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CHAPTER 2

Generative treatments of rendaku and related issues

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This paper provides an overview of how rendaku has been analyzed in the history of generative phonology, the mainstream framework of theoretical phonology. We begin with theoretical analyses of rendaku itself. We then discuss theoretical treatments of the major factors that affect its application. First, we discuss how Lyman's Law has been treated in generative phonology. Here, we also deal with the issue of why Lyman's Law ignores voicing on sonorants. Then we consider another restriction on rendaku, the Right-Branch Condition. The next section deals with other issues, including how theoretical phonology has dealt with the effect of lexical stratification on rendaku. The final section examines remaining questions and offers some concluding remarks.

2.1 General introduction

This paper provides an overview of how rendaku has been analyzed in the history of generative phonology, the mainstream framework of theoretical phonology. As we will observe, since theoretical analyses of rendaku have been developed in tandem with the development of phonological theory, rendaku has been analyzed multiple times across the theoretical frameworks dominant in particular eras. The three major theoretical frameworks discussed in this paper are: (1) the rule-based framework developed by Chomsky and Halle (1968) in their seminal book on generative phonology, *The Sound Pattern of English* (SPE); (2) Autosegmental Phonology (Goldsmith 1976) coupled with Underspecification Theory (Kiparsky 1982); and (3) Optimality Theory (OT: Prince and Smolensky 1993/2004), the currently dominant analytical framework. Although we briefly explain the fundamental

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features of these theories, readers are referred to introductory textbooks for further details.[1]

The organization of this paper is as follows. We begin with theoretical analyses of rendaku itself – how rendaku voicing has been modeled – in §2.2. We then discuss theoretical treatments of the major factors that affect its application. We discuss first, in §2.3, how Lyman's Law has been treated in generative phonology. This section also deals with the issue of why Lyman's Law ignores voicing on sonorants. §2.4 considers another restriction on rendaku, the so-called Right-Branch Condition. §2.5 deals with other issues, including how theoretical phonology has dealt with the effect of lexical stratification on rendaku. The final section examines remaining questions and offers some concluding remarks.

2.2 Theoretical treatments of rendaku

We begin with how analyses of rendaku have developed. We do this in rough chronological order, something which allows us to track the development of rendaku theory in tandem with the development of phonological theory.

2.2.1 SPE-style rules

McCawley, in the first comprehensive generative treatment of Japanese phonology in general, refers to rendaku only briefly (McCawley 1968: 86–87). Although much of his book is formulated using SPE-style phonological rewrite rules, for rendaku he suggests that he is "unable to state the environment in which the 'voicing rule' applies" (McCawley 1968: 87, n.18), where "voicing rule" refers to rendaku. He seems to have been well aware of the lexical irregularity of rendaku, saying that "[t]he relevant data are completely bewildering," and he declines to provide an explicit formulation. He refers to Martin (1952) for factors that affect rendaku but does not attempt to formalize them in the SPE framework adopted in other parts of the book.

1. Roca and Johnson (1999), as well as Gussenhoven and Jakob (2011), offer balanced introductions to both pre-OT theories and OT itself. Goldsmith (1990), Kenstowicz (1994), Roca (1994) and Spencer (1996) present comprehensive coverage of pre-OT phonological theories, including Autosegmental Phonology, Underspecification Theory, and Lexical Phonology, which will be discussed in this paper. Archangeli and Langendoen (1997), Kager (1999) and McCarthy (2002, 2008) offer accessible introductions to OT. Rendaku and Lyman's Law are covered in some of the textbooks mentioned here (Kenstowicz 1994: 493, 511–512; Roca 1994: 75–76; Spencer 1996: 60–61; Gussenhoven & Jakob 2011: 58). See also Tsujimura (2007: 50–58).

Otsu (1980: 217), using the quote from McCawley cited above as an epigraph, offers a more optimistic view and presents a more explicit formalization of rendaku. His SPE-style rule is shown in (1).

(1) C(onsonant) → [+voice] / $[_N$ X[# __ Y
where (i) X ≠ null and
(ii) Y does not contain any voiced obstruents.

Putting the rule in (1) in prose, consonants become voiced when they are preceded by a word boundary (#), which itself is preceded by an element (X) and a noun boundary ($[_N$) (see Otsu's paper for a full justification for positing this structural description). Y is included in the rule to encode the effect of Lyman's Law with the caveat (ii). The first caveat clause (i) says that this rule applies only to compounds, not word-initially. The rule in (1) is formulated as a phonological rule in SPE format, the standard formulation in phonological theorization until Autosegmental Phonology (Goldsmith 1976).

Rule (1) may, in hindsight, be considered too descriptive: it restates what is actually observed about rendaku, encoding many factors affecting rendaku application, including Lyman's Law, in a single phonological rule. This descriptive orientation was very common, however, in the early years of generative phonology (and generative linguistics in general). In later formalizations, rendaku is separated out from Lyman's Law, as we will see below.

2.2.2 Autosegmental analysis

Ito and Mester (1986) developed a comprehensive analysis of rendaku and related issues within the framework of Autosegmental Phonology (Goldsmith 1976). In this theory, each distinctive feature behaves autonomously with respect to every other. Features can exist and behave independently of segments, and when they do so, they are called "floating" features. Indeed, rendaku can be nicely treated as a floating [+voice] feature. Segmenthood in this theory is expressed by so-called "timing slots" (also known as the "skeletal tier") represented in various ways in different versions, including "x-slots" (Levin 1985), "C/V-slots" (Clements & Keyser 1983), and "root nodes" in Feature Geometry Theory (Sagey 1986; Selkirk 1990).

Within this Autosegmental Phonology framework, Ito and Mester (1986: 56–58) posit an autosegmental rule inserting a [+voice] feature linked to an x-slot, as well as a "voicing spreading rule." These rules are reproduced here as (2) and (3) below. Note that in the voicing spread rule, a dashed line represents a new association line that is inserted by the rule at issue (a convention used in Autosegmental Phonology). As a result of this new association line, the initial segment of the second morpheme becomes [+voice].

