robes* or *grated cheese*, should be preserved to a greater extent than their respective schwa-less allomorphs, since the schwa provides a vocalic portion to the suffix. None of the stimuli included the [əz] and [əd] allomorphs, however. We leave the testing of this prediction for future research.

likely than roots to undergo vowel harmony (Bakovic 2000), dissimilation (Suzuki 1998), coalescence or other hiatus-avoiding neutralizations (Casali 1996); and sound inventories are typically more restricted in affixes (McCarthy and Prince 1995). We speculate that this asymmetry reflects the greater importance of root-internal sounds for accurate lexical access and recovery of meaning: a substantial misinterpretation of the speaker's meaning is more likely to occur if the hearer accesses the wrong root than the wrong suffix; and a richer inventory of phonemes must be maintained to distinguish open-class lexical items (as most English roots are) than is needed for the closed class of affixes – particularly the extremely impoverished set of inflectional affixes of English (see Hayes et al., 2002, for reasoning along similar lines).

But whatever its provenance, this generalization motivates some distinction between preservation of root-internal sounds from those of affixes. We therefore predict that both *-s* and *-ed*[9] are less likely to be preserved in pronunciation when speakers think they are suffixes than when they think they are part of the root (cf. Bybee's 1995 review showing that inflectional *-s* and *-ed* are phonetically shorter than the corresponding root-final consonants; see also Kwong, Nicoladis and Kirchner, forthcoming, indicating that hearers are sensitive to this distinction, and use it in parsing phonetic sequences, e.g. [dæks], into tauto- or heteromorphemic structures as reflected in spelling, *dax* vs. *dacks*). This hypothesis is tested in Experiment 2. The distinction in perceived morphological affiliation is induced by the orthography of the stimuli. For example, if the subjects read *dacked van* or *dacks van*, listeners should hear [dæk væn] more frequently than if

[9] We did not attempt to test this hypothesis for *-ing,* as English contains few if any polysyllabic roots ending in [ɪŋ]. We therefore judged it impossible to construct novel word stimuli ending in [ɪŋ] which the participants would treat as monomorphemic.

presented with *dact van* or *dax van*. Note that all our stimuli involved invented words as modifiers in order to remove the effect of previous experience with compounds. Other studies have shown that adults (and children as young as ten years old) use orthography in inferring morphological affiliation within nonsense words (Smith and Nicoladis, 2000).

3. Experiment 1: Perception

3.1. Hypothesis.

The purpose of this study was to test the hypothesis that there is a continuum in the perceptibility of the sounds [ɪŋ], [s/z], and [t/d]. We did this by asking participants to listen to novel compounds (composed of a non-word as modifier and a real word as head) in the context of sentences, and to write down their spelling of the compound. The experimental compounds were constructed so that the modifier ended in [ɪŋ], [s/z], or [t/d]. We predicted that participants would be more likely to omit [t/d] than [s/z] than [ɪŋ].

3.2. Methods.

3.2.1. Participants. 20 native English-speaking adults participated in this study. All were psychology undergraduate or graduate students with little to no training in linguistics. The average age was 25.0 years (SD = 3.8), ranging from 21 to 35 years. 15 of the participants were female.

3.2.2. Materials. 40 experimental compound words were constructed (see Appendix 1), each composed of a non-word as the leftmost element and a real word as the right most element (e.g., *dacks van*). 8 of the non-words were spelled with *-ing* at the end (e.g., *spleeting*), 16 were spelled so that they would be pronounced with a [s] or [z] at the end (e.g., *dacks*) and 16 were spelled so that they would be pronounced with a [t] or [d] at the end (e.g., *kranned*). The compound words were embedded in sentences (see Appendix 2). We did not want our participants to intuit the purpose of the experiment, so we constructed control compounds as well. 40 other control compound words were constructed, each composed of a non-word as the leftmost element and a real word as the rightmost element (e.g., *spee fan*). These, too, were embedded in sentences. The 80 sentences were read by a female undergraduate in exchange for credit toward a psychology course. They were recorded directly to a Macintosh G4 computer using an Andrea USB NC-7100 head-mounted monaural microphone (sampling rate = 44100 Hz), and Sound Studio software, in a quiet but non-sound-proofed room. The reader was blind to the purpose of the experiment.

3.3.3. Procedure. Participants were told that we were interested in how native English speakers spelled non-words. They were provided with a printed copy of the sentences with a blank space where the non-word appeared. They were asked to listen to the sentences played on the internal speaker of a G4 Macintosh and to write in the spelling of the non-word as quickly and as accurately as possible. They listened to each sentence only once. They were allowed to pause the recording, but not to rewind.

