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Lexical Stratification and Ranking Invariance in Constraint-based Grammars*

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1. Introduction

A fundamental tenet in Optimality Theory (OT: Prince & Smolensky 1993) is that a single invariant ranking of constraints represents the grammar of each language. A phenomenon which has proven problematic to this concept is lexical stratification: the partitioning of the lexicon into distinct subsets with different phonological characteristics. Previous OT accounts of lexical stratification have generally compromised ranking invariance, for instance, by allowing faithfulness constraints to re-rank according to the sublexicon (Cf. Itô & Mester 1995b).

In this paper, we discuss a model of lexical stratification which fully adheres to the assumption of invariant ranking. The model, originally proposed by Fukazawa (1997), solves the conflict between language-internal variability and ranking invariance by projecting multiple sets of Input-Output faithfulness constraints. Each set of faithfulness constraints is associated with a sub-lexicon (or stratum) in the language, and all the stratum-specific constraints are ranked with other types of constraints. Such a system can account for stratum-specific phonological phenomena in a single constraint ranking.

The main goal of the paper is to demonstrate the conceptual and empirical advantage of this approach, using lexical stratification in Japanese as a domain of investigation. Further, we will address two issues that arise regarding the claim that multiple projections of faithfulness constraints derive the effects of lexical stratification: i) the question of how multiple faithfulness constraints can be instantiated, and ii) implications for the fundamental organization of the lexicon with strata.

This paper is organized as follows. Section 2 illustrates the superiority of the Correspondence Theoretic approach to lexical stratification to the re-ranking system. We present an analysis of hybrid words in Japanese and show that simultaneous reference to multiple sets of Input-Output faithfulnes constraints is necessary to account for the data. Section 3 provides an answer to the question: how are those multiple sets of IO constraints established? We will indicate that contradicting phonological data touch off multiplication of faithfulness constraints and ranking of constraints in the process of acquisition. Section 4 discusses the relationship between split faithfulness constraints and the core-periphery organization of a stratified lexicon in a language. We will argue that there is no need for a meta-constraint to regulate the ranking consistency of faithfulness because the core-periphery structure is a mere tendency in Japanese and not an inherent property of the grammar. Section 5 concludes the paper.

2. A Correspondence Theoretic Approach to Lexical Stratification
2.1 Multiple Faithfulness Relations in Correspondence Theory

Within the framework of Correspondence Theory (McCarthy & Prince 1995), the notion of multiple sets of faithfulness in a grammar is developed by Urbanczyk (1995, 1996) and Benua (1995, 1997). Urbanczyk proposes in her study on Lushootseed reduplication that two distinct sets of Base-Reduplicant faithfulness constraints for the distributive and the diminutive morpheme classes are instantiated in Lushootseed, and the single invariant ranking of all the constraints can account for two types of reduplicational patterns depending on the morpheme classes. Benua remarks that English class 1 and 2 affixal morphemes each display a different correspondence relation to the output of the root morphemes; hence, there are two sets of Output-Output faithfulness constraints in English. A single invariant ranking of all the constraints explains both class 1 and 2 affixational patterns in English.

Both Urbanczyk's and Benua's studies suggest that phonological patterns can vary depending on the difference between morphological categories within a language: a pattern observed in one category cannot occur in another. Each morphological group gives rise to its own correspondence relation. Therefore, it is possible for each correspondence relation, such as Input-Output (IO), Output-Output(OO), Base-Reduplicant(BR), Tone-Tone-Bearer (TT) etc. to bear multiple sets of faithfulness constraints for each morphonological class in a language.

Fukazawa (1997) concludes from those previous studies on Correspondence Theory that the full set of faithfulness constraints in Universal Grammar (UG) has the potential of propagation for any correspondence relation in a language, and applies this idea to account for Japanese lexical stratification. The next section reviews Fukazawa's proposal of the multiple Input-Output faithfulness constraints in Japanese.

2.2 Multiple Input-Output Faithfulness Relations in Japanese

Japanese vocabulary is divided into five strata based on etymology: *Yamato, Sino-Japanese, Mimetics, Foreign (Assimilated),* and *Alien (Unassimilated)* (McCawley 1968, Itô & Mester 1995a, b).[1] There are many phonological phenomena which are stratum-specific (Itô & Mester 1995b). For example, obstruents after nasals must be voiced in Yamato and Mimetic; therefore, [nt] or [mp] are impossible clusters in those two strata ([kan**d**a]$_{\text{Yamato}}$ 'bite-past', *[kan**t**a]; [Som**b**ori]$_{\text{Mimetic}}$ 'sad', *[Som**p**ori]). On the other hand, both voiced and voiceless obstruents can surface after nasals in the other strata ([sam**p**o]$_{\text{Sino-Japanese}}$ 'a walk', [kom**p**^{j}uutaa]$_{\text{Foreign}}$ 'computer', [Fon**t**o]$_{\text{Alien}}$ 'font').

