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The learnability of the stratified phonological lexicon*

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1. Introduction

Phonological systems often exhibit internal inconsistencies which limit the scope of certain generalizations to a subset of the lexicon. In Japanese, for example, postnasal voicing applies productively to items of native origin (1), but not to those of foreign origin (2).[1]

(1) Postnasal voicing in Japanese

a. Verb forms with the past-tense marker /-ta/
tabe + ta → tabeta 'eat-PAST'
but + ta → butta 'hit-PAST'
šin + ta → šinda 'die-PAST'
nom + ta → nonda 'drink-PAST'

b. Verbal root compounds with /fum/ ('to step on') (Itô and Mester 1999)
fum + tsukeru ('attach') → fumitsukeru/fundzukeru 'trample on'
fum + kiru ('cut')→ fumikiru/fuŋgiru 'to give up'
fum + šibaru ('tie')→ fumišibaru/funžibaru 'immobilize'

(2) Nonapplication of postnasal voicing in Japanese

a. Denominal adjectivization with /-teki/
ši + teki → šiteki 'personal'
but + teki → butteki 'material'
šin + teki → šinteki 'mental'
tan + teki → tanteki 'straightforward'

b. Nominal compounds with /fun/ ('eject')
fun + sui ('water') → funsui 'fountain'
fun + ka ('fire') → fuŋka 'eruption'
fun + šutsu ('emerge') → funšutsu 'spout'

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[1] Nonuniform application of postnasal voicing is also observed in Zoque (between native and Spanish-origin words; Wonderly 1951) and Tamil (between native and Sanskrit-origin words; Asher and Kumari 1997).

The native past-tense morpheme in (1a) displays voicing of the initial stop when preceded by a nasal-ending verbal stem. The native verbal compounds in (1b) have two alternate forms: one with an epenthetic vowel /i/ between the first and second root, and one without. The underlyingly voiceless initial obstruent of the second verbal root becomes voiced in the nonepenthesized form, where it is directly preceded by a final nasal sound of the first stem. On the other hand, postnasal obstruent voicing is not observed in comparable contexts created by the Sino-Japanese denominal adjectivizer /-teki/ in (2a) or the nominal compounds of Sino-Japanese morphemes in (2b).

Similar examples abound in languages that have experienced heavy lexical borrowing, where a sizeable set of loanwords systematically shows vestiges of the donor phonology rather than conforming to the native pattern. Some notable cases include the contrasts between Latinate/Greek and native words in English (Chomsky and Halle 1968), Spanish and native words in Chamorro (Chung 1983) and French and native words in Mohawk (Postal 1968). But language-internal variation of phonological pattern is not limited to cases where the correlate of the division is diachronic. Separate statements of phonological pattern may also be required for different grammatical categories (e.g., noun vs. verb vs. adjective) or morphological categories (e.g., root vs. stem vs. affix). Furthermore, phonological heterogeneity can be found between arbitrary groups of morphemes which are otherwise comparable, such as the English prefixes *in-* (e.g., *implausible*) and *un-* (e.g., *unpalatable*), of which only the former exhibits nasal place assimilation (Siegel 1974).

The treatment of such language-internal inconsistencies has been a long-standing issue in phonological theory (see for example Mathesius 1929, Fries and Pike 1949, Chomsky and Halle 1968, Postal 1968, Mohanan 1986). Recent research in Optimality Theory (OT) deals with phonological nonuniformity by admitting internal variance in constraint interaction (McCarthy and Prince 1995, Itô and Mester 1995a, 1999, Urbanczyk 1995, Benua 1997, Inkeles, Orgun and Zoll 1997, Pater 2000, Inkelas and Zoll 2003, among others).[2] Under this view, the morphological items in (1) are subject to the ranking relation *NT » IDVOICE, where *NT stands for a markedness constraint that militates against a postnasal voiceless obstruent, and IDVOICE for a faithfulness constraint that demands that output strings maintain the values of voice features in the input. The morphological items in (2), in contrast, are subject to the reverse ranking relation IDVOICE » *NT. The interactions of these rankings are illustrated in the tableaux in (3). The effects of *NT are visible only when it outranks IDVOICE as in (3a), where postnasal voicing is observed.

[2] The same approach has been adopted in many OT-based analyses of intra-morpheme variation, though the details of implementation vary across specific proposals (see for example Anttila and Cho 1998, Boersma and Hayes 2001, Hayes 2000, Nagy and Reynolds 1997).

(3) Phonological variance as differences in ranking relationship

a. /-ta/: *NT » IDVOICE

Input: nom-ta	*NT	IDVOICE
a. nonta	*!	
☞ b. nonda		*

b. /-teki/: IDVOICE » *NT

Input: sin-teki	IDVOICE	*NT
☞ a. šinteki		*
b. šindeki	*!	

The purpose of this article is to re-examine – from the perspective of language acquisition – two further assumptions adopted in many OT analyses of nonuniform phonology. The first of these asserts that all lexical items can be assigned to distinct phonological classes even when no evidence for alternation is available (an assumption I term THE STRONG LEXICAL STRATIFICATION HYPOTHESIS). The second assumption is that ranking variance should be resolved by means of multiple faithfulness constraints relativized to sublexica. Both assumptions are shown to suffer from conceptual and empirical problems when we consider the nature of the learning task that confronts a child exposed to nonuniform phonology. I first demonstrate that the strong stratification hypothesis is rendered suspect by a learnability problems it raises. Secondly, I argue that when the strong stratification hypothesis is retracted, questions also arise about the exclusive use of relativized faithfulness in explaining lexicon-internal phonological nonuniformity. Taking these points into account, I present a revised constraint-based model of lexical stratification. Although this alternative approach is not free of epistemological problems, it provides a model of a stratified lexicon that can be acquired using both the available surface evidence in the ambient input and a combination of independently motivated learning principles. In order to present a sufficiently detailed empirical discussion within the limited space, I have focused on the case of postnasal voicing in Japanese. However, it should be emphasized that the issues discussed below have broader implications for general OT approaches to nonuniform phonology and also for OT-based models of phonological acquisition. The generalizability of the specific case of postnasal voicing in Japanese is discussed in the final section.