3.3.4. Coding. Participants' spelling was coded as either having the experimental sound as the final sound or not. For example, if [dæks væn] was spelled *dass van* or *dax van*, these were counted as having *–s* as the final sound. Words spelled with a silent *e* (e.g., "preeze foot") were counted as ending in the experimental sound if the previous letter correctly denoted the experimental sound. We coded for *-ing* in two ways: 1) only if the participants spelled it as *-ing* and 2) if the participants spelled the last element with a vowel and a nasal.

Three items were excluded from the analysis. One with [z] was excluded because between the recording of the sentences and the listening, *sarze mask* had become a real word (i.e., SARS mask) because of the SARS epidemic. Two others (*gropping dam* and *zict bar*) were excluded because 100% of people did not hear the sound, suggesting that it was simply impossible for the sounds to be heard as read.

Participants did not necessarily respond to all items so the results are calculated as the number of omitted sounds out of the total number of responses that they gave for that category (i.e., -ing, -s/z, or –t/d).

3.3. <u>Results</u>.

We first present the results with the coding of *-ing* only as spelled as *-ing*. The average percentage of omissions by sound is summarized in Figure 3. A one-way ANOVA, comparing the percentage of omissions by the three different sounds as a repeated measure revealed a significant difference by sound, $F (2, 38) = 35.02$, $p < .01$. To see if there were any differences by sound, we compared each sound pair on planned paired t-tests. The results revealed no significant difference between *-ing* and *-s* ($t <1$), a significant difference between s/z and t/d, $t (19) = 6.98$, $p < .01$, and a significant difference between *-ing* and t/d, $t (19) = 7.55$, $p < .01$.

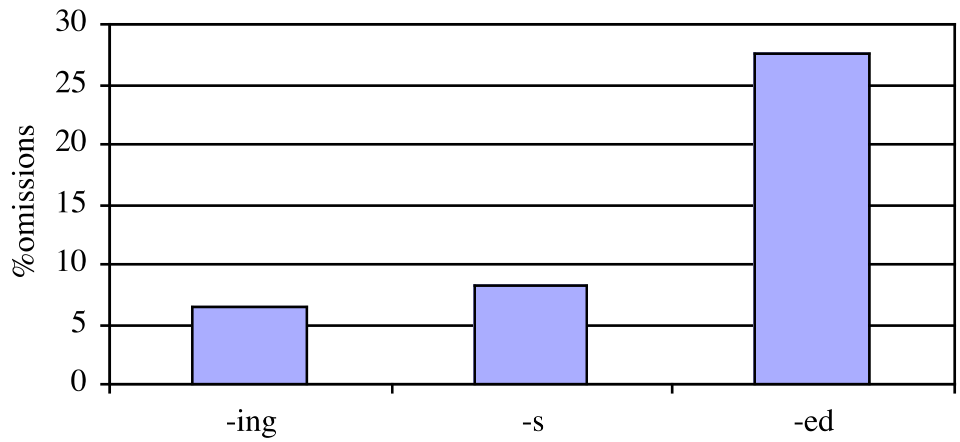


Figure 3. Average percentage of omissions by sound

The number of people who made at least one omission differed by sound: six people omitted at least one *-ing*, 15 people at least one *-s,* and all 20 people at least one *-ed*. This distribution differs significantly from a random distribution, χ^2 (2) = 7.37, $p < .05$.

We next present the results with the coding of *-ing* when spelled as a vowel and a nasal. All of the participants always spelled *-ing* as a vowel and a nasal. A one-way ANOVA, comparing the percentage of omissions by the three different sounds as a repeated measure, revealed a significant difference by sound, $F (2, 38) = 84.23$, $p < .01$. We compared the rate of omissions of *-ing* and *-s* with a planned paired t-test. There was a significant difference between *-ing* and *-s*, $t (19) = 6.35$, $p < .01$. The results of the other t-tests remain as reported above.

3.4. Discussion.

The results of the experiment correspond with our predictions about a continuum, both in terms of the rate of sounds that were omitted in spelling and in terms of the number of people who omitted at least one sound in their spelling. Note that all participants heard minimally a vowel and a nasal for *-ing* but did not always spell it as the morpheme intended by the reader (e.g., *-on* or *-en*). In contrast, participants' spelling suggested that they simply did not hear the intended *-s* or *-ed* in many cases. (The possibility that the reader asymmetrically hypo-articulated these sounds is addressed in §5.1.)

In the majority of cases, however, participants did hear the experimental sound. They were listening to the sentences in fairly ideal circumstances. In the context of natural speech, it is possible that even more sounds would be undetected.

4. Experiment 2: Production.

4.1. Hypothesis.

In accordance with the Production Hypothesis, we predict greater likelihood of the participants omitting (or hypo-articulating to the point of inaudibility) final [t/d] than [s/z], and greater likelihood of omitting (or hypo-articulating) [s/z] than [ɪŋ]. We also predict that participants are more likely to omit or hypo-articulate these sounds or sound sequences if they are orthographically presented as suffixes rather than as part of the root.