(2) Rendaku: [+voice] insertion Insert [+voice] /] _ [

(3) Voicing Spread

The [+voice] insertion rule more or less reflects the historical fact that rendaku originated as a result of reduction of the genitive marker /no/ and its reinterpretation as prenasalization in prehistoric Japanese (Vance 2015a: 400–402). The x slot to which [+voice] is associated in (2) mimics the timing slot of a compound marker (see also §2.2.4 below), a historical residue of this genitive marker. The Voicing Spread rule in (3) mimics the historical effect of prenasalization.

2.2.3 A special case of intervocalic voicing

Most theories of rendaku treat the phenomenon as a language-particular, morphophonological rule. Soon after the birth of Optimality Theory (Prince & Smolensky 1993/2004), which attempts to do away with language-particular phonological devices (rules or constraints), Ito and Mester (1996) attempted to characterize rendaku as a special case of intervocalic voicing that occurs at a morpheme boundary. Intervocalic voicing is a common phonological process observed in many languages (Kirchner 1998; Kaplan 2011), and in this regard, their proposal attempts to put rendaku on the same footing as many other languages. In their words:

> Rendaku is not a language-specific constraint. Rather, in true OT-style, it is the emergence of universal unmarkedness – in this case, of a member of the 'Avoid Effort' family of constraints ruling out changes in glottal state (here, a switch from voicing to voicelessness back to voicing). (Ito and Mester 1996: 12)

Intervocalic voicing is a phonetically motivated process (Kirchner 1998; Kaplan 2011) in the sense that it allows speakers to continue glottal vibration in VCV sequences. In other words, it allows speakers to "avoid the effort" of stopping glottal vibration by abducting the vocal folds during a consonant interval between the two segments for which glottal vibration is required. Ito and Mester's (1996) view is, in short, that rendaku is a morphophonologized version of a phonetically-motivated phonological process. The environment in which it applies may be language-particular, but the process itself is one that is commonly observed in other languages.

2.2.4 Compound marking via Realize-Morpheme

Ito and Mester (2003a: 83–85) go back to an idea that is similar to one in some of their earlier work (Ito & Mester 1986) and capitalize on the similarity between

rendaku and "compound boundary markers" or "linking morphemes" that appear in many other languages (see Labrune [ℙ11] and §2.2.2 above; for lists of featural affixes in other languages, see Akinlabi 1996, 2011). They thus assume (as in Ito and Mester 1986) that the linking morpheme consists of a [+voice] feature. In some languages such markers are segmental, as in German *fugen-s*, whereas in others they are subsegmental (i.e., featural), as in the case of rendaku. In this view, there are no substantial differences between segmental morphemes and subsegmental morphemes.

Instead of the spreading rule shown above in (3), Ito and Mester (2003a) argue that rendaku occurs when a constraint requiring phonological realization of a morpheme is effective. The particular constraint they deploy is Realize-Morpheme (Realize-M). Kurisu (2001) shows that this constraint is motivated in a wide range of different languages in that it causes many phonological changes in order to signal the presence of a morpheme.[2] This constraint requires that the [+voice] feature associated with the compound marker be phonologically realized. To the extent that Realize-M is a universal constraint, as Kurisu (2001) and others claim, rendaku can be characterized as its manifestation, without resorting to the idea that rendaku is a special case of intervocalic voicing (as in Ito & Mester 1996).

§2.3.4 below presents an Optimality Theoretic implementation of how Realize-M works, together with a constraint that is responsible for Lyman's Law. At this point, it suffices to say that the rendaku-as-compound-marker view has its incarnation in Optimality Theory, which capitalizes on the universality of phonological processes.

2.2.5 Rendaku as (lack of) devoicing

All the analyses above assume that when rendaku occurs, morpheme-initial consonants are underlyingly voiceless and get voiced when they undergo rendaku; that is, rendaku is a voicing process. Kuroda (1963, 2002) takes a different approach; he posits that the rendaku-undergoing consonants are in fact underlyingly voiced, and they get devoiced when they appear word-initially. In this view, the word-medial consonants that are voiced undergo no phonological change; instead, word-initial consonants undergo devoicing. This analysis is related to the fact that Old Japanese did not allow word-initial voiced obstruents (Unger 1975: 8; Kuroda 2002: 341; Martin 1987: 29–30; Takayama 2015: 627–628). As Kuroda himself admits (2002: 341), this idea is "radical," and, to the best of our knowledge, it has not been pursued in depth by anyone else.

2. The particular version of Realize-M that Ito and Mester (2003a) use is actually different from Kurisu's formulation, and indeed is equivalent to $\text{Max}_{\text{Subseg}}$[voice] proposed by Zoll (1996), which requires a floating [+voice] feature to be realized.

A challenge for this analysis is the fact that contemporary Japanese does have some words that begin with voiced obstruents, even some native words (e.g., *doo* どう 'how', *der-u* 出る 'leave', *damas-u* 騙す 'deceive'; Ito & Mester 2003a: 32–33). The devoicing analysis is thus obliged to deal with why these exceptional words are allowed. Of course, a similar challenge applies to the rendaku-as-a-voicing-rule analysis as well, in that not all voiceless segments are voiced in the rendaku environment. See §2.5.2 below for further discussion of this point.

2.2.6 Summary

In summary, rendaku has been treated in various ways across a number of different theoretical frameworks. One clear trend is that in earlier work (McCawley 1968; Otsu 1980; Ito & Mester 1986) rendaku was captured as a language-specific rule. After the advent of Optimality Theory (Prince & Smolensky 1993/2004), which emphasizes the role of universality in phonological theorizing, attempts have been made to characterize rendaku in terms of otherwise independently motivated phonological principles. Rendaku was thus tied to intervocalic voicing by Ito and Mester (1986) and to a morpheme realization requirement by Ito and Mester (2003a).

2.3 Theoretical expressions of Lyman's Law

As we observed above in §2.2, there have been various attempts to characterize rendaku from the viewpoint of generative phonology. Equally important in the theoretical development of rendaku analyses is the treatment of Lyman's Law – the blocking of rendaku by a voiced obstruent in the second element of a compound (Vance: §1.4). Recall from the rule above in (1) that Otsu (1980) encodes Lyman's Law in his formulation of rendaku, in clause (ii). Later theories attempt to derive Lyman's Law from independently motivated phonological principles.