In OT, whenever some phonological alternation occurs in a language, we assume that some markedness constraint is satisfied at the expense of violating a faithfulness constraint. Therefore, a ranking "markedness » faithfulness" is established in the language. On the other hand, no alternation is observed in a language when the faithfulness constraint outranks the markedness constraint: "faithfulness » markedness".

On the basis of this approach, the phenomenon of post-nasal voicing in Yamato and Mimetics motivates the ranking scheme of the type "markedness » faithfulness," where the relevant markedness constraint is PNV and the relevant faithfulness constraint, IDENT[voice].

(1) Provisional ranking

/kam-**t**a 'bite-past'/	PNV	IDENT [voice]
☞ a. kan**d**a		*
b. kan**t**a	*!	

However, this ranking cannot hold in the rest of the strata, Sino-Japanese, Foreign, or Alien:

(2) Wrong result

/kom**p**^{j}uutaa 'computer'/	PNV	IDENT [voice]
L a. kom**b**^{j}uutaa		*
b. kom**p**^{j}uutaa	*!	

In (2), the actual output is (b). Thus, we must assume that PNV must be satisfied in the Yamato and Mimetic strata, but can be violated in other strata, resulting in the ranking "IDENT[voice] » PNV." This conflict of ranking is observed not only in post nasal voicing but also in other stratum-specific phonological phenomena. Consequently, there are five phonological patterns depending on the sub-lexicon in Japanese, resulting in five different constraint rankings. If this were the case, a fundamental principle of OT would be called into question. OT assumes that a single invariant constraint ranking defines the entire grammar of a language.

Itô & Mester (1995b) try to respect this invariant constraint ranking hypothesis in OT by restricting re-ranking of constraints only to the faithfulness constraints. They indicate that the fixed invariant ranking of markedness constraints holds through the entire grammar of each language, and only the faithfulness constraints can be re-ranked depending on each morphological group. However, this approach still compromises the invariant ranking hypothesis.

To circumvent this problem, Fukazawa (1997) proposes that each sub-lexicon bears its own Input-Output (IO) correspondence relation in Japanese. Building on Urbanczyk and Benua's research, Fukazawa deems that the basic identity strings such as IO, OO, BR, TT, etc. can be further split into multiple elements for each morphological unit within a language. She claims that five IO relations are found in Japanese, one for each stratum, and a full set of faithfulness constraints is multiplied for each relation.

(3) Split IO-faith for each stratum

IO-Yamato(Y):	{MAX-IO-Y, DEP-IO-Y, IDENT[F]-IO-Y, INTEG-IO-Y,...}
IO-Sino-Japanese(SJ):	{MAX-IO-SJ, DEP-IO-SJ, IDENT[F]-IO-SJ, INTEG-IO-SJ,...}
IO-Mimetics(M):	{MAX-IO-M, DEP-IO-M, IDENT[F]-IO-M, INTEG-IO-M, ...}
IO-Foreign(F):	{MAX-IO-F, DEP-IO-F, IDENT[F]-IO-F, INTEG-IO-F,...}
IO-Alien-(A):	{MAX-IO-A, DEP-IO-A, IDENT[F]-IO-A, INTEG-IO-A,...}

For instance, there are five kinds of IDENT[voice]-IO in Japanese: IDENT [voice]-IO-Y, IDENT[voice]-IO-SJ, IDENT[voice]-IO-M, IDENT[voice]-IO-F, and

IDENT[voice]-IO-A. A markedness constraint PNV and all these faithfulness constraints are ranked in a single invariant hierarchy as follows:

(4) Constraint ranking for PNV:

IDENT[voice]-IO-SJ, IDENT[voice]-IO-F, IDENT[voice]-IO-A	»	PNV	»	IDENT[voice]-IO-Y, IDENT[voice]-IO-M

The difference in the status of post nasal voicing between Yamato/Mimetics and Sino-Japanese/Foreign/Alien can be explained with this single ranking.

(5) PNV in Yamato and Mimetic

/kam-**t**a/ 'bite-past'	IDENT[voice]-IO-SJ, IDENT[voice]-IO-F, IDENT[voice]-IO-A	PNV	IDENT[voice]-IO-Y, IDENT[voice]-IO-M
☞ a. kan**d**a			*
b. kan**t**a		*!	

(6) PNV in Sino-Japanese, Foreign, and Alien

/kom**p**ʲuutaa 'computer'/	IDENT[voice]-IO-SJ, IDENT[voice]-IO-F, IDENT[voice]-IO-A	PNV	IDENT[voice]-IO-Y, IDENT[voice]-IO-M
☞ a. kom**p**ʲuutaa		*	
b. kom**b**ʲuutaa	*!		

The ranking in (4), then, accounts for the phenomenon of post nasal voicing in all the five strata without any conflict.