4.2. Methods.

4.2.1. Participants. The final sample consisted of 22 people. Thirty native English-speaking adults originally participated in this study as partial fulfillment for their introductory psychology course. Data from eight people were eliminated: 2 people did not complete the second part of the experiment because of a computer error and the stimuli 6 others saw was not properly recorded due to experimenter error.

4.2.2. Stimuli. Each stimulus was a compound word composed of a non-word followed by a real word (e.g., *a nild cup*). Each participant read 40 test stimuli (16 with [s/z], 16 with [t/d], 8 with [ɪŋ]), and 32 fillers, one at a time with no other words present. They as also read those same 72 stimuli in sentences (e.g., *Bob decided to get a nild cup/nilled cup to replace his old broken one*). See Appendix 1 for a list of the stimuli.

The participants were randomly assigned to conditions where they saw the sentences first (see Appendix 2) or the stimuli in isolation first, so about half the participants read sentences first and half read the stimuli in isolation first. Within the blocks of sentences and stimuli in isolation, the individual items were presented in random order.

4.2.2. Procedure. Participants were told that we were interested in their pronunciation of compound words with a nonsense word as the first component. We asked them to read the words that appeared on the computer screen as naturally as possible. We asked them to read five lexicalized compounds to remind them how compound stress sounds. When they had finished reading a stimulus, they clicked the return button to proceed to the next item. Each participant was alone in the testing room throughout the testing session. The participants' pronunciations were recorded as in Experiment 1.

4.2.3. Transcription. The participants' pronunciations of the experimental compound words were transcribed in broad phonetic transcription by two linguistics graduate students with training in phonetics. The transcribers were told that we were interested in the participants' pronunciation of nonsense words in compound words, and were asked to attend to whether or not the participants had used canonical compound stress, so that they would not focus their attention on our dependent measure. Each transcriber coded approximately half of the participants' pronunciations.

The dependent measure was the percentage of realized (i.e., transcribed) [ɪŋ], [s/z] and [t/d] in the root vs. suffix conditions. That is, for each participant, we counted the number of the relevant sounds realized out of the total number of experimental words with those sounds.

4.2.4. Coding. Participants were counted as realizing [ɪŋ], [s/z] or [t/d] if they produced that sound in the correct place in the word, even if they deleted other sounds. For example, one speaker read *nopt* as [nɑt] and that was counted as including a [t]. To count *-ing*, both [ɪn] and [ɪŋ] were counted as realizations.

Some items were excluded from the analysis because of vowel addition or other sound changes. Speakers occasionally introduced vowels into their pronunciations, like reading *hond* as [hɑnəd]. In adding vowels, speakers were most often reading vowels that were written (e.g., *nopse*). Furthermore, consonant changes (usually reversals) were also excluded, as in pronouncing *frapse* [fræsp]. Table 1 summarizes the number of items that were not included in the analyses because of consonant changes or vowel additions. There was no obvious difference in the number of [s/z] or [t/d] that were excluded for either of these reasons.

	Sound changes	Vowel addition
[t/d]	10	32
[s/z]	14	38

Table 1. Number of Items with Sound Changes or Vowel Additions by Sound

4.2.5. Reliability. One randomly chosen speaker was transcribed by both transcribers to check for reliability. The rate of realized [ɪŋ], [s/z] and [t/d] for this speaker was 82% according to transcriber 1 and 78% according to transcriber 2. 96% of the items were agreed upon by both transcribers. The few items where there was disagreement were classified according to the first transcriber's judgment (i.e., the one with the more realized sounds).

4.3. Results.

Our coders heard more [ɪŋ], [s/z] and [t/d] sounds when participants read the experimental words alone (M = 94.6%, SD = 4.2%) than in sentences (M = 91.5%, SD = 4.9%). Figure 4 shows the percentage of sounds realized by condition (alone or in sentences) and sound. A 2 x 3 within-subjects ANOVA revealed a significant main effect for sound, $F(1, 21) = 83.43$, $p < .001$, a significant main effect for condition, $F(1,21) = 5.86$, $p < .04$, and a significant interaction effect between sounds and condition, $F(1, 21) = 5.69$, $p < .04$.

Planned orthogonal comparisons revealed significant differences between the rate of speakers realizing [s/z] and [t/d] both alone, $F(1, 5) = 11.91$, $p < .05$, and in sentences, $F(1, 5) = 18.45$, $p < .01$. There were no significant differences between the rate of speakers realizing [ɪŋ] or [s/z], either alone, $F(1, 5) = 0.89$, ns, or in sentences, $F(1, 5) = 0.73$, ns.