We discuss several theoretical implementations of Lyman's Law first, setting aside the issue of why Lyman's Law ignores the [+voice] feature in sonorants. After reviewing several theoretical incarnations, we will come back to this general issue in §2.3.5. In §2.3.6, we will discuss how Lyman's Law interacts with another phonological process in Japanese, velar nasalization, resulting in so-called opacity.

2.3.1 Lyman's Law as an autosegmental feature deletion rule

Ito and Mester (1986: 60) first characterize Lyman's Law as an autosegmental deletion rule (their [26]), which is reproduced below as (4).

(4) Lyman's Law (Ito and Mester 1986)[3]

$$[+voice] \rightarrow \emptyset \;/\; \underset{\displaystyle x'}{\underline{\;\;}}\; [+voice]$$

This rule deletes the rendaku [+voice] feature when it is followed by another [+voice] feature.

2.3.2 OCP(voice)

Ito and Mester (1986: Appendix II) go beyond the language-particular formulation of Lyman's Law in (4), and attempt to characterize it in terms of a more general phonological mechanism. Essentially, they propose deriving Lyman's Law from a more general principle in phonology, namely, the Obligatory Contour Principle (OCP) (Leben 1973; Goldsmith 1976; McCarthy 1986), a principle that prohibits adjacent identical features and is intended to account for the cross-linguistic observation that languages avoid similar segments in proximity.[4] In many languages, indeed, similar segments are avoided by way of dissimilation (see Suzuki 1998: 152–158 for a list of examples). Ito and Mester (1986) thus propose that Lyman's Law is an instance of the OCP, more specifically, OCP(voice). The blocking of rendaku due to Lyman's Law is, in a sense, dissimilation, that is, prevention of the creation of a configuration that would otherwise be avoided by dissimilation.

3. The notation x′ ("x-prime") here means "stray" or unsyllabified. See §2.4.2 for why this formulation is useful. See also Ito and Mester (1986) for the full justification.

4. To what extent OCP(voice) is a universal principle remains debatable, however. In fact, dissimilation in voicing is cross-linguistically very rare, and usually arose historically from dissimilation of other features, such as aspiration (Ohala 1981, 1993). In the case of Japanese, it was dissimilation of a prenasalization contrast in Old Japanese (Unger 1975; Vance 2005b). Building on Ohala's work, Kawahara (2008) argues that OCP(voice) is actually neither universal nor innate and must be learned on a language-by-language basis, based on positive evidence in the learning data. Data from actual language acquisition patterns would bear on this debate in important ways. Another paper in this volume (Nakazawa et al. ℙ5) reports a study of L2 acquisition of rendaku.

The OCP was first proposed for tonal features by Leben (1973); hence the word *contour* in its name. The OCP is extended to non-tonal segmental features in several subsequent works (Ito & Mester 1986; McCarthy 1986; Mester 1986). Ito and Mester's (1986) work was instrumental in the development of Autosegmental Phonology in showing that [+voice] can behave as a floating, autosegemental feature, and that [+voice] can be subject to a phonological principle like the OCP. This is a showcase example of a recurrent theme in Ito and Mester's work: they deploy independently proposed phonological mechanisms to apparently language-specific processes like rendaku. See §2.5.3 below for more on this general point.

OCP(voice) was also tied to the observation that native morphemes rarely or never contain two voiced obstruents (*huda* 'amulet', *buta* 'pig', but no **buda*: Ito & Mester 2003a: 35–36; Suzuki 1998: 12), and was thus proposed to function as a Morpheme Structure Condition (MSC: Stanley 1967) on the Japanese lexicon (Ito & Mester 1986: 67–68). In this view, OCP(voice) applies both to underlying representations and to derivational processes (McCarthy 1986). See §2.5.1.2 below for further implications of this observation about the dual nature of Lyman's Law.

2.3.3 Local conjunction

Alderete (1997) argues that dissimilation targets not only segmental features but also structures which are not commonly expressed with distinctive features, such as long vowels, geminates, and complex segments. For example, long vowels and geminates are usually not expressed in terms of [+long] (despite Chomsky & Halle 1968), but instead a segment linked to two timing slots (see the references cited in §2.2.2). Alderete (1997) proposes that crucial to dissimilation is that what gets simplified is a structure that is marked – a notion that became central in Optimality Theory (Prince & Smolensky 1993/2004).

To formalize this idea, Alderete (1997) argues that dissimilative effects should be derived via local self-conjunction of a markedness constraint $\{*M\&*M\}_D$, using the theory of local conjunction (Smolensky 1993, 1995, 1997).[5] A self-conjoined constraint is violated for each domain containing two instances of a structure that is penalized by *M. According to this theory, Lyman's Law is $\{*[+voice,-son]\&*[+voice,-son]\}_{Stem}$ (Alderete 1997: 20–23). This local-conjunction-based analysis of Lyman's Law is further developed by Ito and Mester (1996, 2003a).

2.3.4 Interlude: A fully OT analysis

By way of a summary of (some of) the discussion so far, a full OT-analysis developed in a series of studies by Alderete (1997) and Ito and Mester (1996, 2003a,

5. The general idea of local conjunction was first proposed and developed by Paul Smolensky as a means to explicate the internal structure of the universal constraint set CON in Universal Grammar, which is assumed in Optimality Theory (Smolensky 1993, 1995, 1997). It was later extended as a means of creating a new constraint based on two independently motivated constraints (Fukazawa & Lombardi 2003). See McCarthy (2002: 43) for further discussion and references on local conjunction. Self-conjunction was already being pursued in original work by Smolensky (1995: 4). Zamma and Kikuchi (2015) argue that, compared to normal conjunction of constraints, self-conjunction may require additional stipulations concerning constraint violation computation.

2008) is reproduced in this section. Their analyses make use of the constraint set shown in (5), where D stands for voiced obstruents in general.

(5) Constraint Definitions

a.	No-D^2_m:	No two voiced obstruents within a morpheme.
b.	Realize-M:	The input rendaku morpheme [+voice] should have a phonological exponent.
c.	Ident(voi):	A segment must have the same specification for [voice] in inputs and outputs.
d.	No-D:	No voiced obstruents.