Following Fukazawa's proposal, we assume that all multiplied IO faithfulness constraints are evaluated with respect to all other constraints in a single ranking in the grammar of Japanese. The next section provides an analysis of the actual data with the multiple Input-Ouput faithfulness constraints to make it clear that the multiple faithfulness system is superior to the re-ranking system in accounting for lexical stratification.

2.3 Evidence for Multiple Faithfulness Relations

The multiple faithfulness system and the re-ranking faithfulness system do not bring forth any significant empirical difference, as long as we examine lexical items from each sub-lexicon independently. However, once we turn our eyes to structures involving items from more than one sublexica, only the multiple faithfulness approach can provide a coherent account within a parallelist framework. The relevant data in Japanese can be found in hybrid words such as those in (7).

(7) a. [tombo-kenk^{j}uuka] ‘a dragonfly-researcher’
([tombo]$_{\text{Yamato}}$ - [kenk^{j}uuka]$_{\text{Sino-Japanese}}$)
b. [toNkatsu-domburi] ‘bowl of rice with pork cutlet’
([[toN]$_{\text{Sino-Japanese}}$ - [katsu]$_{\text{Foreign}}$] - [domburi]$_{\text{Yamato}}$)
c. [supootsugappa] ‘a sport raincoat’
([supootsu]$_{\text{Foreign}}$ - [kappa]$_{\text{Yamato}}$)[2]
d. [tSiimu-tiitSiNgu] ‘team-teaching’
([tSiimu]$_{\text{Foreign}}$ - [tiitSiNgu]$_{\text{Alien}}$)

To explain these hybrids, multiple Input-Output faithfulness constraints for each sub-lexicon must simultaneously attend the same tableau.

For example, the word [tombokenk^{j}uuka] ‘a dragonfly-researcher’ consists of both Yamato and Sino-Japanese elements. In such a hybrid, two kinds of IO faithfulness constraints for each sub-lexicon are needed in the evaluation. In the word [tom**b**oken**k**^{j}uuka], the markedness constraint PNV (Post Nasal Voicing) is satisfied in the Yamato part, while it is violated in the Sino-Japanese part in order to satisfy the faithfulness constraint for voicing. Without two different IO faithfulness constraints for Yamato and Sino-Japanese, this datum cannot be accounted for.

(8) Multiple IO faithfulness constraints interaction in a hybrid:

/tom**p**oken**k**^{j}uuka/	IDENT[voice]-IO-SJ	PNV	IDENT[voice]-IO-Y
a. tom**p**oken**k**^{j}uuka		**!	
b. tom**b**oken**g**^{j}uuka	*!		*
☞ c. tom**b**oken**k**^{j}uuka		*	*
d. tom**p**oken**g**^{j}uuka	*!	*	

As tableau (8) shows, this hybrid can be explained only with simultaneous attendance of multiple IO faithfulness constraints in a parallelist OT. In the re-ranking system, PNV » IDENT[voice] can account only for the first Yamato part of this hybrid at a stage, and the re-ranked ranking IDENT[voice] » PNV has to explain the latter Sino-Japanese part in a different stage. Therefore, the re-ranking model cannot bring forth the correct analysis of hybrids in a single tableau in OT.

When a phonological process that crosses the morpheme boundary takes place in a hybrid, the problem for the re-ranking approach becomes more serious. For instance, two components of a hybrid must be evaluated within the same tableau in order to account for *Rendaku* --- voicing of the initial obstruent in the second member of a compound. In the word [supootsugappa], a markedness constraint *[p] ([p] cannot singly occur) is violated in the first Foreign part, but respected in the latter Yamato part. A faithfulness constraint INTEGRITY (no element of the input has multiple correspondents in the output: McCarthy & Prince 1995) must be satisfied in the Foreign stratum, while it can be violated in Yamato.

(9) Multiple IO faithfulness interaction in a hybrid with *Rendaku*:

/su**p**ootsuka**p**a/	Rendaku	INTEG-IO-F	*[p]	INTEG-IO-Y
a. su**pp**ootsu**g**a**pp**a		*!		*
b. su**pp**ootsu**g**a**p**a		*!	*	
☞ c. su**p**ootsu**g**a**pp**a			*	*
d. su**p**ootsu**g**a**p**a			**!	
e. su**p**ootsu**k**a**pp**a	*!		*	*

In tableau (9), Rendaku does not take place in candidate (e); therefore, it loses. In candidate (c), [p] surfaces as a singleton in the Foreign part, [p] is geminated in the Yamato part, and Rendaku takes place. All of the constraints in this tableau, i.e. Rendaku, INTEG-IO-F, INTEG-IO-Y, and *[p] are necessary to account for the winning candidate.