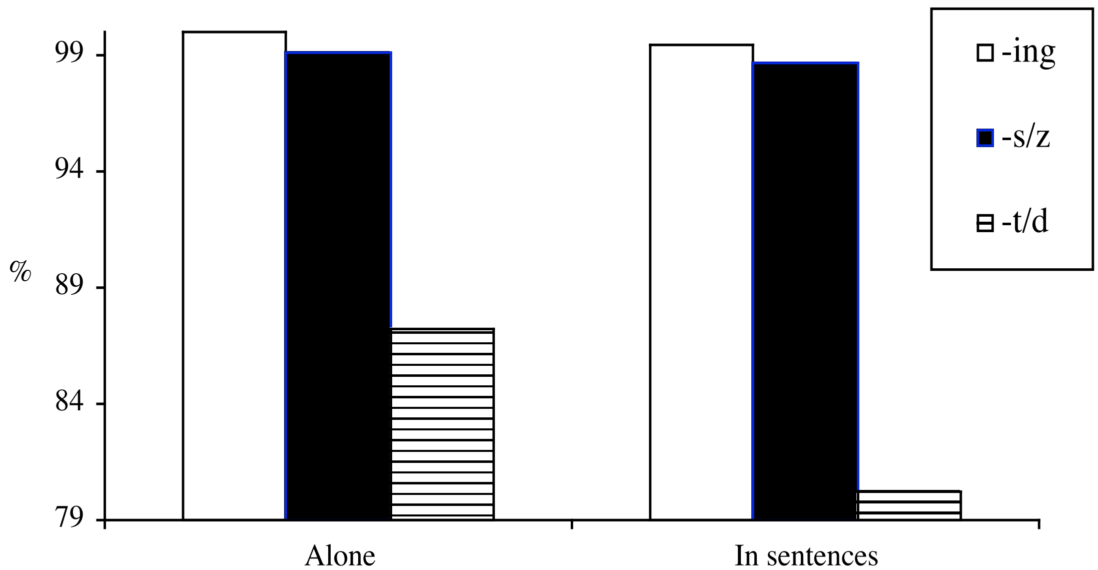


Figure 4. Average percentage of realized sounds.

We next looked to see if there was an effect of whether [s/z] and [t/d] were spelled as part of the root (e.g., *nopt* or *zax*) or as an affix (e.g., *nopped* or *zacks*). We did the analyses separately for the words read alone and words read as part of sentences because of the different rate of realized sounds noted above. First, we looked at the rate of realized sounds when participants read the compound words alone. A 2 x 2 within-subjects ANOVA comparing the [s/z] and [t/d] sound depending on whether they were presented as parts of roots or affixes revealed a significant main effect for sound, F (1, 21) = 36.62, p < .001, and no other significant effects. This analysis showed that when the words were pronounced alone, the participants realized [s/z] more often (M = 99.1%, SD = 2.3%) than [t/d] (M = 87.3%, SD = 9.6%).

We then looked at the rate of realized sounds when participants read the compound words in sentences. A 2 x 2 within-subjects ANOVA comparing the [s/z] and [t/d] sound depending on whether they were presented as parts of whole words or morphemes revealed a significant main effect for sound, $F(1, 21) = 43.97$, $p < .001$, and a significant main effect for whether the sound was spelled as part of the root or as a separate affix, $F(1, 21) = 6.87$, $p < .02$. There was no significant interaction effect. Figure 5 summarizes the results for these sounds realized when participants read the compound words in sentences.

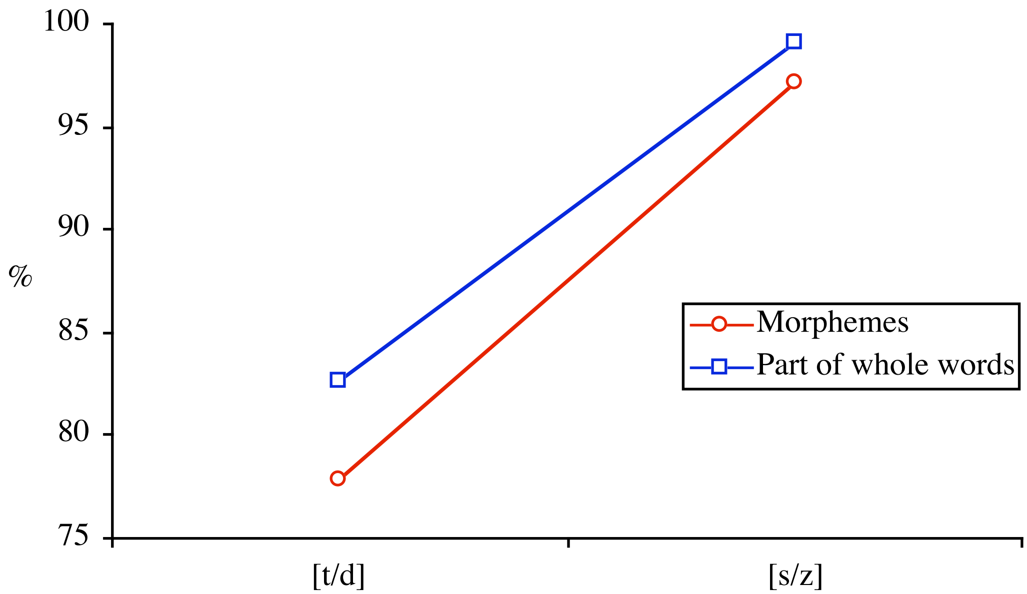


Figure 5. Average percentage of realized sounds when words read in sentences

4.4. <u>Discussion</u>.