The first constraint (5a) is, as reviewed above, a theoretical expression of Lyman's Law. Recall that Ito and Mester (2003a) posit a [+voice] feature as a compound marker, and constraint (5b) requires this morpheme to be realized in the output. (5c) is a faithfulness constraint which militates against featural change between the input and the output. Constraint (5d) is not active (in any obvious way) in contemporary Japanese, but it is posited because of the cross-linguistic observation that voiced obstruents are marked (Hayes & Steriade 2004; Kawahara 2006).

The constraint ranking, given in (6), is adopted from Ito and Mester (2003a:96; their [38]).

(6) OT Constraint Ranking

No-D^2_m
| "Lyman's Law blocks rendaku."
Realize-M
| "Rendaku changes underlying voicing specification."
Ident(voi)
| "Obstruent voicing is contrastive."
No-D

These analyses are illustrated in the following tableaux (their [39] with slight modifications). Portions that show crucial ranking arguments are outlined in bold. R represents a linking [+voice] morpheme.

(7) a. No-D^2_M >> Realize-M blocks rendaku

/naga+R+sode/	No-D^2_m	Realize-M	Ident(voi)	No-D
naga zode	*!		*	***
☞ naga sode		*		**

b. Realize-M >> Ident(voi) causes rendaku

/natu+R+sora/	No-D^2_m	Realize-M	Ident(voi)	No-D
☞ natu zora			*	*
natu sora		*!		

c. IDENT(VOI) >> NO-D protects voicing contrasts in other environments

/aza/	NO-D^2_m	REALIZE-M	IDENT(VOI)	NO-D
☞ aza				*
asa			*!	

As shown in tableau (7a), the ranking NO-D^2_M >> REALIZE-M blocks rendaku, as per Lyman's Law. When Lyman's Law is not relevant, rendaku applies, as in (7b), in response to the pressure of REALIZE-M. The ranking IDENT(VOI) >> NO-D guarantees that voicing is contrastive in non-rendaku environments in Japanese phonology.

2.3.5 Why sonorant voicing is ignored by Lyman's Law

One important issue that has been repeatedly discussed in the theoretical literature is why sonorant voicing is ignored in the calculation of Lyman's Law in Japanese, as assumed in tableau (7b) above. It is only voicing on obstruents that blocks rendaku, with voicing on sonorants apparently ignored in this regard. If it were not, then rendaku would be blocked even by a vowel and would not occur in any environment.

2.3.5.1 *Underspecification*

To answer the question of why sonorant voicing is phonologically inert, Ito and Mester (1986) built on the then-dominant theory of underspecification (Kiparsky 1982; Archangeli 1988), in which redundant or predictable feature specifications are underspecified in (some phases of) phonological derivation.[6] Since [voice] is not contrastive on sonorants in Japanese (and many other languages), sonorant consonants are not specified for [voice], and hence Lyman's Law only looks at [voice] on obstruents.

6. There are/were two major versions of Underspecification Theory: contrastive underspecification, in which only non-contrastive features are underspecified (Steriade 1987), and radical underspecification, in which non-contrastive features as well as default/unmarked features are underspecified (Kiparsky 1982; Archangeli 1988; see Steriade 1995:124–147 for an overview). Here it suffices to say that sonorants were proposed to be underspecified for voicing specifications in Japanese and other languages (again, see Steriade 1995:115–116). Ito and Mester (1986) use radical underspecification, whereas Mester and Ito (1989) use contrastive underspecification. Since this debate is not crucial to our current understanding of rendaku and Lyman's Law, their arguments are not reproduced here. Mester and Ito (1989:259–267) provide an accessible summary of the comparison between the two different versions of Underspecification Theory.

We note in passing that this phonological "inertness" of voicing on sonorants is not uncommon cross-linguistically. A famous case is voicing of sonorants in Russian, which is phonologically inert in voicing assimilation (e.g., Hayes 1984). The underspecification of [voice] on sonorants therefore seems to be motivated on cross-linguistic grounds.

2.3.5.2 *Privative feature theory*

Mester and Ito (1989: 277–279), on the other hand, argue that [voice] is a non-binary, privative feature that is specified only for obstruents throughout the phonological derivation (for a similar view see also Steriade 1987; 1995: 147–157; Cho 1990; Lombardi 1991). In this view, there are no [–voice] features. Voiceless obstruents are therefore unspecified for voicing, instead of having a [–voice] feature.[7] Since sonorants do not bear a [voice] feature at all, Lyman's Law can look only at obstruent voicing.

2.3.5.3 *Obstruent voicing and sonorant voicing as different features*

Both of the explanations proposed by Ito and Mester (1986) and Mester and Ito (1989) assume that voicing in sonorants in Japanese is phonologically inert. Rice (1993), on the other hand, argues that Japanese sonorants do need to bear a [+voice] feature, because Japanese nasals trigger post-nasal voicing in past tense formation, as in /sin-**t**a/ → [ɕin-**d**a] 死んだ 'died' (see also Ito, Mester and Padgett 1995 for discussion of this apparent paradox). Rice (1993) therefore proposes that sonorant voicing and obstruent voicing are different features.

The general idea behind this theory is that, whereas voicing in sonorants occurs spontaneously (Chomsky and Halle 1968), voicing in obstruents requires some articulatory maneuvering in order to deal with the aerodynamic challenge posed (Ohala 1983; Hayes & Steriade 2004; Kawahara 2006). Thus, some theories of voicing posit two voicing features: [S(pontaneous)V(oicing)] for sonorants and [L(aryngeal)V(oicing)] for obstruents (Rice & Avery 1989; Avery & Idsardi 2001). Rice (1993) argues that it is [LV] that Lyman's Law targets, whereas post-nasal voicing occurs as an assimilation process involving [SV].