With the re-ranking system, the ranking "INTEGRITY » *[p]" can account for the Foreign part [supootsu] in one stage, and another ranking "*[p] » INTEGRITY" can take care of the Yamato part [kappa] at a different stage. Thus, the re-ranking system requires two or more different stages to evaluate hybrids. This is already a significant problem in OT which assumes parallel evaluation of well-formedness. Moreover, in (9), the Foreign part [supootsu] and the Yamato part [kappa] must simultaneously attend in the tableau to account for the Rendaku phenomena. Since evaluation of Rendaku requires simultaneous access to the representations of the two components in a hybrid, the re-ranking appoach runs into a serious problem.

This section has observed that multiple Input-Output sets of faithfulness constraints are crucial to account for lexical stratification. The next section will discuss how those multiple Input-Output faithfulness relations are instantiated.

3. How multiple sets of faithfulness constraints are instantiated

In the previous sections, we argued that Japanese stratum-specific phonological phenomena can be explained with a single ranking if we introduce five distinct sets of IO-FAITH constraints. Such language-specific propagation of faithfulness must be realized in the course of acquisition. But how does a child come to project several distinct Input-Output relations in the target language? At the onset of acquisition the child does not know a priori how many lexical strata, if any, there are in the target language; neither does the child know which lexical items are grouped together to form a stratum. Thus the task of projecting the right number of lexical strata and constraint sets seems non-trivial. Furthermore, whatever the mechanism that underlies such propagation of faithfulness constraints may be, it has to be properly constrained so as not to allow excessive splitting of faithfulness constraints.

These potential problems can be circumvented by positing two learning procedures: i) a data-driven mechanism which projects (and restricts) multiple faithfulness constraints, and ii) an evaluation metric which computes the fewest number of strata necessary to account for the target data pattern. In what follows, we will explain each of these procedures in detail.

3.1 Propagation of Multiple Faithfulness

First, we propose that a basic faithfulness constraint is split and ranked independently if and only if a ranking paradox posed by the ambient data cannot be resolved otherwise. The relevant situation arises when the ranking of a faithfulness constraint motivated for a particular datum contradicts the ranking motivated for another datum. If invariant ranking is to be maintained, such ranking contradictions can be resolved only by postulating more than one faithfulness constraint of the same kind and ranking them independently. This ensures that constraint splitting occurs only under pressure from the primary linguistic data, thus it eliminates vacuous propagation of faithfulness constraints.

As an example, consider the case of IDENT[voice]-IO as it relates to the markedness constraint PNV. Let us suppose that the learner is exposed to the following two surface forms in no particular order.

(10) Sample target data

a. [santa] 'Santa (Claus)'	/santa/ (monomorphemic):	Foreign
b. [kanda] 'bit'	/kam-ta/ ('bite' + past tense affix):	Yamato

The surface form [santa] contains a post-nasal unvoiced obstruent, a marked structure with respect to PNV. In order for this form to surface, PNV must be ranked below IDENT[voice]. Thus we obtain the following ranking.

(11) Constraint ranking for [santa]: IDENT[voice] » PNV

/santa/	IDENT[voice]	PNV
☞ a. [santa]		*
b. [sanda]	*!	

The ranking motivated by [kanda] however will be different, given the learner's access to the stem+affix morphology involved in the representation.

(12) Verbal inflectional paradigm (phonetic surface forms)

	nonpast	negative	past	meaning of root
a.	taberu	tabenai	tabe**ta**	'eat'
b.	miru	minai	mi**ta**	'see'
c.	tatsu	tatanai	tat**ta**	'stand'
d.	jobu	jobanai	jon**da**	'call'
e.	kamu	kamanai	<u>kan**da**</u>	'bite'

We take that the child is equipped with a fairly standard assumption in generative phonology that redundant information is excluded form the lexicon (Cf. the Minimal Redundancy principle in Prince and Smolensky 1993 as one formulation of this idea). Faced with the data in (12) then, voice would not be specified underlyingly for the past-tense morpheme since the voicing in the alternating [ta] and [da] is predictable from PNV. The preferred input for the coronal stop would therefore be [-voice] (or [0voice] if voice is privative). We now have the input-output pair /kam-ta/ - [kanda], which motivates the ranking in (13) where PNV outranks IDENT[voice].

(13) Ranking for /kam-ta/ - [kanda]: PNV » IDENT[voice]

/kam-ta/	PNV	IDENT[voice]
a. kanta	*!	
☞ b. kanda		*

The ranking in (13) contradicts the ranking for [santa] in (11). If grammars adhere to the principle of invariant ranking, the only solution to this conflict is to project two distinct faithfulness constraints and rank one of them above and the other below PNV, as shown in (14).

(14) Resolving the ranking paradox in an invariantly ranked constraint grammar

IDENT[voice]$_{santa}$ » PNV » IDENT[voice]$_{kanda}$

The same process can be applied to other faithfulness constraints and their ranking with respect to some markedness constraints whenever such contradictory input data are encountered.[3] A hypothetical outcome of this algorithm is given in (15), where the subscript letters stand for lexical items indexed with the faithfulness constraints.