These results show that our hypotheses were largely true. As expected, speakers audibly realized *-ed* less often than *-s* or *-ing*. Also, they audibly realized both *-ed* and *-s* less often when they thought they were inflections rather than words, at least in the context better approaching natural speech. One hypothesis was not confirmed: speakers' realization of *-s* did not differ significantly from that of *-ing*. However, there was a trend for speakers to realize *-s* less than *-ing*. We speculate that our failure to find a significant difference is due to the artificially quiet laboratory environment in which the experiment was conducted; with more natural background noise levels this trend might reach significance.

5. General discussion and phonological analysis.

5.1. <u>An apparent confound, and why it isn't important</u>.

Since the responses relied on the perception of the graduate student transcribers, it is possible that Experiment 2, at least with respect to the perceptibility hierarchy, does not represent a distinct result from Experiment 1. That is, the participant-speakers may have pronounced instances of [ɪŋ], [s/z], or [t/d] but the transcribers failed to perceive them, just as we assumed the participant-hearers did for the reader in Experiment 1. The asymmetries could be attributed entirely to the inherent perceptual salience (or lack thereof) of these sounds, without invoking the Production Hypothesis. On the other hand, Experiment 2 at least shows that the effect of the perceptibility hierarchy is present, not only for naïve participants, but also for linguistic graduate students with training in phonetic transcription. Moreover, the transcribers, unlike the participants in Experiment 1, were able to replay the recordings as much as they wanted. If the realizations of of [ɪŋ], [s/z], or [t/d] were inaudible to these trained transcribers under these conditions, they must have been inaudible indeed. Moreover, given Bybee's (1995) previously mentioned finding of measurably different realizations of inflectional *-s* and *-ed* vs. the corresponding root-final consonants, it seems clear that it is within speakers' control to hyper- or hypo-articulate these sounds. Therefore it is plausible to interpret the transcriptions with missing [ɪŋ], [s/z], or [t/d] in Experiment 2 as reflecting speakers' asymmetric hypo-articulation of these sounds. Note, however, that our general prediction, the effect of the perceptibility hierarchy on compound-internal [ɪŋ], [s/z], or [t/d], is confirmed, whether we adopt the perception or production interpretation of the results.

By the same token, asymmetric hypo-articulation may have been present in the reader's pronunciations, and influenced the hearer-participants responses, in Experiment 1. This possibility, however, does not undermine the validity of the perceptibility hierarchy. That is, if there is asymmetric hypo-articulation occurring, the asymmetries match up with our *a priori* assessment of the inherent perceptual salience of [ɪŋ], [s/z], and [t/d], as the Production Hypothesis predicts. It is difficult to conceive of a plausible alternative, non-perceptually-based account for why processes of hypo-articulation should target these sounds in this asymmetric manner.

We conclude that both perceptibility and status as morpheme contribute to the avoidance of inflection inside English compounds.

5.2. <u>Formal analysis</u>. The experimental results, particularly the production interpretation of Experiment 2, can be interpreted within an OT framework. Part of the appeal of OT lies in its ability to derive analyses of particular language sound patterns from independently motivated, functionally based principles, such as notions of ease of articulation and ease of perception. For example, the *HETERORGANIC CLUSTER constraint mentioned in §1.2 plausibly reduces to the more general biomechanical imperative to minimize effort: by substituting a single extended labial closure gesture ([mb]) in place of the coronal + labial sequence of gestures in (nb), a less effortful articulation is presumably achieved. Jun (1995) and Kirchner (1998) deploy this idea directly, in effort-based treatments of consonant assimilation and lenition patterns.