2. Lexical stratification and Optimality Theory

2.1 The strong stratification hypothesis

There are two fundamental issues that underlie the OT analysis of nonuniform phonology. The first concerns the relationship between ranking diversity and the organization of the lexicon. A position that is tacitly assumed in many analyses is that items in the phonological lexicon can be unambiguously assigned to distinct and internally-coherent classes or sublexica, such as roots, stems and affixes (McCarthy and Prince 1995), nouns and verbs (Smith 2001), or ‘Class 1’ and ‘Class 2’ affixes (Benua 1997). Each phonological class is then considered to have its own pattern of constraint interaction. This approach is extended to most analyses of phonological nonuniformity in Japanese (Itô and Mester 1995a, 1995b, 1999, Fukazawa, Kitahara and Ota 1998, 1999, 2002). According to this view, Japanese has four to five lexical strata including NATIVE (N) (or YAMOTO), SINO-JAPANESE (SJ), MIMETICS (M),

ASSIMILATED FOREIGN (AF), and UNASSIMILATED FOREIGN (UF) (or ALIEN).[3] Each of these strata systematically displays a cluster of phonological properties, some of which are listed below in (4). The ranking pattern in (3a) holds for items that belong to the NATIVE stratum where postnasal voiceless obstruents are disallowed, while the pattern in (3b) applies to items in the remaining strata where they are admitted.

(4) Generalizations that apply to lexical strata in Japanese (Itô and Mester 1995a, b, 1999); ✓= applies, * = does not apply

	N	SJ	M	AF	UF
a. No postnasal voiceless obstruent	✓	*	*	*	*
b. Rendaku (Sequential voicing in compounds)	✓	*	*	*	*
c. No nongeminate /p/	✓	✓	*	*	*
d. Root is monosyllabic	*	✓	*	*	*
e. Root is bimoraic	*	*	✓	*	*
f. No voiced geminates	✓	✓	✓	✓	*
g. No codas with place specification	✓	✓	✓	✓	✓

Crucial to this claim is the idea that the generalizations made for each stratum are output restrictions with consequences for patterns of both alternation and distribution. By obeying the restriction against postnasal voiceless obstruents, morphemes in the NATIVE stratum not only show alternations for postnasal voicing but also lack postnasal voiceless obstruents in the surface level; in other words, [voice] is not contrastive after a nasal. This analysis rides on the strength of OT, which unifies explanations of alternation patterns and distributional restrictions under the umbrella effects of constraint interaction.

In the context of a nonuniform phonological system, however, this approach raises an interesting epistemological issue. Alongside morphemes such as those listed in (1) and (2), which participate in alternations, we find words that do not show distinct morphophonological behaviors and yet are thought to belong to separate strata. For instance, the NATIVE stratum is said to contain items such as the attested *tombo* 'dragonfly' and *kangae* 'idea,' but not structures such as **tompo* or **kankae*. According to this analysis, the voicing of the postnasal stop in *tombo* and *kangae* is predictable and redundant. However, the conclusion is contingent on the assignment of these words to the NATIVE stratum. If *tombo* belonged to a different stratum, the postnasal [voice] feature would be considered contrastive. Yet, there is nothing in the surface phonology of *tombo* which suggests that it should be separated from words such as *temba* 'flying horse' (a SINO-JAPANESE word) or *kombo* 'combo' (a FOREIGN word), all of which include a postnasal obstruent. How do we know, then, that *tombo* and *kangae* are NATIVE words and not SINO-JAPANESE or FOREIGN? Needless to say that support does not come from the etymological references, which have no synchronic import other than their being convenient labels for these morphological

[3] Classification differs across studies. Itô and Mester (1995a), for example recognize all of these morpheme classes, while the list in Itô and Mester (1999) does not include MIMETICS. FOREIGN here indicates borrowed lexical items of non-Chinese origin.

classes.[4] Nor can alternations other than postnasal voicing determine the membership of *tombo* or *kangae*. Although a native-specific process such as rendaku, if applicable, would provide telltale evidence, rendaku is blocked by Lyman's law, which prohibits a second voiced obstruent in the same morpheme, masking any potential effects on *tombo* and *kangae*.[5] Another suggestion that does not hold up is that morphemes should be assigned to the least marked (i.e., the most restricted) stratum unless the surface evidence suggests otherwise. By this criterion, a FOREIGN word such as *kombo* should be assigned to the NATIVE sublexicon since it contradicts none of the NATIVE conditions listed in (4). Most analysts would find this conclusion difficult to accept. More importantly, the criterion can eliminate contrasts that should reside within the same sublexicon by separating contrasting pairs, such as *kombo* 'combo' vs. *kompo* 'component,' into different sublexica.

While the analyst, equipped with etymological knowledge, may be able to assign all morphological items to the different sublexica in (4), it is doubtful that the same stratified lexicon can be reconstructed in a bottom-up fashion if the membership of some items can be determined only on the basis of surface distribution pattern. A similar point has been made by Rice (1997), who criticizes Itô and Mester's model of lexical stratification (1995b) on the grounds that much of its evidence comes from distribution rather than alternations. Note, however, the issue here is not that lexical stratification itself cannot be motivated for lack of relevant alternations. Rather, the point is that even if we can justify the existence of phonological sublexica, we cannot determine the classhood of all lexica based solely on distributional evidence. This problem has severe implications for the acquisition of nonuniform phonology, as will be seen in Section 3.1.

2.2 The indexed faithfulness approach

The second issue related to the OT analysis of phonological nonuniformity has to do with the way in which different ranking relationships, such as those in (3), are implemented in the grammar. There have been two major proposals on this point. One proposal (the COPHONOLOGY approach) admits distinct rankings for morpheme classes (Itô and Mester 1995b, Inkelas, Orgun and Zoll 1997, Inkelas and Zoll 2003). For instance, the past-tense morpheme /-ta/ (or the stratum it belongs to) has its own ranking of constraints, which includes the domination relation *NT » IDVOICE, while the denominal adjectivizer /-teki/ (or the stratum it belongs to) has a different ranking of constraints, which includes IDVOICE » *NT. These are seen as separate rankings that coexist in the same phonological system. Another proposal (the INDEXED FAITHFULNESS approach) adheres more closely to the idealization that each language has one invariant constraint ranking. It attempts to account for the different ranking relations by postulating multiple instantiations of the same faithfulness constraint,

[4] There are also many cases of mismatch between lexical groups that share phonological properties and their etymological sources. Some morphemes of Chinese origin consistently undergo rendaku (e.g., *kaiša* 'company'; *oya* 'parent' + *kaiša* → *oyagaiša, *oyakaiša*), while some native morphemes consistently resist the process (e.g., *himo* 'lace'; *kutu* 'shoe' + *himo* → *kutsuhimo*, **kutsubimo*) (Vance 1987). With regards to the lack of voiceless obstruents after a nasal, there are some known native words that do not conform to the condition: e.g., *anta* 'you', *uŋka* 'leafhopper', and *tampopo* 'dandelion'.