(15) Pairs of split faithfulness constraints

a. IDENT[voice]$_{a, b, c...}$ » PNV » IDENT[voice]$_{d, e, f...}$
b. IDENT[lab]$_{g, h, i...}$ » *[p] » IDENT[lab]$_{k, l, m...}$
c. IDENT[voice]$_{n, o, p...}$ » NOVOIGEM » IDENT[voice]$_{q, r, s...}$

As we can see from this demonstration, propagation of multiple faithfulness constraints can be realized by a mechanism that resolves a potential ranking paradox. Since the process takes place only at the face of contradictory data, there is a built-in pressure against multiple faithfulness. The learning procedure therefore defines a dimension of markedness on multiple faithfulness: the more splitting of faithfulness, the more marked the grammar.[4]

3.2 Formation of lexical strata

As a second learning procedure, we propose a mechanism that projects the exact number of lexical strata needed in the target grammar. The computation is achieved by generating the minimum number of faithfulness constraint sets required to account for all ranking differences. We take the view that each lexical item must be uniquely indexed to a set of faithfulness constraints. Each faithfulness constraint set must be complete in the sense that two realizations of IDENT[voice], for instance, imply two full families of FAITH constraints and hence two realizations of IDENT [lab], MAX-IO, DEP-μ and so on. Thus if some input data are not consistent with an already established ranking of FAITH, a whole new set of faithfulness constraints is generated by the grammar. Otherwise all lexical items are hypothesized to be associated with one of the available sets of FAITH constraints.

As an illustration, suppose that the learner knows five lexical items and the relative rankings of faithfulness and markedness constraints motivated by the phonology of these items, as shown in (16).

(16) Forming lexical strata (‘?’= no evidence for ranking)

Stratum	Lex. item	Rankings		
1	A B	PNV»IDENT[voi]$_a$ PNV»IDENT[voi]$_b$	NOVOIGEM»IDENT[voi]$_a$?	*[p]»IDENT[lab]$_a$ *[p]»IDENT[lab]$_b$
2	C	IDENT[voi]$_c$»PNV	NOVOIGEM»IDENT[voi]$_c$	?
3	D E	IDENT[voi]$_d$» PNV IDENT[voi]$_e$» PNV	IDENT[voi]$_d$»NOVOIGEM IDENT[voi]$_e$»NOVOIGEM	IDENT[lab]$_d$»*[p] IDENT[lab]$_e$»*[p]

The rows represent the constraint sets and rankings associated with a group of lexical items. The rankings motivated for lexical item C indicate that it cannot be grouped with A and B since they differ in the relative ranking of IDENT[voice] and PNV. Item C cannot share a faithfulness constraint set with D and E either due to the different rankings of IDENT[voice] with respect to NOVOIGEM. Therefore C must be indexed to a distinct set of faithfulness constraints. Note that lack of evidence for some ranking relations, indicated by ‘?’ in (16), does not necessarily hinder this procedure. If there is some positive evidence for a difference in the ranking, a distinct constraint set will be projected (as in the case of C vs. A/B and D/E). As long as there is no evidence for conflict, however, lexical items will be associated with the minimum number of faithfulness constraint sets. For example, B will be indexed to the same constraint set as A since all the available ranking evidence for B is consistent with the ranking motivated by A.

Indexation of faithfulness constraints will eventually be made to a group of lexical items rather than the individual items. The IDENT[voi] constraints for lexical items A and B will be indexed to Stratum 1 to which A and B belong (hence IDENT [voi]$_1$). Since all lexical items are now uniquely associated with a stratum even if some ranking information may be missing for certain items, the stratum-specific rankings of constraints can be unified into a single overall constraint ranking of the language, as shown in (17).

(17) Overall ranking[5]

a. IDENT[voi]$_3$ » NOVOIGEM » IDENT[voi]$_2$ » PNV » IDENT[voi]$_1$
b. IDENT[lab]$_3$ » *[p] » IDENT[lab]$_1$

The upshot of this second learning algorithm is that it takes the fragmented rankings of constraints in (15) and collapses them into a single ranking. As it minimizes the number of distinct sets of faithfulness constraints, this process also militates against the unnecessary projection of lexical strata.

4 Split Faithfulness Constraints and the Core-Periphery Structure

4.1 (Non)restriction on faithfulness constraint ranking

In Sections 1 and 2, we proposed that five sets of faithfulness constraints coexist in the grammar of Japanese, and that stratum-specific versions of a given faithfulness constraint can be ranked independently of each other. This opens up a possibility for the different types of faithfulness constraints to be ranked freely across FAITH types so that some markedness constraints are respected in the first stratum but not in the second, while other types of markedness are fulfilled in the second but not in the first. Contrary to the commonly held view, we argue that such a state of affairs is in fact licensed by the grammar as a consequence of the multiple faithfulness model.