Similarly, Steriade (1999), *inter alia,* explores application of ease of perception considerations to phonotactic patterns, building upon Jun's Production Hypothesis. Under her Licensing-by-Cue proposal, phonotactics follow from the restriction of consonants and vowels to contexts where they enjoy sufficient auditory cues, thus facilitating recoverability.[10] Broadly speaking, vowels have strong internal cues (strong periodic signal, clear formant structure), while consonants are relatively quiet. Under Licensing-by-Cue, it follows that consonants are typically phonotactically constrained to be in close proximity to vowels, where their perceptibility is enhanced by transitional cues; hence sound sequences such as [tata] are ubiquitous in the phonologies of the world's languages, whereas sequences such as [npkt] are vanishingly rare. Steriade formalizes the Licensing-by-Cue proposal in terms of a meta-constraint on Optimality Theoretic rankings of context-sensitive featural faithfulness constraints: if the cues to some contrast F in context K are stronger than the cues in context K', then Preserve(F)/K outranks Preserve(F)/K', universally. Similarly, if the cues to F in K are stronger than the cues to some other contrast F' in that same context, then Preserve(F)/K outranks Preserve(F')/K, universally. Interleaved with articulatory markedness constraints, this constraint system results in a greater propensity for neutralization of a contrast the weaker its cues in that context.

Applying Licensing-by-Cue to the topic at hand, we infer the perceptibility hierarchy *-ing* > *-s* > *-ed*, on the phonetic grounds adduced in §2; and under Licensing-

[10] For a general review of acoustic cues to speech distinctions, including experimental support for their role in perception, see Wright, Frisch and Pisoni 2001.

by-Cue, we infer the corresponding constraint hierarchy, Preserve([ɪŋ]) » Preserve([s/z]) » Preserve([t/d]).[11] The dropping of suffixes (or root consonants) may be attributed to the constraint Reduce (Jun 1995), which, we will assume, incurs one violation mark for each segment present in the surface representation. In stochastic extensions of OT, this constraint need not be assigned a fixed ranking relative to the hierarchy of Preserve constraints, but may rather be assigned a variable ranking within a certain range (Anttila 1997), or with a normal distribution about some mean (Hayes and MacEachern 1998, Boersma and Hayes 1999), as schematized in Figure 6.

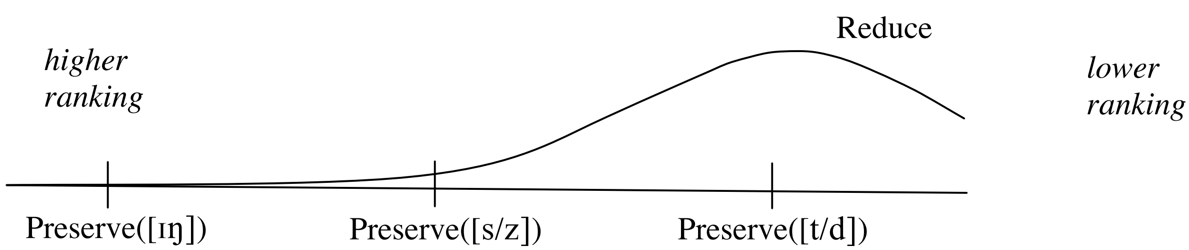


Figure 6. Stochastic ranking of Reduce relative to Preserve constraints

That is, Reduce most frequently is ranked below Preserve([t/d]), and by transitivity, below the other Preserve constraints as well. But in a substantial percentage of cases, Reduce » Preserve([t/d]), and in a much smaller percentage of cases, Reduce even outranks Preserve([s/z]), while the probability of Reduce » Preserve([ɪŋ]) is negligible.

The morphological affiliation effect can be analysed in similar terms, appealing to the meta-constraint Preserve(F)/root » Preserve [i.e. generally, in affixes as well] (McCarthy and Prince 1995, Kawahara 2003), motivated by the root/affix asymmetries

[11] These constraints are intended as shorthand for "Preserve the phonological features present in the sequence [ɪŋ]," etc., not as constraints referring to particular morphemes of English. 'A » B', in OT notation, means that A is ranked above B.

discussed in §2.2. If we accordingly posit distinct root versions of the Preserve constraints, and assign them distinct positions in the ranking, shifted higher relative to Reduce, as schematized in Figure 7, we capture the our experimental result, that [ɪŋ] and [s/z] are preserved in a greater percentage of cases than [t/d], and that these all sounds are preserved in a greater percentage of cases if they are part of the root rather than an affix.

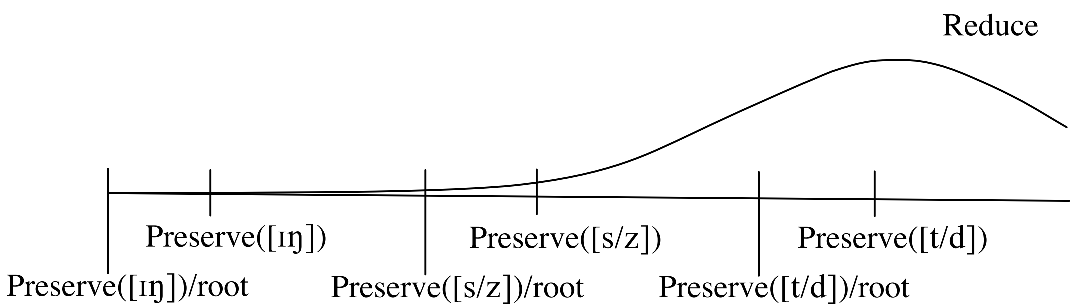


Figure 7. Stochastic ranking of Preserve/root relative to Reduce and Preserve constraints