[5] For complications raised by these phenomena for constraint-based phonology, see Itô, Mester and Padgett (1995).

which are associated with specific classes of morphemes (Alderete 2001, Benua 1997, Fukazawa, Kitahara and Ota 1998, 1999, 2002, Itô and Mester 1999, Pater 2000, Smith 2001). Under this approach, the difference between the native morpheme /-ta/ and the Sino-Japanese morpheme /-teki/ is attributed to two different versions of the faithfulness constraint IDVOICE: one parochial to the native stratum ($\text{IDVOICE}_{\text{N}}$) and the other to the Sino-Japanese stratum ($\text{IDVOICE}_{\text{SJ}}$). $\text{IDVOICE}_{\text{N}}$ and $\text{IDVOICE}_{\text{SJ}}$ are ranked in different positions with respect to *NT as in (5). Any item indexed to $\text{IDVOICE}_{\text{N}}$ must best satisfy *NT » $\text{IDVOICE}_{\text{N}}$, and thus has redundant voicing of postnasal consonants, while any item indexed to $\text{IDVOICE}_{\text{SJ}}$ must best satisfy $\text{IDVOICE}_{\text{SJ}}$ » *NT, and therefore maintains contrastive postnasal voicing. IDVOICE constraints specified for other strata are also ranked above *NT, giving the fully indexed hierarchy in (5).

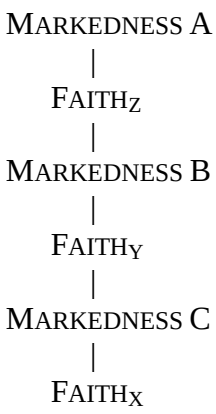
(5) Indexed faithfulness analysis of stratified postnasal voicing

$\text{IDVOICE}_{\text{UF}}$, $\text{IDVOICE}_{\text{AF}}$, $\text{IDVOICE}_{\text{M}}$, $\text{IDVOICE}_{\text{SJ}}$ »*NT » $\text{IDVOICE}_{\text{N}}$

Several arguments have been put forward in support of the indexed faithfulness approach, and more specifically, why relativization or indexation must be confined to faithfulness constraints. One reasoning is that faithfulness constraints, unlike markedness constraints, are not constraints by themselves but rather schemata that provide the template for constraints (Itô and Mester 1999). Each type of faithfulness schema (such as MAX or 'no deletion') defines a basic correspondence mapping, which is applied to different phonological or grammatical relationships (e.g., lexical input vs. surface output, base vs. reduplicant, base vs. truncated form). The actual faithfulness constraints, such as MAX-IO, MAX-BR, MAX-BT, are the instantiations of a given correspondence type associated with the specific contexts. Faithfulness indexation to lexical strata, therefore, is a natural extension of this conceptualization of faithfulness relationship.

The second motivation for faithfulness indexation rests on the empirical consequences that follow from the model. According to this argument, the benefit of relativizing only faithfulness constraints is that it predicts markedness invariance across sublexica within a language (Alderete 2001). Suppose a stratified lexicon has the type of underlying ranking structure illustrated in (6), where MARKEDNESS A, B, and C represent different types of markedness constraints, but FAITH X, Y, and Z correspond to different instantiations of the same faithfulness, indexed respectively to STRATA X, Y, and Z.

(6) A schematic hierarchy containing indexed faithfulness constraints



This configuration gives rise to a cumulative effect of markedness, by which any item that respects MARKEDNESS B also respects MARKEDNESS A, and any item that respects MARKEDNESS C also respects both A and B. But no item in this language should be subservient to MARKEDNESS A and C without being so to MARKEDNESS B. Thus when a monolithic ranking of markedness constraints is interspersed with relativized faithfulness constraints, as in (6), sublexica within a language are predicted to form a subset relation – what Itô and Mester (1995a, 1999) call the CORE-PERIPHERY STRUCTURE of the phonological lexicon. In (6), STRATUM X is at the core and least marked since its lexicon is restricted by all three markedness constraints. STRATUM Y allows all the structures found in STRATUM X in addition to those disallowed in STRATUM X by MARKEDNESS C. The peripheral STRATUM Z allows all the structures admitted in STRATA X and Y, plus those that are disallowed in STRATUM Y by MARKEDNESS B.

It has been shown, however, that this argument meets some empirical problems. First, invariant ranking of markedness constraints does not prevent markedness reversals unless we also restrict the ranking order of the indexed faithfulness constraints. The core-periphery structure in (6) can be disrupted by adding another set of faithfulness constraints that are not ranked in the same order as the first one (Fukazawa, Kitahara and Ota 1998). Furthermore, markedness reversal does occur in natural languages (Itô and Mester 1995b, Inkelas and Zoll 2003). For instance, the table in (4) reveals that the NATIVE, SINO-JAPANESE and MIMETICS strata in Japanese do not form a subset relation with respect to properties (4a), (4b), (4d), and (4e).

The discussion so far shows that the strong distributional analysis and the faithfulness indexation approach to lexical stratification are not without problems. These problems become even more apparent when we evaluate the claims in the context of language acquisition. This is the issue that I now turn to.

3. The learnability of a stratified lexicon

3.1. Learning a lexicon with strong stratification

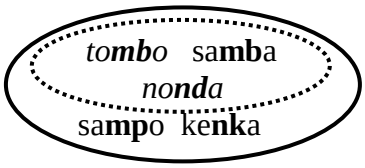
Despite its descriptive adequacy and theoretical parsimony, a model of phonological nonuniformity based on the strong stratification hypothesis leads to an unrealistic scenario of phonological learning. The heart of the problem lies in how the child arrives at the conclusion that constraints are ranked differently across subsets of the lexicon without a priori knowledge of the division. Take for instance the case of a child exposed to surface forms from the native and Sino-Japanese sublexica. The following sample input contains the affixed forms listed in (1a) and (2b), repeated here as (7a) and (8a), as well as some nonaffixed forms ((7b) and (8b)).

(7) Native surface forms
   a. *tabeta* ‘eat (past),’ *butta* ‘hit (past),’ *šinda* ‘bite (past),’ *nonda* ‘drink (past)’
   b. *tombo* ‘dragonfly,’ *kangae* ‘idea’

(8) Sino-Japanese surface forms
   a. *siteki* ‘personal,’ *butteki* ‘material,’ *sinteki* ‘mental,’ *tanteki* ‘straightforward’
   b. *samba* ‘midwife,’ *manga* ‘cartoon,’ *sampo* ‘walk,’ *kenka* ‘fight’

The strong stratification hypothesis expects children to be able to associate all the morphemes listed in (7) with the ranking pattern NT » IDVOICE, and all those listed in (8) with the ranking pattern IDVOICE »*NT. In principle this classification must be achievable on the basis of distributional evidence, since the words in (7b) do not participate in voicing alternation. The difficulty learners encounter in accomplishing such a task is that the data in (7) and (8) are not flagged for their classhood. Rather it is the union of the sets of surface forms in (7) and (8) that learners are exposed to. As illustrated in (9), this pool of data contains both surface forms that obey *NT (within the dotted circle) and those that violate *NT (outside the dotted circle). The native lexical items (italicized in the figure) are all contained within the inner set, and the Sino-Japanese lexical items (nonitalicized) have elements within and outside this subset. Because children do not a priori know the distinction between the native and Sino-Japanese words, they proceed to learn the superset data (solid circle) that contain both voiceless and voiced obstruents in postnasal position. As a consequence, learners will arrive at the more inclusive ranking IDVOICE » *NT, under which voicing of postnasal obstruents is distinctive. This is a rather undesirable state to be in if the ultimate goal is to establish the reversed ranking *NT » IDVOICE for a subset of the lexical items. The ranking IDVOICE » *NT admits all the wellformed surface outputs that the ranking *NT » IDVOICE gives. Once that ranking is obtained, no positive surface evidence seems available to assist the learner in retreating from the overgeneralization.