It has been claimed that relations between sublexica follow a systematic pattern characterized as the ‘core-periphery’ structure (Itô & Mester 1995a,b, to appear). In a perfect core-periphery organization, the following nested structure holds among the lexical items where *Lex* stands for a set of lexical items which always fulfill certain markedness constraints.

(18) $\text{Lex}_n \supset \text{Lex}_{n-1} \supset \text{Lex}_{n-2} \supset ... \supset \text{Lex}_2 \supset \text{Lex}_1$

Lex$_1$ can be seen as the ‘core’ and Lex$_n$ the entire lexicon. In this schema, a lexical stratum can be defined as a complement of an immediate inner set: Lex$_n$ - Lex$_{n-1}$, Lex$_{n-1}$ - Lex$_{n-2}$ etc. Items in Lex$_{n-1}$ are subject to all the markedness constraints fulfilled by items in Lex$_n$, but not all items in Lex$_n$ are subject to the markedness constraints that regulate items in Lex$_{n-1}$. The set of markedness constraints M$_1$, which define the group of lexical items belonging to stratum Lex$_1$, properly includes the set of markedness constraints M$_{2/1}$ that define the stratum Lex$_2$ - Lex$_1$. M$_{2/1}$ in turn properly include M$_{3/2}$ that define the lexical stratum Lex$_3$ - Lex$_2$ and so on with the rest of the lexicon *mutatis mutandis*:

(19) $\text{M}_1 \supset \text{M}_{2/1} \supset ... \supset \text{M}_{n-1/n-2} \supset \text{M}_{n/n-1}$

A necessary condition to guarantee such a structural organization of the lexicon, as pointed out by Itô & Mester (1995a,b), is the maintainance of the ranking invariance of markedness constraints across strata. If all types of faithfulness constraints are clustered together, a strict core-periphery structure can be captured by changing only the ranking position of the stratum-specific FAITH.

In (20), due to the fixed ranking of markedness constraints and the unified FAITH, the set of markedness constraints fulfilled in Stratum$_n$ is properly contained in the set of markedness constraints fulfilled in Stratum$_{n-1}$. Any two strata will stand in a relation which can be defined by two sets of markedness constraints in a subset-superset relation.

(20)

Stratum$_1$	Stratum$_2$	…	Stratum$_{n-1}$	Stratum$_n$
M_z	M_z		M_z	M_z
M_y	M_y		M_y	**FAITH$_n$**
M_x	M_x		**FAITH$_{n-1}$**	M_y
:	:		M_x	M_x
:	:		:	:
M_b	M_b		:	:
M_a	**FAITH$_2$**		M_b	M_b
FAITH$_1$	M_a		M_a	M_a

(21)

Stratum$_1$	Stratum$_2$
M_z	M_z
M_y	M_y
FAITH$_{1x}$	M_x
M_x	FAITH$_{2x}$
:	:
M_b	M_b
M_a	**FAITH$_{2A}$**
FAITH$_{1A}$	M_a

However, if stratum-specific constraints are allowed for all types of FAITH, and the different types of faithfulness constraints can be ranked independently, the grammar can generate a stratified lexicon that ignores such core-periphery structure even if the markedness constraints are ranked invariantly with respect to each other. In (21), there are two types of faithfulness constraints FAITH_a and FAITH_x, each relevant to markedness constraints M_a and M_x, respectively. The stratum-specific versions of these faithfulness constraints are ranked independently in such a way that the domination relations with respect to the relevant markedness constraints are inconsistent. Thus lexical items in Stratum_1 are subject to M_a but not to M_x, while lexical items in Stratum_2 are subject to M_x but not to M_a. Here we see that the core-periphery structure is no longer maintained despite the consistent ranking of markedness constraints, because the set of markedness constraints that defines Stratum_1 (which includes M_a but not M_x) does not properly contain the constraint set that defines Stratum_2 (which includes M_x but not M_a).

If we were to maintain a strict core-periphery structure, we would need to implement a meta-constraint that rules out this type of ranking. The restriction would be formulated as (22).[6]

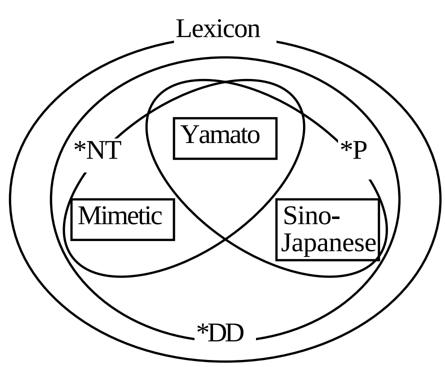
(22) Ranking Consistency across itemized faithfulness constraints

> Let F and G be two types of IO-faithfulness constraints, and *i* and *j* be two lexical strata. If for some faithfulness constraint F the stratum-specific versions stand in the domination relation F_i » F_j, then there is no faithfulness constraint G such that its stratum-specific versions stand in the relation G_j » G_i.