The formal analysis presented above corresponds to the stronger form of our hypothesis, that perceptual factors directly, synchronically determine the avoidance of inflection, in the phonological grammar of the speaker and/or hearer. The weaker, diachronic form of our hypothesis could be formalized as well, in terms of language-specific, possibly stochastic, morphological expression constraints, which the speaker learns inductively, i.e. from detection of morphological/phonological patterns across the lexicon (see e.g. Hayes 1999, Hayes and Albright, to appear; cf. Krott and Nicoladis, 2005, for discussion of the role of analogy in the acquisition of compounds).

6. Conclusion

These results have demonstrated that English speakers are less likely to perceive, and/or more likely to drop, *-ed* than *-s* or *-ing* within compounds. Furthermore, when speakers thought that these sounds were affixes (i.e., *-ed* and *-s* respectively), they were more likely to drop these sounds than if they were treated as part of roots. These results were significant only when speakers read our nonsense words in the context of sentences rather than when speakers read them in isolation. The sentence context is probably closer to normal speech than the compounds in isolation. In normal speech in normal listening conditions with untrained listeners, the rates of preserved sounds would presumably be much lower.

The perceptibility effect should affect English speakers' processing of existing compounds. So listeners are more likely to hear the *-ing* in *hummingbird* than the *-s* in *drinks cabinet* and that *-s* more than the *-ed* in *corned beef.* Furthermore, the perceptibility effect can help explain results with English-speaking children's compounds. Notably, children avoid *-s* on the first constituent of a compound much more often than the second constituent. The highest rate of inclusion of *-s* on the first constituent of noun-noun compounds is about16% (Nicoladis, 2003) while the lowest rate of inclusion of *-s* on the second constituent of ungrammatical verb-object compounds is around 30% (Nicoladis, in press). That is, English-speaking children are less likely to say *-s* in the middle of a compound like *flowers socks* (meaning socks with many flowers on them) than at the end of an ungrammatical compound like *a ring-bells* (meaning a single machine ringing several bells).

A further point is that our proposal and analysis are consistent with the observation, noted previously, that many of the compound modifiers which retain the plural *-s* have a plurale tantum reading, e.g. *glasses case, drinks cabinet.* If plurale tantum nouns such as *drinks* (i.e. liquor) are listed independently from their respective singular forms, then the *-s* ending need not be regarded as an affix at all, but as part of the root.[12] As such, our analysis predicts that it is more likely to be retained in the compound, as the higher-ranked Preserve/root constraints are then applicable.[13]

In sum, we note that:

- the asymmetric retention of certain inflectional suffixes within compounds;
- the relation of these retention patterns to perceptual considerations, and to the general phenomenon of asymmetric preservation of root features over affix features; and
- the stochastic character of these patterns

are all captured under our approach, whereas they are beyond the capacity of the classic Level Ordering account; nor can we conceive of any extension of Level Ordering which might accommodate these considerations.

[12] This solution to the plurale tantum nouns problem has also been adopted by proponents of Level Ordering, see Gordon (1985).

[13] Alternatively, this idea could be expressed in more quantitative terms, by invoking the notion of relative listedness (e.g. Myers 2001, Bybee 2001). If both singular and plural versions of nouns are listed as lexical entries, but the singular form gets relatively little activation in the processing of a plurale tantum noun due to its semantic opacity, the plurale tantum form then behaves, to a greater or lesser extent as a morphologically simplex word. Consequently, the final [s/z] is retained, as in roots.

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Appendix 1

Stimuli Used in Experiments

[s/z] experimental words:

Part of whole word	Morpheme
Nilze cup	Nills cup
Frapse car	Fraps car
Kranz book	Krans book
Zix bar	Zicks bar
Sloovze dog	Slooves dog
Difse doll	Diffs doll
Jurze farm	Jurrs farm
Preeze foot	Prees foot
Crilze vine	Crills vine
Dax van	Dacks van
Honze jar	Hawns jar
Nopse jig	Nops jig
Puvze nest	Puves nest
Shreeze nap	Shrees nap
Sarze mask	Sarrs mask
Gofse man	Goffs man

In the first experiment, the reader saw half the experimental words with [s/z] spelled as part of the whole word and half as a morpheme. In the second experiment, each participant saw each [s/z] stimulus either as part of a whole word or a morpheme but not both.