2.3.5.4 *Direct encoding in constraint formulation*

With the shift from rule-based to constraint-based phonology in Optimality Theory (Prince & Smolensky 1993/2004), a greater explanatory burden came to

7. Voiceless sonorants are treated as aspirated sonorants (Mester & Ito 1989: 279; Lombardi 1991: ch.4). Apparent assimilation in terms of voicelessness in obstruent clusters is accounted for by the combination of neutralization and spreading (Lombardi 1991: ch.2).

be placed on constraint formulation than on representational assumptions. To formulate Lyman's Law within this framework, Kawahara (2006), instead of relying on any of the representational assumptions reviewed above, or on local conjunction, simply formulates Lyman's Law as a rendition of the OCP against two voiced obstruents, namely OCP([+voice, −son]).[8] See Alderete (1997) and Ito and Mester (1996, 2003a) for related ideas based on local conjunction.

2.3.5.5 *Lyman's Law as orthotactics*

Backing up from all the theoretical analyses described above, from a non-linguistic point of view there may be a very straightforward characterization of Lyman's Law in terms of Japanese *kana* orthography. As noted in the introduction to this volume (Vance: §1.3), Japanese orthography marks voicing on obstruents, but not on sonorants, with a diacritic called *dakuten* (as in だ for *da* vs. た for *ta*). Lyman's Law can therefore be understood as a prohibition against two *dakuten* diacritics.

Fukazawa et al. (2013) and Kawahara (2015) entertain this hypothesis, independent of rendaku. Fukazawa et al. (2013) analyze the patterns of geminate devoicing in loanwords. Geminates devoice (optionally) when they co-occur with a voiced obstruent, as in ***d*oggu** → ***d*okku** 'dog' (Nishimura 2003), and this devoicing can be understood as an effect of OCP(voice) (whose effect manifests itself as Lyman's Law on rendaku). Moreover, /p/ seems to cause devoicing of geminates as well, as in ***p*iramid*d*o** → ***p*iramit*t*o** 'pyramid'. This observation raises the possibility that the devoicing occurs because moras beginning with /p/ are also written with a diacritic mark called *han-dakuten* 半濁点, as in ぱ for *pa* (cf. は for *ha*). It is then very straightforward to say that Lyman's Law prohibits two diacritics within a morpheme.[9]

This view treats Lyman's Law as orthotactic, that is, a restriction on letter configurations (Bailey and Hahn 2001) rather than on sound configurations: Lyman's Law is OCP(diacritic) rather than OCP(voice). This view naturally explains why sonorant voicing is ignored in the computation of Lyman's Law as well, because sonorant voicing is not marked by *dakuten* in Japanese orthography. Note also that rendaku is more transparent when viewed from an orthographic point of view than from a phonetic point of view (Vance: §1.2). This orthotactic theory of Lyman's Law

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8. Kawahara (2006) does not discuss rendaku *per se* but analyzes the devoicing of geminates due to OCP(voice) that is found in loanwords (Nishimura 2003, 2006). See §2.3.5.5 below for more discussion of this devoicing pattern.

9. Interesting support for this hypothesis, suggested by Mark Irwin (p.c.), comes from the fact that *gubbai* 'good-bye' does not become *guppai*, despite the fact that *gubbai* contains a voiced geminate co-occurring with a voiced obstruent.

makes a testable prediction that those children who have not learned the Japanese orthographic system will not show the effects of Lyman's Law.

2.3.5.6 *Summary*

One prominent theme in the theorization of Lyman's Law has been to address why sonorant voicing is systematically ignored. Various theoretical proposals, proposed on independent grounds, have been deployed: underspecification, privative features, and an obstruent-specific voicing feature. In addition, we argued here that a less theory-oriented, orthography-based explanation should also be given some serious consideration.

2.3.6 Lyman's Law and velar nasalization: Derivational opacity

We conclude the discussion of Lyman's Law by addressing how it interacts with another phonological process in Japanese. The blocking of rendaku by Lyman's Law is rendered opaque by intervocalic nasalization of [g] (Ito & Mester 2003b). In some dialects of Japanese, [g] nasalizes to [ŋ] (Ito & Mester 1997a; Vance 1987). This segment [ŋ] is not a voiced obstruent, but it still blocks rendaku, as in [sakatoŋe] 'reverse thorn'.

This interaction is opaque in the sense that, although its surface realization is a sonorant, [ŋ] acts as if it is a voiced obstruent in that it triggers Lyman's Law. In other words, blocking of rendaku due to Lyman's Law overapplies and rendaku underapplies, despite the application of velar nasalization.[10] This situation is opaque, because it is not clear from the surface representations alone why Lyman's Law fails to apply.

In a derivational theory of phonology, if rendaku (along with its blocking) precedes velar nasalization, this opacity is explained. Illustrative derivations are shown in (8).

(8)

Correct Ordering		Incorrect Ordering	
UR	/saka+toge/	UR	/saka+toge/
rendaku	blocked by LL	velar nasalization	/saka+toŋe/
velar nasalization	/saka+toŋe/	rendaku	/saka+doŋe/
SR	[saka+toŋe]	SR	*[saka+doŋe]

10. See Benua (1997) for the two terms (overapplication and underapplication), as they relate to phonological opacity. The two terms are originally due to Wilbur (1973) as they apply to reduplication, and became widely used again because of influential work by McCarthy & Prince (1995). The classical reference on phonological opacity is Kiparsky (1973). For further references on rule ordering, opacity, and the combination of Lexical Phonology with OT, see McCarthy (2002: 62,184,185).

This rule order (rendaku > velar nasalization) is also supported by the fact that [g], created by rendaku, is fed into the velar nasalization rule and becomes [ŋ], as in *nise-gane* [nise+ŋane] 偽金 'fake money'; cf. *kane* 'money' (see Ito & Mester 1997a).

Ito and Mester (2003b) develop an OT equivalent of this derivational analysis, incorporating the distinction between Lexical Phonology and post-Lexical Phonology (Kiparsky 1982) back into Optimality Theory. See Ito and Mester (1997b) for an analysis based on Sympathy Theory (McCarthy 1999) and Ito and Mester (2003b) for criticisms of the Sympathy-based analysis.

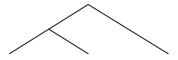
2.4 The Right-Branch Condition

In addition to rendaku itself and to Lyman's Law, another aspect of rendaku that has received theoretical attention is the Right-Branch Condition (Otsu 1980: 219). This condition is restated in (9).[11]

(9) Rendaku applies only when a potential rendaku segment is a right branch constituent.