However, we believe there is empirical evidence suggesting that such restriction of faithfulness constraint ranking is not inherent to the architecture of the grammar.

First, Itô & Mester (1995a) have already observed that there is a non-subset relation between Yamato, Sino-Japanese and Mimetic strata involving the *[p] and PNV constraints (called *NT in Itô & Mester 1995a). Yamato words are subject to both constraints. However, while Sino-Japanese words are only subject to *[p], Mimetics are exempt from *[p] and subject to PNV.

(23) Non-subset relation between strata (Itô & Mester 1995a: p823)[7]



As we have shown in Section 1, in order to account for this situation, we need stratum-specific IDENT constraints itemized for two different phonological features and rank them separately.

(24) Split and itemized faithfulness constraints

a. For the distribution of *[p] items:
IDENT[lab]-IO-M » *[p] » IDENT[lab]-IO-SJ, IDENT[lab]-IO-Y

b. For the distribution of *[NT] items:
IDENT[voice]-IO-SJ » PNV » IDENT[voice]-IO-M, IDENT[voice]-IO-Y

The two rankings in (24) reside in a single hierarchy in the actual grammar. Although the relative ranking between (24a) and (24b) cannot be determined from the data, the following inconsistent rankings of itemized faithfulness constraints must hold contra (22).

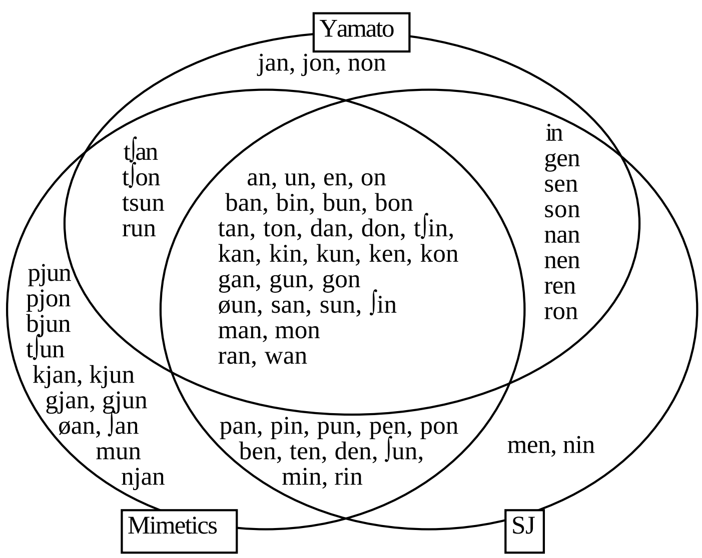
(25) Inconsistent ranking of itemized faithfulness constraints

IDENT[lab]-IO-M » IDENT[lab]-IO-SJ
vs.
IDENT[voice]-IO-SJ » IDENT[voice]-IO-M

There are at least two other reported examples of non-core-periphery relations in the Japanese lexicon. First, the prosodic size restriction on stems or roots is only applicable for Mimetic and Sino-Japanese but not for Yamato, Foreign and Alien (Hamano 1986, Tateishi 1989). Second, the accentuation pattern in compounds shows that faithfulness to the underlying accent location in the second member of the compound is ranked higher than the markedness constraint NON-FINALITY in Yamato and Foreign but not in Sino-Japanese (Kubozono 1997).

Another piece of evidence comes from a detailed analysis of permissible intra-syllabic phonology of each stratum. As shown in (26), observable segmental patterns within a heavy syllable closed with a moraic nasal do not exhibit a clear core-periphery structure at all.

(27) Observable intra-syllable patterns for each stratum [8]



As our survey of the literature and a new look into the phonotactics of sublexica show, there are several counter-examples for the core-periphery structure in Japanese. We take these as evidence that different types of faithfulness constraints can be freely and independently ranked across FAITH types. This casts doubts on the hypothesis that the core-periphery structure derives from an inherent property of the grammar regulating the ranking of faithfulness constraints.

4.2 The origin of the core-periphery structure

If the core-periphery structure does not reflect the design of the grammatical system, where does it come from? Although there is evidence that runs counter to a strict subset relation among the sub-lexica, there is no denying that there is an apparent tendency for core-periphery organization in the Japanese lexicon.

We suspect that the trend is a result of an assimilation process involved in the formulation of the loanword lexicon. When a language borrows foreign words, what enters the lexicon is mainly the surface structure of the foreign lexical items and, only to a far lesser extent, the phonology of the source language. The surface form of a borrowed word may contain a structure which is more unmarked or marked in the recipient language phonology. An unmarked structure reflects a ranking type of $\mathbb{M}$(arkedness) » $\mathbb{F}$(aith) in the source language. Although $\mathbb{F}$ may be ranked above $\mathbb{M}$ in the recipient language, there is no positive evidence in the input data that motivates the re-ranking of $\mathbb{F}$ (via FAITH splitting) below $\mathbb{M}$ because the surface forms of all borrowed words will be unmarked with respect to $\mathbb{M}$.