[t/d] experimental words:

Part of whole word	Morpheme
Nild cup	Nilled cup
Frapt car	Frapped car
Krand book	Kranned book
Zict bar	Zicked bar
Sloovde dog	Slooved dog
Dift doll	Diffed doll
Jurd farm	Jurred farm
Prede foot	Preed foot

Crild vine	Crilled vine
Dact van	Dacked van
Hond jar	Hawned jar
Nopt jig	Nopped jig
Puvde nest	Puvved nest
Shrede nap	Shreed nap
Sard mask	Sarred mask
Goft man	Goffed man

In the first experiment, the reader saw half the experimental words with [t/d] spelled as part of the whole word and half as a morpheme. In the second experiment, each participant saw each *ed* stimulus either as part of a whole word or a morpheme but not both. If a participant had seen the invented word with [s/z] as part of a whole word (e.g., *nilze cup*), then he/she saw the corresponding [t/d] stimulus as a morpheme (e.g., *nilled cup*) and vice versa.

-ing **experimental words**

Cruffing cart
Pooksing bin
Gropping dam
Spleeting fawn
Zupping vat
Shreening jam
Julling night
Crufting mink

In both experiments, each participant saw/heard all of the *-ing* experimental words.

Fillers

Shrull cat
Nosp core
Pirn back
Hisk band
Shreeve dart
Goffe dish
Darr fish
Splee fan

Zurl vat
Prack vein
Frinn jack
Hupp gym
Jave nut
Skreekst neck
Khurr map
Craff mint
Shrall cat
Nusp core
Parn back
Hask band
Shroove dart
Groff dish
Dirr fish
Spee fan
Zulle vat
Pruke vein
Frane jack
Happ gym
Jarve nut
Streekt neck
Khirr map
Criff mint

In both experiments, each participant saw/heard all of the fillers. Note that there are two filler stimuli with each head (e.g., *jarve nut* and *jave nut*) to mirror the repetition of the head in the experimental words (e.g., a single participant saw both *nilze cup* and *nilled cup*).

Appendix 2

Sentences for Experiments

-ing

The biologist correctly identified the pelt as that of a crufting mink, even though these animals had long been extinct.

To transport dead bodies in the Middle Ages, undertakers used a cruffing cart to prevent the spread of the plague.

Brewers have found that aging whiskey in a zupping vat adds an oaky taste to the brew.

Trudy was frustrated to find herself caught in a shreening jam on the way to work.

To celebrate an adolescents' passage into adulthood, Thai youngsters must pass a julling night in the wilderness.

The hunter was excited when he spotted a spleeting fawn with its mother.

Train riders in England are asked to deposit candy wrappers in a pooksing bin to prevent IRA attacks.

After the construction of a gropping dam on the Yangste, all the native fish died.

[s/z]

A good gift for a two-year old girl is a diffs doll that eats and drinks.

He accidentally stabbed a sloovze dog with his fishing spear.

Jeff has always wanted a job as a goffs man in the film industry.

Because Sam had a dacks van, he often volunteered to drive the soccer team.

After the accident, the dog had a prees foot but he could still walk.

Uncle Joe didn't want to know about a frapps car Arthur saw in the stable.

If you see a nilze cup in the closet, don't let it fall.

Sally found a puvze nest in the oak tree in her backyard.

The best way to stay awake on the job is to take a shrees nap at about one o'clock.

The Welsh are famous for dancing a nopps jig after winning a football game.

Yesterday Jill tried eating a zicks bar, just to see how it would taste.

She wore a sarze mask to cover up her disfiguring scar.

The movie No Return was set against the backdrop of a jurze farm in Ireland.

In order to can her zucchini, Helen looked for a honze jar in her cupboard.

Aunt Mary found a kranz book on the dining room table.

To mark the advent of the winter solstice, Italians often plant a crilze vine in their front gardens.

[t/d]

To keep their babies safe from coyotes, the robins built a puvved nest in the eaves.

My nephew shocked his parents by asking for a dift doll for Christmas.

My father always answered the door wearing a sarred mask to scare the trick-or-treaters on Halloween.

To make workouts seem less stressful, Mark recommended reading a kranned book while on the step machine.

My mother always said that a goft man would make the best husband.

The beauty contestant danced a nopt jig for the talent portion of the contest.

My literature degree did not prepare me to deal with a slooved dog running wild with rabies.

The gardener found a crilled vine growing wild among the weeds.

My grandparents still live on a jurred farm not far from Stetler, Alberta.

To meet Kyoto Accord requirements, Ford is introducing a frapt car to the North American market.

At the farmers' market, I saw a zict bar that wasn't too expensive.

The advertisement claimed that thirteen elephants could fit in a dact van with room left over for the driver.

Bob decided to get a nilled cup to replace his old broken one.

I had to confess that I had had a prede foot ever since I was born.

According to the old wives' tale, babies will take a shrede nap after drinking from a bottle.

It is traditional to keep the ashes of the Yule log in a hawned jar on the mantelpiece.

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