

Rendaku: Its domain and linguistic conditions

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[Summary]

This article reviews past works on *rendaku* with main focus on its domain and linguistic conditions. It begins with Fukuda & Fukuda's data on specific language impairment, which suggest that *rendaku* voicing falls into two kinds, lexical(ized) and rule-governed. It then discusses syntactic and phonological conditions on the productive process of *rendaku* voicing. One phonological condition concerns the so-called Lyman's Law, a typical case of dissimilation. It will be demonstrated that this constraint operates in a wider domain than is usually assumed, at least in a certain type of compound nouns. A second phonological condition is a mora condition by which *rendaku* fails to apply in compound nouns with a certain phonological length. As a typical case of syntactic constraint on *rendaku*, we will discuss the so-called branching condition that prevents the voicing process from applying to compounds with a certain syntactic configuration. The most important point is that these conditions represent more or less general constraints that apply not only to *rendaku* but also to other independent processes in Japanese and other languages. This paper summarizes basic facts about the domain and conditions of *rendaku* voicing as well as a number of questions that remain unsolved for future work.

1. Two kinds of *rendaku* voicing

One of the most fundamental questions regarding Japanese *rendaku*, or sequential voicing, concerns its linguistic nature: is it a productive process or is it no more than a property of a specific lexical entry? The first hypothesis pays attention to the productivity of *rendaku* and defines it as a productive phonological (or morphophonological) process of voicing that permits lexical exceptions (Otsu 1980, Itô and Mester 1986, forthcoming; cf. Kuroda 2002). On the other hand, the second hypothesis focuses on the extremely large number of lexical exceptions and attributes *rendaku* to a lexical property of a certain word (Ohno 2000).

Let us consider the pair *hiragana* and *katakana* (the two types of *kana* letters), for example. Etymologically, these words are made up of two morphemes, /hira+kana/ and /kata+ kana/. In the course of the history, the first word underwent voicing as in (1), while the second did not.

(1) hira + kana → hiragana

According to the first hypothesis mentioned above, this historical process of voicing remains a productive process in modern Japanese by which /hira+kana/ turns into /hiragana/. The word *katakana* is regarded as an exception to this synchronic process. The second hypothesis, in contrast, posits *hiragana* and *katakana* as underlyingly /hiragana/ and /katakana/, respectively: the presence of voicing in the first word and the lack of voicing in the second are lexical properties of the respective words.

These two hypotheses are difficult to assess because *rendaku* is extremely productive in modern Japanese, on the one hand, and, on the other, it admits an extremely large number of exceptions whose

exceptionality is difficult to explain. One important study that has tackled this difficult question is the experimental work by Shinji and Suzy Fukuda (Fukuda & Fukuda 1999). They looked at children with a language disorder called ‘specific language impairment’ (henceforth ‘SLI’ for short). People with SLI are linguistically normal in every respect except that they cannot apply productive grammatical rules to morphological/syntactic strings. For example, native English speakers with SLI are unable to produce plural forms for countable nouns (2a) and to put an ending /s/ to a verb to mark a third person, singular form (2b).

- (2) a. I have three apple.
b. Mary walk in the yard.

Fukuda & Fukuda (1999) examined how native Japanese speakers with the same language impairment produce Japanese utterances. Specifically, they looked at the way their eight- to twelve-year-old subjects produced voicing in compound nouns. If the subjects should fail to produce voicing in words like /hiragana/, then it would mean that voicing is a productive rule in modern Japanese, hence supporting the first hypothesis mentioned above. If, on the other hand, the subjects should produce voicing in words like /hiragana/ just as normal native speakers do, then it would suggest that the phonological form with voicing is a lexical form of the word, namely, that voicing has been lexicalized and is not produced by rule in the synchronic grammar. What Fukuda & Fukuda (1999) found out is something that compromises the two predictions. On the one hand, their subjects showed voicing in some basic compound nouns like *nagagutu* ‘long + shoes; boots’, suggesting that voicing in these words is part of their underlying representation. On the other hand, they also showed lack of voicing in non-frequent and novel compounds such as those in (3a), which were pronounced with voicing by normal native speakers of the same age group as shown in (3b). This latter result reveals a contrast between normal speakers and speakers with SLI, with the first but not the latter group of speakers being able to produce voicing in non-frequent and novel compounds. This suggests that voicing in non-frequent and novel compounds should be attributed to a productive rule and, hence, that there exists a productive process of voicing in normal speakers’ grammars.

- (3) a. kotoba + tukai → kotoba-tukai ‘language use’
kotoba + hon → kotoba-hon ‘language book’
b. kotoba + tukai → kotoba-dzukai ‘language use’
kotoba + hon → kotoba-bon ‘language book’

Fukuda & Fukuda’s experimental data are interesting in revealing that some instances of *rendaku* voicing are lexicalized while others are due to a productive rule. Native speakers of Japanese deal with the first type of voicing by memorizing the form with voicing as a lexical entry. In contrast, they deal with the second type of voicing by acquiring a voicing rule, or *rendaku* rule, and applying it to unfamiliar and novel compounds. What remains unclear is the boundary between the two kinds of voicing, more specifically, between ‘frequent’ and ‘non-frequent’ compounds. This will be an intriguing empirical question for future research.