On the other hand, a structure that is marked within the recipient language phonology reflects the ranking $\mathbb{F}$ » $\mathbb{M}$ in the source language, and it will be met by the recipient language ranking $\mathbb{M}$ » $\mathbb{F}$. In this case, the incoming structures are marked for violations of $\mathbb{M}$, and therefore there is positive evidence for a new ranking of $\mathbb{F}$. The foreign version of $\mathbb{F}$ must be ranked higher than $\mathbb{M}$ even if the oppostite ranking holds for the native words. In short, there is an asymmetry in the ranking adjustments caused by borrowing. Marked surface structures in foreign words motivate upward movement of faithfulness constraints, but unmarked surface structures make little impact to the recipient language phonology. As a result, faithfulness constraints parochial to foreign sublexica tend to be equally or higher ranked than their native counterparts.

The timing of borrowing is also a contributing factor for the core-periphery structure. Naturally, the longer foreign words stay in a language, the more assimilated to the native phonology. The relation between the Sino-Japanese stratum and the Foreign/Alien strata follows this pattern, with the older Sino-Japanese vocabulary standing closer to the native lexicon, and the relatively newer 'Foreign/Alien' (=European, mainly English) lexicon in the periphery. The core-periphery relation between Foreign and Alien, seen from this point of view, is almost tautological.

In short, the core-periphery structure can be seen to result from the process of lexical assimilation rather than a structural restriction built in the grammar. As such, the phenomenon by itself does not seem to motivate a meta-constraint such as (22) that restricts the ranking of multiple faithfulness constraints.

5. Conclusion

In this paper, we have proposed a model of lexical stratification that appeals to mutiple faithfulness. Under this view, each sub-lexicon has its own unique IO-Correspondence relation and each IO-relation comes with a full set of faithfulness constraints which are ranked independently in a single ranking. This model can accurately capture the state of affairs in which the relative position of a particular faithfulness constraint with respect to some markedness constraint varies within a language depending on the types of lexical items. In support of this approach, we have presented evidence from hybrid words, which require simultaneous reference to more than one faithfulness constraints in their evaluation of well-formedness.

We have also shown that such propagation of faithfulness does not cause a learnability problem, nor does it lead to unrestricted multiplication of faithfulness constraints. A learning procedure that splits constraints only under pressure from the ambient data functions as an evaluation metric on grammars and defines multiple faithfulness as the marked case.

Finally, we have seen that it is necessary to have itemized faithfulness constraints ranked freely across faithfulness types to cover the empirical facts. Thus, a meta-constraint that regulates the ranking consistency of faithfulness constraints is not desirable in the grammar. This leads us to the idea that the core-periphery is a mere tendency in Japanese and not an inherent property of the grammar.

Notes

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1. McCawley (1968) and Itô & Mester (1995a) introduce the four sub-lexica: Yamato, Sino-Japanese, Mimetics, and Foreign. Ito and Mester (1995b) further split the Foreign stratum into two: Foreign (Assimilated Foreign), and Alien (Unassimilated Foreign). We indicate that identification of these five sub-lexica is also phonologically grounded. Some loan-words, which etymologically belong to the Foreign stratum, are treated as components of the native stratum, if they are phonologically assimilated.

2. [kappa] is originally borrowed from Portuguese *capa*, in the 16th century. This word is so well-asimilated to Japanese that we can treat them as Yamato phonologically (see section 4.2).

3. If available in the target language, hybrid words, such as those discuseed in Section 2, can provide the most direct evidence for the need to rank these split FAITH constraints independently.

4. We thank Paul Smolensky for bringing up this point.

5. The two threads of constraints are presented separately here since there is no evidence at hand to estalish the relative ranking of the two. However, they are seen to be parts of the same constraint ranking system.

6. Itô & Mester (to appear) also discuss the issue of ranking consistency between faithfulness constraints. However, their main concern is to regulate the range of possible nativization, and their conceptualization of ranking consistency is designed to ensure consistent ranking between faithfulness constraints within each stratum.

> Ranking Consistency (Itô & Mester, to appear)
> Let F and G be two types of IO-faithfulness constraints (e.g., Ident-Place and Ident-mora). There are no strata A, B such that the relative rankings of the indexed versions of F and G are inconsistent with each other. If F/A » G/A for some stratum A, then there is no stratum B such that G/B » F/B: $\neg$ AB (F/A » G/A $\cap$ G/B » F/B)

However, this meta-constraint has nothing to say about the kind of ranking consistency between itemized faithfulness constraints discussed here. Note that this restriction does not rule out the ranking in (21).

7. *DD is equivalent to the NoVoiGem constraint which demarcates Alien from other strata.

8. This observation is based on an analysis of a database which contains about 42,000 items from all the strata in Japanese. The database is based on NHK (1985) and Asano (1978).

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