(9) The overgeneralization trap

The data	→	Grammar
		IDVOICE » *NT

Itô and Mester's (1999) proposal to preempt this developmental pitfall involves a learning principle dubbed Ranking Conservatism:[6]

(10) Ranking Conservatism: In expanding the grammar (for example, by diversifying faithfulness constraints by stratal indexation), dominance relations of the current state H_i are maximally preserved in the subsequent state H_{i+1}.

Ranking Conservatism works in conjunction with the H_0 = M » F assumption, or the proposal that the initial state of acquisition (H_0) ranks all markedness constraints above all faithfulness constraints (Smolensky 1996). Using Ranking Conservatism, a scenario for arriving at the ranking in (5) proceeds in the following fashion. The H_0 = M » F assumption states that the initial constraint hierarchy contains the ranking *NT » IDVOICE. Upon hearing an output form that violates *NT (e.g., *sampo*), a different ranking IDVOICE » *NT is established so that the *NT-violating cluster can surface. However, this does not lead to global reranking of the constraints. Ranking Conservatism preserves the original ranking (*NT » IDVOICE) except where the

[6] The importance of this learning principle has also been advocated independently by Hayes (2004) and Prince and Tesar (1999).

reranking is necessary, and only for those exceptional cases does the partial reranking occurs, by placing above *NT a copy of IDVOICE that is indexed to the stratum of the newly identified lexical items. Eventually, this process will index all *NT-violating forms to the higher instantiation of IDVOICE.

The problem with Ranking Conservatism, however, is that for it to fully function it still requires independent information about the lexical classhood. When distributional information is the only available evidence, the procedure itself cannot determine whether a particular word contains a postnasal voiced obstruent because it is not allowed to have a voiceless counterpart or because it happens not to have a voiceless obstruent. If the former is the case, the word should be assigned to the less marked stratum where postnasal voicing is predictable, but if the latter is the case, it should be assigned to the more marked stratum where [voice] is contrastive after a nasal. Applied indiscriminately, Ranking Conservatism will draw a line between all structures that violate the relevant markedness constraint and those that do not, producing unwelcome results. For example, the Sino-Japanese word *samba* 'midwife' will be grouped with the native word *tombo* 'dragonfly,' both as outputs that respect *NT, while putative stratum-mates of *samba*, such as *sampo* 'walk' which violates *NT, will be assigned to a different sublexicon. Another *reductio ad absurdum*, due to Rice (1997), is the conclusion that the English words *font* and *fond* belong to two separate strata: one that conforms to *NT and one that does not.

The necessity to prevent this calamity is recognized by Itô and Mester (1999), who ascribe the solution to a property of early developmental input, which presumably contains an overwhelming number of exemplars from the less marked stratum (i.e., the native sublexicon). Once this initial dose of input establishes the core stratum, marked structures that require partial reranking of the faithfulness constraints can be treated as part of a peripheral stratum. As Rice (1997) points out, however, this assumption of input structure cannot be upheld given the large proportion of words with *NT-violating clusters found in the ambient data for young Japanese-speaking children. An estimate based on data collected by Ota (1999, 2003) shows that *NT is violated in more than half (54%) of the two-year-olds' productive lexical items that contain a nasal-obstruent sequence. Many examples of postnasal voiceless obstruents can be found in words produced by children before the age of two years.

(11) Postnasal voiceless obstruents in early production (a-f from Ota 1999, 2003; g-h from Miyata 1995)

a.	*Kenčan*	'Ken-DIMINUTIVE'	(Takeru, 1;4)
b.	*Ampamman*	'(cartoon character)'	(Takeru, 1;5)
c.	*pompon*	'tummy'	(Hiromi, 1;9)
d.	*žaŋkempon*	'paper-scissor-stone'	(Hiromi, 1;11)
e.	*Nontan*	'Non-DIMINUTIVE'	(Kenta, 1;9)
f.	*očinčin*	'penis'	(Kenta, 1;10)
g.	*žampu*	'jump'	(Aki, 1;8)
h.	*denša*	'train'	(Aki, 1;10)

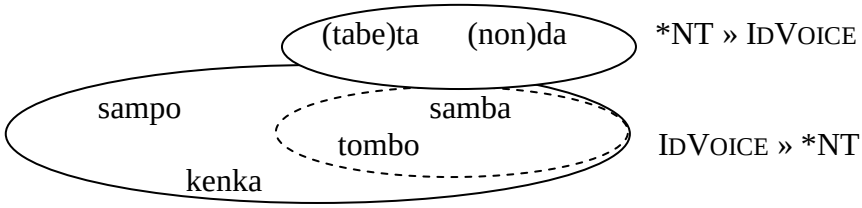
The input children receive, therefore, does not conspire to establish a core lexicon before introducing them to more marked structures. If anything, young children are exposed to a nontrivial amount of words that indicate that *NT can be violated in the surface forms.

The learnability arguments and empirical evidence presented above cast grave doubts on the claim that distributional generalizations alone can invite the learner to

postulate lexical strata. However, this does not justify the total abandonment of lexical stratification in favor of a "fully representational approach" (Rice 1997), according to which postnasal voicing is distinctive throughout the lexicon in Japanese, including cases where surface alternations are found (e.g., *tabeta* 'eat-PAST' vs. *nonda* 'drink-PAST'). To do so amounts to denying the grammatical status of the bona fide processes given in 1b (Itô, Mester and Padgett 1999).[7] The regularity and productivity of these alternations compel us to treat them as part of a grammatical pattern that separates itself from the rest of the lexicon.

Short of throwing the baby out with the bath water by eliminating lexical stratification altogether, a viable solution is to assign items to separate strata only when positive evidence is available from alternations. Under this restricted approach to lexical stratification, the overall phonotactics of the language (based on the union set of data) gives the default ranking. In the case of *NT and IDVOICE in Japanese, that general ranking is IDVOICE » *NT because the global distributional evidence in the input leads the learner to conclude that voiceless obstruents must be allowed after a nasal. Unless there is indication to the contrary, this ranking evaluates all morphemes, including, for example, words such as *tombo* and *kangae*, for which there is no positive evidence that the postnasal voicing is redundant. The morphemes that form the special stratum are those with alternations showing that the opposite ranking *NT » IDVOICE must hold. The state of affairs can be schematized as in (12).