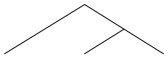
The Right-Branch Condition is intended to account for the difference between pairs like the following, attributed to Susumu Kuno by Otsu (1980: 223), in which elements on a right branch of a compound get voiced, as in (10a), but those on a left branch do not, as in (10b).

(10) a.



nise + ***d****anuki* + *ziru*
[['fake'+'raccoon']+'soup']

b.



nise + ***t****anuki* + *ziru*
['fake'+['raccoon'+'soup']]

2.4.1 C-command requirement

Otsu (1980: 220–221) argues that an element that c-commands N1 (=X in (1)) undergoes rendaku, given the definition of c-command in (11).

11. Whether the Right-Branch Condition is psychologically real or not has been debated in various experimental studies (Kozman 1998; Ihara & Murata 2006; Kumagai 2014). See also Vance (1980a) and Kubozono (2005) for criticisms of the Right-Branch Condition. See Kawahara (§3.3.3) for details of this debate. The analyses reviewed in this section assume that the Right-Branch Condition is true and psychologically real.

(11) Definition of c-command
Node A c-commands node B if neither A nor B dominates the other and the first branching node which dominates A dominates B.
(adopted from Otsu 1980: 220; based on Reinhart 1976: 32)

More plainly put:

(12) Go one node up higher in the tree and go down from there (but do not come back).

In (10a), *tanuki* 'raccoon' c-commands *nise* 'fake', so it undergoes rendaku. At the next morphological concatenation, *siru* 'soup' c-commands *nise+danuki* and thus also undergoes rendaku. In (10b), on the other hand, *siru* c-commands *tanuki*, so it undergoes rendaku, but *tanuki* does not c-command *nise* and hence does not undergo rendaku. If this argument holds, then it shows that the same principle – c-command – may play an important role in syntax, semantics, and phonology.

2.4.2 A cyclic analysis

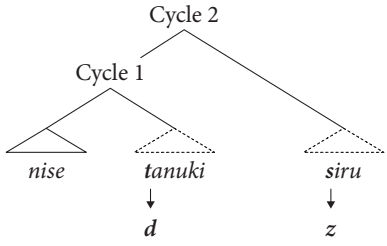
Ito and Mester (1986) expressed a concern about the theoretical expression of the Right-Branch Condition as formulated in (9). In many phonological theories, internal morphological structure is erased after each concatenation or cycle. This is known as Bracket Erasure (Chomsky & Halle 1968: 20; Pesetsky 1979: 44; Kiparsky 1982: 140). A typical formulation is given below in (13) (taken from Pesetsky 1979: 44), and this principle is assumed in many theories of phonology.

(13) Bracket Erasure
Given the nested constituents $[_n \ldots [_{n-1} \ldots \ldots _{n-1}] \ldots _n]$, the last rule of the cycle n is: erase brackets n−1.

Assuming the bracket erasure convention, information such as "right branch" should not be visible to phonological operations. Moreover, the inclusion of a syntactic principle like c-command in a phonological rule was of some concern.

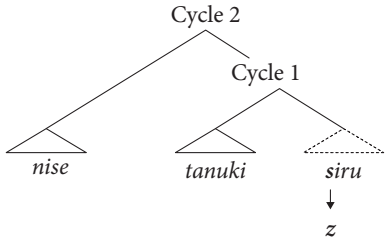
Ito and Mester (1986) instead proposed that the cyclic concatenation of morphemes naturally explains the effect of the Right-Branch Condition. Consider (14), taken from Ito and Mester (1986: 63; their [30]).

(14) a.



'[fake raccoon] soup'

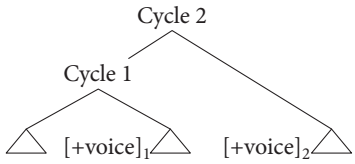
b.



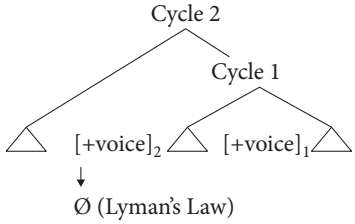
'fake [raccoon soup]'

In the right-branching compound shown in (14b), *tanuki* and *siru* are combined first at Cycle 1, with rendaku occurring on *siru*. In Cycle 2, *nise* is combined with *tanuki+ziru*, and here rendaku is blocked because the second element already contains a [+voice] feature in *z* [dz]. In the left-branching compound shown in (14a), in Cycle 1 *nise* and *tanuki* are concatenated first, with rendaku applying and yielding *nise+danuki*. In Cycle 2, *nise+danuki* is combined with *siru*, and rendaku applies, since *siru* does not contain [+voice] feature. Ito and Mester's (1986) more general idea is illustrated in (15) (their [31]).

(15) a.



b.



The gist of the idea is that in a right-branching compound rendaku is blocked in the second element because [+voice] is already inserted in Cycle 1 in E2 (15a). Importantly, it should not matter whether the [+voice] feature is segmentally realized or not, since rendaku needs to be blocked in examples like [*nuri*+[*hasi*+*ire*]] ['lacquered'+['chopstick'+'container']], where [+voice] in the third element is not realized. A floating $[+voice]_1$ should suffice to trigger Lyman's Law and delete $[+voice]_2$.

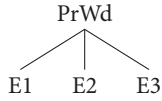
Indeed, Otsu (1980: 218–219) entertains this cyclic analysis but ultimately rejects it, perhaps because in 1980 the notion of a floating feature was not common. Without deploying floating features in examples like [*nuri*+[*hasi*+*ire*]], rendaku on *hasi* cannot be blocked because *ire* is not realize with a [+voice] feature.

Autosegmental Phonology allowed a feature to be active without being realized segmentally, and made a cyclic analysis of the Right-Branch Condition possible.