2. Lyman’s Law revisited

2.1 Original version

One of the best-known conditions concerning the domain of *rendaku* is the so-called ‘Lyman’s Law’, which can be defined as in (4). Representative examples are given in (5) in contrast to those that are not subject to the condition.

- (4) *Rendaku* is blocked in a compound word [AB] if B already contains a *dakuon*, or a voiced obstruent.
- (5) a. aka + huda → aka-huda, *aka-buda ‘red tag’
 cf. uwa + huta → uwa-butā ‘top lid’
 roten + huro → roten-buro ‘outdoor, bath; outdoor bath’
- b. ai + kagi → ai-kagi, *ai-gagi ‘duplicate key’
 cf. ama + kaki → ama-gaki ‘sweet, persimmon; sweet persimmon’
 umi + kame → umi-game ‘sea, turtle; sea turtle’
- c. yama + kazi → yama-kazi, *yama-gazi ‘forest fire’
 cf. wa + kasi → wa-gasi ‘Japanese cake’
 temuzu + kawa → temuzu-gawa ‘Thames, river; River Thames’

As these examples indicate, Lyman’s Law represents a case of OCP (Obligatory Contour Principle) by which an identical element or feature is prohibited from occurring more than once within a certain domain. In *rendaku*, the feature in question is [+voice, +obstruent], with the relevant domain of OCP being the morpheme or the second member of a compound. While this is a well-known fact in Japanese phonology, there are certain cases where Lyman’s Law requires a larger domain. This can be seen rather clearly in the data provided by Sugito (1965), which we will consider in detail in the next section.

2.2. Sugito’s data and Lyman’s Law

Sugito (1965) looked at the alternation between /ta/ and /da/ shown by the morpheme //ta// ‘rice field’ as it is combined with a bimoraic morpheme to form a personal name: e.g. /siba-ta/ vs. /ima-da/. This particular morpheme exhibits a rather clear pattern of alternation, which is more or less predictable from the consonant in the immediately preceding mora.[NOTE 1] The results of Sugito’s analysis can be summed up as follows.

- (6) a. The morpheme is usually realized as /da/ when it is immediately preceded by a mora containing either /s/, /m/, /n/, /t/, or /k/, as well as when it is preceded by a heavy syllable (except a syllable containing a moraic obstruent).
- b. The morpheme is invariably realized as /ta/ when it is preceded by a mora containing either /d/, /b/, /g/, /z/ or /y/, or when it is preceded by a moraic obstruent.
- c. The morpheme is predominantly realized as /ta/ but permits /da/ occasionally when it is preceded by a mora containing either /r/ or /w/.

Representative examples are given below.

- (7) a. asa-da, hama-da, sana-da, kata-da, huku-da; soo-da, sai-da, kan-da
 b. kubo-ta, kado-ta, naga-ta, mizu-ta, haya-ta
 c. ari-ta vs. hara-da, iwa-ta vs. sawa-da

We can develop Sugito’s analysis one step further and reinterpret the data in terms of natural classes.[NOTE 2] This reanalysis leads to the generalization in (8). The contrast between (8a) and (8b) is illustrated in (9).

- (8) a. /da/ is preferred after voiceless obstruents and nasals.
 b. /da/ is prohibited after voiced obstruents.
 c. /ta/ is preferred after liquids.
- (9) a. huku-da, kasi-da, kusu-da, asi-da, kase-da, kaku-da, sima-da, naka-da (or naka-ta), kata-da
 b. hugu-ta, kazi-ta, kuzu-ta, azi-ta, kaze-ta, kagu-ta, siba-ta, kubo-ta, naga-ta, sugi-ta, kado-ta

In terms of the markedness of voicing, this generalization means that /ta/ is chosen if the consonant in the immediately preceding mora has the feature [+voice], whereas /da/ may be chosen if the consonant in question is [-voice] or unspecified with respect to voicing (as in nasals). Here the variation between /ta/ and /da/ for some words like //naka + ta// (/nakata~/~/nakada/) does not directly concern us. What is of interest is the fact that /da/ is never permitted if the immediately preceding mora already contains a voiced obstruent. This is a clear case of OCP, or an extension of Lyman's Law we saw in (5). In (5), *rendaku* voicing is blocked if the second element of the compound already contains a voiced obstruent. In (9), the same process is blocked if the first element ends in a mora containing a voiced obstruent. The similarity between the two cases is obvious: presence of a voiced obstruent in the neighborhood prevents *rendaku* from creating another voiced obstruent. The OCP effect in (9b) is particularly interesting because voiced obstruents block *rendaku* across a morpheme boundary.