(12) Weak lexical stratification



The lower plane represents the general phonology of postnasal voicing in Japanese, which is under the control of IDVOICE » *NT. Here, [voice] is contrastive after a nasal although some morphemes obviously respect *NT (those within the dotted oval). The upper plane represents the restricted native stratum, whose membership is determined on the basis of alternations. It is associated with the ranking relation *NT » IDVOICE. The superimposition of the upper plane onto the dotted area of the lower plane suggests that the two areas share the common property of satisfying the markedness constraint *NT, even though the status of the voicing of the postnasal obstruent is different between the upper and lower planes.

Essentially, the analysis above treats any postnasal [voice] as contrastive if there is evidence somewhere in the language that voiceless obstruents can appear after a nasal and no alternations impose the interpretation that the [+voice] feature is forced by the preceding nasal. To the extent that it admits certain phonological processes that apply only to subsets of the lexicon, this approach maintains some degree of lexical stratification. On the other hand, it abandons the idea that the stratification also holds between words which do not present any alternations signaling their membership to different phonological sublexica. The motivation behind this weak stratification hypothesis is that any further stratification cannot be learned in a constraint-based grammar.

[7] The gerundive forms of verbs also follow the same pattern. Cf. *tabete* vs. *nonde*.

3.2. Learning a stratified lexicon with indexed faithfulness

Reducing the strong lexical stratification hypothesis to a weaker version has some important consequences for the indexed faithfulness approach. Coupled with the strong stratification hypothesis, the indexed faithfulness approach models a stratified lexicon using a constraint hierarchy in which the various instantiations of IDVOICE are indexed to nonoverlapping subsets of the lexicon. For the data in (7) and (8) this means the learner will project one faithfulness constraint indexed only to the items in (7) ($\text{IDVOICE}_{\text{N}}$) and one indexed only to the items in (8) ($\text{IDVOICE}_{\text{SJ}}$). It is assumed – though wrongly, as I argued above – that membership to the native or the Sino-Japanese sublexica can be independently established. Thus the grammar knows which version of IDVOICE it needs to refer to when evaluating any input-output pair. If we apply the indexed faithfulness approach to the weak stratification hypothesis, however, the groups of items to which the two instantiations of IDVOICE are indexed have a different set relation; that is, one of the sets is only identifiable as the complement of the other with respect to the entire lexicon. Under the weak stratification analysis of the data in (7) and (8), the set of morphemes with a distinct phonological property is (7a) only, i.e., those that exhibit voicing alternations. In contrast, the items in which [voice] is contrastive are identifiable only by virtue of not being part of the set in (7a). The relevant faithfulness therefore has to be indexed 'elsewhere'. This and the version of IDVOICE indexed to the items in (7a) (call it $\text{IDVOICE}_{\text{N}}$) must be ranked as in (13).

(13) Faithfulness indexation applied to a weakly stratified lexicon

$\text{IDVOICE}_{\text{Elswhere?}}$ »*NT » $\text{IDVOICE}_{\text{N}}$

This ranking faces a computational problem. The evaluation of the IDVOICE applicable to the 'elsewhere' context requires reference to the index list of another constraint, i.e., $\text{IDVOICE}_{\text{N}}$. In other words, the constraints cannot independently evaluate the candidates.

A solution to this problem is to relativize the markedness constraint instead of the faithfulness constraint. This involves splitting the markedness constraint *NT into two versions, one that is general (and ranked below IDVOICE) and one that is indexed to the identifiable members of (7a) (and ranked above IDVOICE), as given in (14).

(14) Markedness indexation applied to a weakly stratified lexicon

$*\text{NT}_{\text{N}}$ » IDVOICE »*NT

Relativizing markedness eliminates the need to index constraints to an elsewhere context. This is because, in weak stratification, the markedness constraint indexed to the specific context is ranked above the markedness constraint related to 'elsewhere'. As demonstrated in (15), the lower *NT does not need to be indexed to the complement set of items, since all the violations a candidate incurred against this constraint are mirrored by the violation marks of the higher-ranked *NT if and only if the morpheme under evaluation belongs to the 'native' set. Thus any constraint interaction between the 'native'-specific *NT and IDVOICE is given priority over the effects of the general *NT, making it unnecessary to refer to a complement context defined by the specific *NT constraint.

(15) Evaluation of indexed markedness

	Input: nom-ta (N)	$*NT_N$	IDVOICE	*NT
	a. nonta	*!		*
☞	b. nonda		*	

	Input: šin-teki	$*NT_N$	IDVOICE	*NT
☞	a. šinteki			*
	b. šindeki		*!	

If the weak stratification hypothesis is on the right track, therefore, it cannot be implemented along with the indexed faithfulness approach without generating a serious problem in candidate evaluation. Taken together with the problems discussed in Section 2.2., this examination of learnability poses further questions for the claim that a stratified lexicon must be expressed in terms of indexed faithfulness constraints.