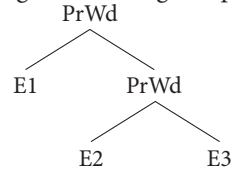
2.4.3 Positional faithfulness at a PrWd edge

In Optimality Theory it is common to do away with cyclic derivations, either phonological or morphological (Benua 1997). In this spirit, Ito and Mester (2003a) proposed a non-derivational analysis of the Right-Branch Condition. In particular, they proposed different prosodic structures for right-branching compounds and left-branching compounds, as shown in (16) (Ito and Mester 2003a: 207–208). The structure in (16b) is based on the independent observation that right-branching compounds are often divided into two accentual phrases (Kubozono 1993).[12]

(16) a. left-branching compound



b. right-branching compound



Building on the two different representations in (16), Ito and Mester (2003a) argue that E2 in (b) is located in initial position in a Prosodic Word, and that it is protected by a special positional faithfulness constraint that protects the voicing value of segments that appear in this position (Beckman 1998). This analysis is illustrated in the tableaux below (Ito & Mester 2003a: 207–208).

(17) a. Rendaku applies in a left-branching compound

//nise+R+tanuki/+R+siru/	IDENT(VOI)$_{PR\_INI}$	REALIZE-M	IDENT(VOI)
☞ {$_{PrWd}$ nise+danuki+ziru}			**
{$_{PrWd}$ nise+tanuki+ziru}		*!	

b. Rendaku is blocked in a right-branching compound

/nise+R+/tanuki+R+shiru//	IDENT(VOI)$_{PR\_INI}$	REALIZE-M	IDENT(VOI)
{$_{PrWd}$ nise{$_{PrWd}$danuki+ziru}}	*!		**
☞ {$_{PrWd}$ nise{$_{PrWd}$tanuki+ziru}}		*	

12. In more recent work by Ito and Mester (e.g. 2007), left-branching compounds also receive a recursive parsing as well, but in a way that E2 does not appear Prosodic-Word-initially: {$_{PrWd}${$_{PrWd}$ E1 E2} E3}. This detail does not affect the discussion that follows here.

2.5 Other issues and general discussion

Before concluding this paper, we wish to examine some other issues related to rendaku. Some of these have been extensively discussed in the literature, others less so.

2.5.1 Other issues

2.5.1.1 *Rendaku and lexical stratification in Japanese*

One issue that did not come up in the discussion above, but which is nevertheless important, is the fact that rendaku applies mostly to native but not to foreign words. This characteristic of rendaku was taken as evidence that the Japanese phonological lexicon is stratified according to quasi-etymological features, most famously in the core-periphery model developed by Ito and Mester (1995a, 1995b, 1999, 2003a, 2008) (for criticisms of this view, see Rice 1997; Kuroda 2002; Tateishi 2003). Ito and Mester model the blocking of rendaku in loanword items by positing faithfulness constraints that are specific to recent loanwords (here referred to as "foreign items") and to Sino-Japanese items. Their analyses are illustrated below (adopted from Ito and Mester 2003a: 148 with slight modifications).[13]

(18) a. IDENT(VOI)$_F$ >> REALIZE-M blocks rendaku in foreign words

/kankoo+R+takusii$_F$/	IDENT(VOI)$_F$	IDENT(VOI)$_{SJ}$	REALIZE-M	IDENT(VOI)
kankoo+dakusii	*!			*
☞ kankoo+takusii			*	

b. IDENT(VOI)$_{SJ}$ >> REALIZE-M blocks rendaku in Sino-Japanese words

/kari+R+keiyaku$_{SJ}$/	IDENT(VOI)$_F$	IDENT(VOI)$_{SJ}$	REALIZE-M	IDENT(VOI)
kari+geiyaku		*!		*
☞ kari+keiyaku			*	

13. Some Sino-Japanese nouns do undergo rendaku (Takayama 2005), and these can be treated as nativized and hence subject to the general IDENT(VOI) constraint. Alternatively, it could be that these words form a new quasi-etymological category ("Common Sino Japanese"), and that they are subject to IDENT(VOI)$_{CSJ}$, which is ranked lower than REALIZE-M (Ito & Mester 2003a: 150–151). Mark Irwin (p.c.) pointed out that the problem with the latter theory is that some SJ items which undergo rendaku are not particularly common at all: (e.g., *hyoohoo* 兵法 'strategy; tactics').

c. Realize-M >> Ident(voi) triggers rendaku in native words

/kisetu+R+tayori/	Ident(voi)$_F$	Ident(voi)$_{SJ}$	Realize-M	Ident(voi)
☞ kisetu+dayori				*
kisetu+tayori			*!	

This analysis, going beyond the specific case of Japanese, bears on the general theory of how to treat exceptions. Within the context of Optimality Theory, there is a general debate about whether we should posit lexical-specific faithfulness constraints (Ito & Mester 1995b, 1999, 2003a, 2008), lexical-specific markedness constraints (Ota 2004; Pater 2000, 2010; Flack 2007), or even both (Inkelas & Zoll 2005, 2007). See Ito & Mester (2008: 92–94) for recent discussion of this general debate from the perspective of Japanese phonology.[14]

2.5.1.2 *Lyman's Law, conspiracy, and the duplication problem*

Another important aspect of rendaku, or more strictly speaking Lyman's Law, which has contributed to the development of phonological theory is its dual – or even tripartite – nature. Recall from §2.3.2 that Lyman's Law – or more technically, OCP(voice) – functions as a morpheme structure condition in the sense that there are very few native Japanese morphemes that contain two voiced obstruents. OCP(voice) also blocks rendaku, thereby avoiding the creation of an output containing two voiced obstruents. OCP(voice) thus seems to apply both at the level of the lexicon and at the output of phonological processes.

This dual nature of constraints was pointed out to be theoretically redundant (Ito & Mester 1986: 67–68) – a problem more generally known as the duplication problem, where linguistic generalizations need to be stated twice, both at the underlying level and the surface level (Kenstowicz & Kisseberth 1977). Optimality Theory (Prince & Smolensky 1993/2004) overcomes this problem by eliminating the conditions on underlying representations – the thesis known as the Richness of the Base (see McCarthy 2002: 70–74,178). In this sense, the duplication problem as instantiated in Japanese, that is, that Lyman's Law seems to hold both on underlying representations as well as on the output of rendaku, may have had an influence on the birth of Optimality Theory.