3.3 Can alternations stop ranking overgeneralization?

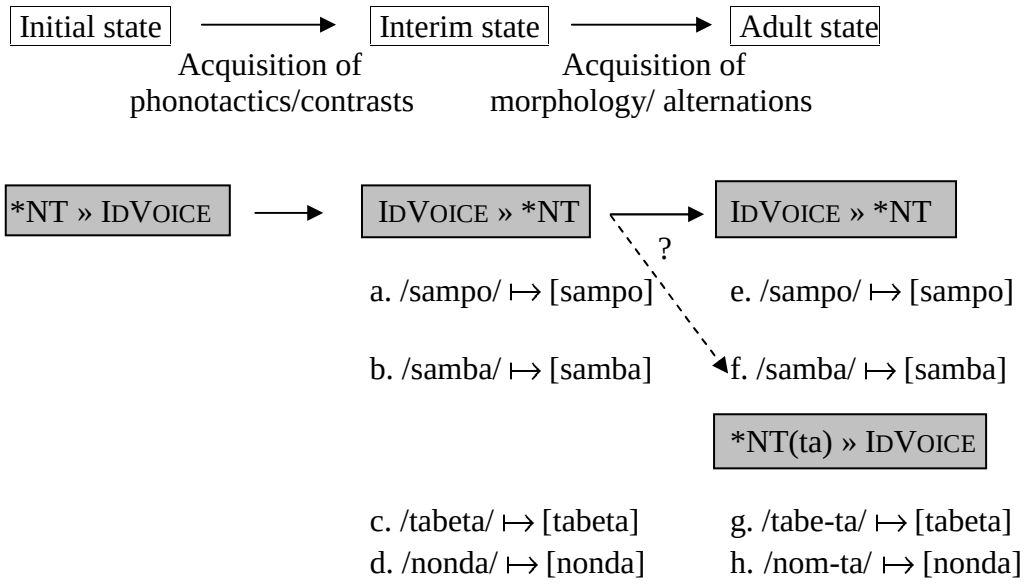
So far not much has been said about the possibility that alternations can reveal phonotactic restrictions imposed on a subsection of the lexicon, thereby preventing children from falling into the overgeneralization trap illustrated in (9). If such a mechanism is available, it can preserve the initial ranking *NT » IDVOICE just for those morphemes exhibiting postnasal voicing processes, even if the overall distribution pattern motivates the reranking to IDVOICE » *NT (see Fukazawa, Kitahara and Ota 1998). For this to happen, the child must acquire the relevant alternations no later than they acquire the general phonotactics of the language. Research on language acquisition, however, shows that this is not the developmental path that most children follow. On the contrary, knowledge of phonotactics develops in children long before they begin to acquire any morphology. By the age of 10 months, children can distinguish legal segments and sequences from illegal ones (Friederici and Wessels 1993, Jusczyk, Luce, and Charles-Luce 1994, Jusczyk, Hohne and Mandel 1995). In contrast, productive use of morphology does not fully take off until the age of 18 months, up to which point morphologically complex forms are treated as unanalyzed structural amalgams (Cazden 1968, Slobin 1985, MacWhinney 1985, Cox 1989, Marcus, Pinker, Ullman, Hollander, Rosen and Xu 1992). The development of morphophonemic alternations may even continue into school age (Berko 1958, Derwing and Baker 1986).

The impact of morphological development on phonological acquisition has been demonstrated experimentally by Jusczyk, Smolensky and Alloco (2002). They tested whether English-learning infants show effects of the ranking M_{NP} » F_{NP}, where M_{NP} is a markedness constraint that requires nasals to assimilate in place to a following consonant within the same stem, and F_{NP} is a faithfulness constraint that demands the nasal place in an output be identical to that in the input. This is the target ranking, since nasal place assimilation is observed in English except when the nasal-consonant cluster crosses a stem boundary (e.g., *input*, *pinpoint*). Their experimental data show that infants from 4-1/2 to 10 months prefer input-output pairs that conform to this ranking, but the preference temporarily disappears in 15-months-olds. One interpretation they offer (which they attribute to D. A. Dinnsen) is that by 15 months children may have misanalyzed words such as *input* and *pinpoint* to be monomorphemic and demoted M_{NP} below F_{NP} accordingly. As adultlike

morphological junctures are acquired, the erroneous learning data are removed, and the correct ranking is reestablished.[8]

The lack of morphological analysis in the earlier stages of language development has a larger impact on the phonological acquisition of postnasal voicing in Japanese. None of the Japanese-speaking children mentioned above showed evidence of productive inflectional morphology during the time period the examples in (11) were collected. This indicates that they had acquired words with nasal/voiceless-consonant clusters before they began to notice the morphemic status of [ta ~ da] in structures such as *tabeta* ('ate') and *nonda* ('drank'). The consequences of this developmental timetable are illustrated in (16). The form between slashes indicates the child's lexical representation and the form between square brackets, the surface form associated with that underlying form. The shaded boxes show the rankings established based on the ambient input and the child's current state of grammar.

(16) Ranking, input-output mapping and the acquisition of phonology/morphology



The learning begins with the initial state ranking *NT » IDVOICE. The sum of the learning data includes surface forms that violate *NT (e.g., [sampo]), which motivate the ranking IDVOICE » *NT. At this stage, children have not completed the morphological analysis of alternating forms (cf. (c) and (d)), and therefore these forms are not protected from the global reranking to IDVOICE » *NT. It is after the next ('interim') stage that the crucial morphological acquisition takes place. But in order to reach the hypothesized adult state, the child must also partially reverse the already established ranking IDVOICE » *NT to *NT » IDVOICE.

Accomplishing this last step is not a trivial matter. Even when the child realizes the morphological status of the past-tense affix, the surface forms that include it (e.g., [tabeta], [nonda]) do not conflict with the ranking of the interim state (i.e.,

[8] Hayes (2004) mentions a different type of erroneous acquisition that can result from the later acquisition of morphology. Children may mistake grammatically-conditioned allophones for cases of real phonemic contrasts (e.g., the raised vs unraised diphthong found in some dialectal forms of *writer* and *rider*).

IDVOICE » *NT). Since structures marked with respect to *NT are allowed in this grammar, there is no positive evidence in the ambient input that prompts the child to carry out the extra procedure. In the scenario discussed by Jusczyk, Smolensky and Alloco (2002), it is stipulated that the relevant markedness constraint M_{NP} applies only to stem-internal nasal-consonant clusters, thus opening up the possibility that a morphological reanalysis provides sufficient motivation for restructuring the temporary phonological grammar in early child English. However, in the Japanese data examined here, and probably in most similar cases, restricting the domain of markedness constraints is not a viable option since the phonological division between *NT-observing items and non-observing items does not correlate with morphological domains.

3.4. Two mechanisms for partial reranking

What else, then, could compel and allow the child to retreat from a Faithfulness » Markedness ranking albeit only for a subset of morphemes? Intuitively, we see that the force behind such restructuring must come from the deep-surface disparity found in the morphologically complex forms /tabe-ta/ → [tabeta] and /nom-da/ → [nonda].[9] This intuition can be captured in a simple developmental model if we credit the child with the following general learning principles.

(17) Uniform lexical entry principle (ULEP)[10]
A morpheme has a single underlying form.

(18) Biased Constraint Demotion (BCD) (Prince and Tesar 1999, Tesar and Prince to appear)
Recursively place at the top of the hierarchy constraints that do not prefer 'losers' (suboptimal competitors, as opposed to 'winner' or the attested outputs). In applying this procedure, place markedness constraints first into the hierarchy.[11]

For the sake of argument, let us for the time being suppose that there is no lexical stratification in Japanese, and all postnasal voicing is redundant. Following the standard assumption in phonological acquisition theory, we assume that children first map the perceived surface form onto the underlying structure. For example, they postulate /tombo/ as the underlying form for [tombo] 'dragonfly', /kome/ for [kome] 'rice' and /gomi/ for [gomi] 'trash'. How this information can be used to rank the constraints is described below in (19) using the format of the comparative tableau (Prince 2003). For each lexical entry, the tableau compares the attested output (the winner) and a potential but suboptimal output (the loser) with respect to the three

[9] Since the focus here is on the voicing of the past-tense morpheme, I abstract away from the place assimilation of the stem-final nasal in /nom/ in the following discussion.

[10] This is essentially the same principle employed in most classical generative analyses of non-suppletive alternations (Cf. the Unique Underlyer Condition in (Lass 1984)). A different label is deliberately chosen to emphasize its role as a learning, rather than an analytical, principle.

[11] This is a somewhat simplified statement of a complex learning principle. For a full formal algorithm of BCD, see Tesar and Prince (to appear).

constraints whose ranking the learner is trying to establish: *NT, IDVOICE and *VOICEDOBS ('no voiced obstruents'). The 'W' mark indicates that the constraint favors the winner of the pair. The 'L' marked cells shows where the loser is favored. Because [voice] is not contrastive after a nasal, no words with postnasal voiceless obstruents are included in the learning dataset.

(19) Initial learning in a nonstratified (pseudo-)Japanese lexicon

Lexicon	Winner ~ Loser	IDVOICE	*VOICEDOBS	*NT
tombo	tombo~tompo	W	L	W
kome	kome~gome	W	W	
gomi	gomi~komi	W	L	

BCD states that markedness constraints that do not prefer losers should first be ranked at the top. There is one such markedness constraint: *NT, which bears no L marks. This brings *NT over IDVOICE and *VOICEDOBS, giving *NT » IDVOICE, VOICEDOBS. Next, the grammar sees if it can rank the other two constraints below *NT. The other markedness constraint VOICEDOBS, however, has L marks, so it is not available for ranking. Instead, the faithfulness IDVOICE with no L marks will be put into place below *NT. The resulting ranking is shown in (20).

(20) Ranking consequence in a nonstratified (pseudo-)Japanese lexicon

Lexicon	Winner ~ Loser	*NT	IDVOICE	*VoicedObs
tombo	tombo~tompo	W	W	L
kome	kome~gome		W	W
gomi	gomi~komi		W	L

Thus far, past-tense verbs such as *nonda* and *tabeta* have been treated as monomorphemic units, but at this point, children begin to analyze the morphology behind the verb forms and identify the past-tense morpheme [ta~da]. Now they are ready to apply ULEP, whose primary function is to find a single lexical input that converges on all of its attested allomorphic realizations. When learners optimize the lexicon, the ULEP holds the lexical entry of the target morpheme constant across input-output evaluations, such that any morphologically related pair will have the same input form for the shared morpheme. In (21), the uniform input for the past-tense affix is hypothesized to be [da], and the input pair /nom-da/ - /tabe-da/ are compared with the attested outputs. As the tableaux show, the optimal outputs chosen by the grammar are [nonda] and [tabeda]. The former converges with the attested output [nonda] but the latter diverges from the attested output [tabeta]. In contrast, when the single underlying form is taken to be /ta/, as in (22), both /non-ta/ and /tabe-ta/ show convergence with the attested outputs. Because only /ta/ gives non-contradictory results, the learner selects it as the uniform lexical form of the past-tense marker.

(21) Evaluating /da/ as a uniform lexical input when *NT » IDVOICE

Input: nom-da	Output	*NT	IDVOICE	*VoicedObs	Attested	Result
	a. nonta	*!	*			
☞	b. nonda			*	nonda	converge

Input: tabe-da	Output	*NT	IDVOICE	*VoicedObs	Attested	Result
	a. tabeta		*!	*	tabeta	
☞	b. tabeda			**		diverge

(22) Evaluating /da/ as a uniform lexical input when *NT » IDVOICE

Input: nom-ta	Output	*NT	IDVOICE	*VoicedObs	Attested	Result
	a. nonta	*!				
☞	b. nonda		*	*	nonda	converge

Input: tabe-ta	Output	*NT	IDVOICE	*VoicedObs	Attested	Result
	a. tabeta			*	tabeta	converge
☞	b. tabeda		*!	**		

3.5 Partial reranking toward a stratified lexicon

Now let us see how this learning mechanism works when postnasal voicing is restricted to a subset of the phonological lexicon, as in real Japanese. This time, the overall input dataset contains some words with postnasal voiceless obstruents, e.g., *sampo* 'walk'. As shown in (23), the presence of such words changes the outcome of the ranking in the first phase.

(23) Initial learning in a stratified Japanese lexicon

Lexicon	Winner ~ Loser	IDVOICE	*VOICEDOBS	*NT
tombo	tombo ~tompo	W	L	W
sampo	sampo~ sambo	W	W	L
kome	kome~gome	W	W	
gomi	gomi~komi	W	W	

The winner~loser pair for *sampo* incurs an L mark on *NT, making it unavailable for ranking in the first round. The other markedness constraint *VOICEDOBS also has an L mark and cannot be put at the top of the hierarchy either. Despite being a faithfulness constraint, IDVOICE is placed into the ranking first because it is the only constraint that does not favor suboptimal outputs for this winner~loser set. After IDVOICE, no constraints can be ranked. The result is given in (24).

(24) Ranking consequence in a stratified lexicon

Lexicon	Winner ~ Loser	IDVOICE	*VOICEDOBS	*NT
tombo	tombo ~tompo	W	L	W
sampo	sampo~ sambo	W	W	L
kome	kome~gome	W	W	
gomi	gomi~komi	W	W	

This is the ranking used when the child begins to analyze the components of past-tense forms and looks for the single input to the allomorphic [ta ~ da]. The tableaux in (25) and (26) present the outcome of this hypothesis-testing procedure.

(25) Evaluating /da/ as a uniform lexical input when IDVOICE » *NT

Input: nom-da	Output	IDVOICE	*NT	*VoicedObs	Attested	Result
	a. nonta	*!	*			
☞	b. nonda			*	nonda	converge

Input: tabe-da	Output	IDVOICE	*NT	*VoicedObs	Attested	Result
	a. tabeta	*!		*	tabeta	
☞	b. tabeda			**		diverge

(26) Evaluating /ta/ as a uniform lexical input when IDVOICE » *NT

Input: nom-ta	Output	IDVOICE	*NT	*VoicedObs	Attested	Result
☞	a. nonta		*			diverge
	b. nonda	*!		*	nonda	

Input: tabe-ta	Output	IDVOICE	*NT	*VoicedObs	Attested	Result
☞	a. tabeta			*	tabeta	converge
	b. tabeda	*!		**		

Neither /da/ or /ta/ converges on both the attested surface forms [nonda] and [tabeta]. The key difference from (22) where input-output pairs with /ta/ converged on the attested outputs is the mapping /nom-ta/ → [nonta] due to the ranking IDVOICE » *NT. Since no inputs that respect the ULEP give the desired outcome, the child is compelled to adjust the ranking. This ranking adjustment will be confined to the particular morpheme that is causing the problem. Otherwise, the operation to obtain the intended outputs would result in an global reranking to *NT » IDVOICE with obvious detrimental effects on the entire grammar. As the overall surface evidence in the input speaks to the contrary, such reranking is thought to be blocked, or immediately repaired back to IDVOICE » *NT until the child tries out a local modification. As illustrated in (27) and (28), the localized reranking follows BCD, while still adhering to the ULEP.