14. Ito and Mester (1995a) deploy reranking instead of indexation of constraints. For the general debate about the controversy between reranking and indexation of constraints to account for lexically-conditioned phonological patterns, see Antilla (2002), Inkelas & Zoll (2005, 2007), Inkelas (2011), Ito & Mester (1999, 2008), Pater (2010) and Zamma (2012), among others.

2.5.1.3 *Lyman's Law and the dual nature of phonological constraints*

Furthermore, in more recent years, it has been pointed out that OCP(voice) triggers devoicing of geminates in recent loanwords (Nishimura 2003, 2006; see §2.3.5.5). Therefore, not only does OCP(voice) block a phonological process (rendaku), it also triggers a phonological process (devoicing) (Kawahara 2012). This kind of situation is referred to as a conspiracy in phonological theory (Kisseberth 1970a), and conspiracies played an important role in promoting the phonological constraints, since rule-based theories cannot account for such cases in a unified manner (McCarthy 2002: 62–63).[15]

In short, OCP(voice) instantiates both a duplication problem and a conspiracy, because it has three aspects: it restricts underlying forms, it blocks rendaku, and it triggers geminate devoicing in loanwords.

2.5.2 Remaining questions about theories of rendaku

There are a number of issues related to rendaku which have not been fully discussed in the literature up to now but nevertheless merit further discussion in the future.

One issue is the question of whether rendaku is phonological or not. In the work reviewed above, rendaku is assumed to be phonological and hence assumed to bear on phonological theories in general. However, this point is rarely discussed explicitly.[16] This issue is not a matter of all or nothing; it seems to us unpromising to say that rendaku is entirely phonological (with no lexical influences) or entirely lexical (without any phonological characteristics). A complete theory of rendaku, then, should delineate lexical and phonological aspects and offer proper accounts of both.

Another remaining issue is how to deal with the variation within rendaku. Rendaku involves lexical variation in three senses. First, there is variation among different lexical items in such a way that some items undergo rendaku, and some others do not (i.e., how often a particular element undergoes rendaku varies across lexical items). Second, there is sometimes inter-speaker variation as to whether some items undergo rendaku or not. Third, even within a single speaker, there can

15 See also Kawahara & Sano (2014b) for another similar case of rendaku-related conspiracy, in which the Identity Avoidance constraint both triggers and blocks rendaku (Kawahara: §3.3.2).

16. However, see Vance (2014b), Kawahara (2015), and Kawahara (§3.2) for recent explicit discussions of this issue. See de Lacy (2009, 2014) and Kawahara (2011b) for a recent summary of concerns about the quality of phonological data.

be variation as to whether rendaku applies or not.[17] In recent years, theories of phonological variation have developed to account for these kinds of lexical variation (see Coetzee & Pater 2011 and Coetzee & Kawahara 2013 for recent reviews), but they have not been applied to the study of rendaku. The previous theories reviewed in this paper have dealt with regular exceptions, most notably Lyman's Law, but they have not dealt with item-specific behavior. This is one aspect that we hope further theories of rendaku will attempt to model.

This last issue is particularly important because, for those linguists who do not know Japanese, rendaku may be mistakenly taken as a regular, exceptionless process. The textbook examples mentioned above in §2.1, for example, do not refer to the lexical irregularity of rendaku (Kenstowicz 1994: 493,511–512; Roca 1994: 75–76; Spencer 1996: 60–61; Gussenhoven & Jakob 2011: 58).[18] Anecdotally, the first author was told by a non-Japanese linguist that a student of his once asked why *aka+gami* 赤髪 'red hair' undergoes rendaku, whereas *kuro+kami* 黒髪 'black hair' does not. The non-Japanese linguist, who must have been misled by oversimplified descriptions of rendaku, responded that he had no answer to the question and that he believed rendaku was a regular, exceptionless process. It is therefore important that theoretical treatments of rendaku address both its regular and irregular aspects.

2.5.3 Concluding remarks

As discussed throughout this paper, rendaku has been analyzed within various theoretical frameworks, and analyses of rendaku have been developed in tandem with the development of phonological theory. We hope to have shown that the

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17. Theoretically speaking, the first issue is about lexical exceptionality (Kisseberth 1970b; Pater 2010), which has been treated with mechanisms such as minor rules (Chomsky and Halle 1968) or constraint indexation (Pater 2000, 2010). The second issue is not often addressed in theoretical phonology, but is dealt with extensively in the sociolinguistics literature. The third issue is about optionality of phonological processes, and various models have been proposed to account for optional phonological processes in Optimality Theory (e.g., Antilla & Cho 1998; Zuraw 2000; Boersma & Hayes 2001; Antilla 2002; Coetzee & Pater 2011; Zamma 2012).

18. This is not to say that Ito and Mester did not acknowledge such lexical irregularity of rendaku. For example, they discuss minimal pairs like *kata+kana* and *hira+gana* (the names of the two parallel quasi-syllabaries used in the Japanese writing system). They do note, however, that "it is easy to overestimate the degree of irregularity and arbitrariness of the process … While the contrast is certainly noteworthy, it is at least equally significant that every other compound with /kana/ in section position … show uniform voicing" (Ito & Mester 2003a: 149). Ultimately, it is important to look at both regular and irregular aspects to achieve a full theoretical model of rendaku (Vance 2014b; Kawahara 2015).

direction of rendaku's contribution was not at all one way: not only have contemporary theories been applied to analyses of rendaku, but analyses of rendaku themselves, most notably those by Ito and Mester, contributed to theoretical debates at the time, ultimately leading to development in phonological theory.

The recurrent theme in Ito and Mester's work, as we see it, is that they try to understand rendaku, especially its "bewildering," seemingly language-specific aspects, by deploying general phonological devices independently proposed elsewhere. This is why their work is so well-known and influential in the field of general phonology, even among those who are not interested in Japanese phonology *per se*.

Before concluding this paper, we would like to make one final remark. We have limited our discussion to those matters which have had major impact on phonological theory (in Japanese and beyond), but our overview is in no way comprehensive. Other generative treatments of various aspects of rendaku include, though are not limited to, Suzuki (1997, 1998), Haraguchi (2001), Rosen (2003), Rice (2005), Kurisu (2007), and Nishimura (2007, 2013, 2014) (see the annotated bibliography in this volume for more).

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