(27) Data for partial reranking based on -/da/

Lexicon	Winner ~ Loser	IDVOICE	*VOICEDOBS	*NT
nom-da	nonda ~nonta	W	L	W
tabe-da	tabeta ~ tabeda	L	W	

(28) Data for partial reranking based on -/ta/

Lexicon	Winner ~ Loser	IDVOICE	*VOICEDOBS	*NT
nom-ta	nonda ~nonta	L	L	W
tabe-ta	tabeta ~ tabeda	W	W	

The learning procedure looks for a markedness constraint that can be placed higher in the hierarchy so that all the L-marked constraints are dominated by a W-marked constraint. This cannot be achieved in (27) where IDVOICE and *VOICEDOBS have the opposite W/L marking and *NT does not have W marks to 'cover' the L marks on these constraints. In (28), however, reranking *NT to the top achieves the desired result as the W mark of *NT dominates the L mark of IDVOICE. This local reranking will be earmarked on the markedness constraint *NT so that the moved *NT is indexed to the morpheme that is analyzed. The resulting ranking is *NT(ta) » IDVOICE » *VOICEDOBS.

(29) Successful partial reranking

Lexicon	Winner ~ Loser	*NT(ta)	IDVOICE	*VOICEDOBS
nom-ta	nonda ~nonta	W	L	L
tabe-ta	tabeta ~ tabeda		W	W

Combining this with the general ranking IDVOICE » *NT, *VOICEDOBS gives the child the ranking of the weakly stratified lexicon in (30).

(30) Partially reranked hierarchy
NT(ta) » IDVOICE » *NT, *VOICEDOBS

Thus, a partial retreat from a Faithfulness » Markedness configuration can be achieved if morphological information is employed. The advantage of this approach is that it does not invoke any ad hoc learning mechanisms. Procedures such as BCD and the ULEP are motivated for general phonological acquisition, and it is a welcome result to see that a weakly stratified lexicon is learnable on the basis of such broad mechanisms. What is different from the general case is the inconsistencies children run into in applying the ULEP to their morphological reanalysis of the target phonology (see (25) and (26)). That the previously established ranking is compromised only in the face of such data is also a desirable feature of this learning model, as the restrictiveness of the process prevents it from being applied haphazardly.

4. Discussion and conclusions

In this article, I have argued that considerations of learnability expose the empirical problems of two ideas often adopted in modeling a nonuniform phonological system. The first of these, which I termed the strong lexical stratification hypothesis, assumes that all lexical items can be assigned to sublexica on the basis of distributional evidence. It is unrealistic to think that membership of lexical items can be learned in this manner by a learner who has no a priori knowledge of the lexical strata in the ambient language. If we take this point seriously and restrict stratum assignment to cases for which there is alternation evidence, we arrive at the conclusion that lexical stratification can only be weakly implemented, i.e., by having stratum-specific ranking for those morphemes which are less marked than the rest of the lexicon on the basis of alternation. If correct, this conclusion threatens another widely adopted idea regarding nonuniform phonology, namely the indexation of faithfulness constraints. I have suggested that the indexed faithfulness approach encounters a computational problem, which nevertheless can be resolved in a weakly stratified lexicon if we entertain the idea of indexing markedness constraints instead. When these modifications are made, we can model the acquisition of a stratified lexicon using only general learning mechanisms that have been independently proposed.

The discussion presented here is based on a single phenomenon, and it is possible that the conclusions may not generalize to all other cases of nonuniform phonology. First, much of the distribution of Japanese postnasal voicing is arbitrary from a synchronic point of view. There are few apparent diagnostics through which the child can arrive at the conclusion that *tombo* 'dragonfly' and *panda* 'panda' reside in different phonological sublexica.[12] In this sense, Japanese postnasal voicing is akin to the arbitrary division in English between words that accept or resist stress on pretonic heavy syllables (Pater 2000). However, other cases of nonuniform distributional phonology come with grammatical or semantic correlates. For instance, mimetic forms in Japanese, in which postnasal voice is contrastive, are typically onomatopoeic. Accent location Japanese is unpredictable in nouns but systematic in verbs and adjectives (Poser 1984). Sezar stems in Turkish, which exhibit a distinct stress pattern, are prototypically place names (Sezar 1981). Children may be sensitive to such grammatical and semantic information and able to condition their phonological acquisition by prescribed categories.

Second, as mentioned above, postnasal voiceless obstruents are quite frequent in the input Japanese children are exposed to. The substantial presence of the marked configuration in the input confutes any account that rests on the assumption that postnasal voiceless obstruents can be held in check because of their paucity. However, there are marked configurations that are in fact infrequent in the input. One example is the sequence [si], which is found only in unassimilated foreign words. It is possible that [si] appears so infrequently in early input that a core stratum that prohibits a [s]-[š] contrast before [i] can be established despite the occasional instances of [si] children may encounter. Obviously, quite how frequency of marked forms in the input affects constraint ranking is an empirical question that requires further research.

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[12] Rendaku also shows this type of arbitrariness. Compare *karasu* 'crow', which undergoes rendaku (e.g. *oo* 'big' + *karasu* → *oogarasu* 'raven'; *hasi* 'edge' + *futo* 'thick' + *karasu* → *hasibutogarasu* '*jungle crow*') with *taka* 'hawk', which systematically resists sequential voicing (e.g., *oo* 'big' + *taka* → *ootaka* 'goshawk'; *kuma* 'bear' + *taka* → *kumataka* 'hawk eagle').

Despite these qualifications, it is still clear that language-internal inconsistencies can complicate the process of phonological acquisition. It is then rather surprising that only scant attention has so far been given to the issue of phonological nonuniformity in acquisition research. Although some phonological learning models explicitly address free variation and gradient wellformedness (e.g., Boersma and Hayes 2001), few tackle the inter-morpheme inconsistencies of the type discussed in this study. The preliminary exploration presented in the preceding section is promising in that it shows existing proposals for learning mechanisms to be robust enough to incorporate some cases of lexical stratification; however the empirical scope of this approach remains to be tested.

A final implication of this study is that learnability consideration can lead to conclusions that do not square well with the most rational analysis of a phonological problem. As Itô, Mester and Padgett (1999: 44) succinctly put, a fruitful approach to phonological theorizing is to "explore how far the explanatory net of phonology can be cast." The more desirable theory of phonology, therefore, is one in which the same phonotactic generalizations are maximally applied to alternation and distribution patterns. The solution to the epistemological problems proposed here runs counter to this meta-theoretic principle, but careful examination of such tension between deduction and induction is likely to further our understanding of natural phonological systems.

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