This extended effect of OCP in *rendaku* is not a new finding, however. Kindaichi et al. (1988: 264), citing examples like /maga-tama/ 'ancient accessory' and /muzu-tama/ 'polka dot', note that this 'law' has existed in Japanese since the ancient period. According to Itô and Mester (forthcoming), this was originally reported by Tatsumaro Ishizura in his 1801 writing. Itô and Mester claim that the domain of Lyman's Law has narrowed from the word (prosodic word) in Old Japanese to the morpheme in modern Japanese. It remains unclear why this domain change has taken place and how the old effect of Lyman's Law leaves its trace in modern Japanese. These are very interesting questions for future work.

Returning to Sugito's data regarding the /ta/-/da/ alternation, there are several additional facts that are worthy of special attention. One is the fact that liquids (/r/, /w/ and /y/) pattern more or less with voiced obstruents, while nasals (/m/ and /n/) pattern with voiceless obstruents. These two groups of sounds form a natural class in Japanese phonology in that they are all voiced and lack voiceless counterparts. It is puzzling that they pattern differently with respect to the /ta/-/da/ alternation. Particularly mysterious is the behavior of liquids which, as summarized in (10), tend to show the same behavior as voiced obstruents.

(10)		-/ta/	-/da/
	/rV/-	31	3
	/wV/-	7	2
	/yV/-	8	0

In terms of the markedness of voicing, liquids should pattern with voiceless obstruents and nasals since they involve an unmarked value of voice. This 'unmarkedness' shows itself very clearly in the general cases of Lyman's Law which we saw in (5) above. Namely, unlike voiced obstruents, liquids do not block the voicing process when they occur in the second member of compound nouns, and they pattern exactly with voiceless obstruents and nasals in this respect. It is very strange to find that liquids display the same pattern as voiceless obstruents and nasals with respect to Lyman's Law in the original sense, while they pattern with voiced obstruents in the extended version of the same law.

Another interesting fact about the /ta/-/da/ alternation concerns the peculiar behavior of /r/. As shown in (10), /r/ predominantly prefers /ta/ rather than /da/. The three exceptions to this in Sugito's data are /hara-da/, /tera-da/ and /tora-da/, in all of which /da/ is preceded by the low vowel /a/. [NOTE 3] This

may hint that the choice between /ta/ and /da/ after /r/ has to do with the quality (or height, to be more exact) of the immediately preceding vowel, i.e. the final vowel of the preceding morpheme. This possibility is also worth exploring.

A final noteworthy fact about Sugito's data is that /k/ behaves somewhat differently from other voiceless obstruents. While /t/ and /s/ invariably choose /da/, /k/ admits quite a few exceptions as the following statistics and examples show.

(11)		-/ta/	-/da/
	/sV/-	0	35
	/tV/-	0	26
	/kV/-	13	31

- (12) a. /ta/: iku-ta, aki-ta, oki-ta, kaki-ta, maki-ta, saka-ta
 b. /da/: huku-da, oka-da, taka-da, toku-da, oku-da, kaku-da, ike-da, take-da, huka-da

It is true that /k/ prefers /da/ rather than /ta/, but it is obviously different from other voiceless obstruents in the extent to which it tolerates /ta/. The reason for this peculiar behavior of /k/ remains unclear.

2.3 Summary

In the preceding section we have seen Sugito's data concerning the /ta/-/da/ alternation in personal names consisting of three moras. It should be clear now that in the particular type of compound nouns, Lyman's Law exerts its effect in a wider domain than is usually assumed. The same effect is found in many pairs of personal names including /naga-sima/--/naka-zima/, /naga-sawa/--/naka-zawa/ and /naga-saki/--/naka-zaki/. This said, it is also important to point out that not all morphemes or personal names exhibit the same extended effect of Lyman's Law. Restricting ourselves to personal names, we find that some morphemes invariably undergo *rendaku* even when they are preceded by a voiced obstruent. //sono// 'garden' and //buti// 'the depth, an abyss', for example, get voiced no matter what morpheme they may be combined with. Indeed, these morphemes invariably undergo *rendaku* as long as they stand in a non-initial position of a compound:

- (13) a. hoka-zono, mae-zono, kubo-zono, azi-zono, naka-zono, naga-zono, sugi-zono, eno-ki-zono
 b. naka-buti, naga-buti, sugi-buti

On the other hand, some morphemes tend to resist *rendaku* voicing in any context. //hara// 'field' and //saka// 'slope' may be such morphemes, which are realized as /hara/ and /saka/, respectively, in most cases:

- (14) a. oo-hara, o-hara, naga-hara, naka-hara, saka-hara; cf. kanbara,
 b. e-saka, oo-saka, naka-saka, no-saka, ta-saka

Most morphemes including //ta// discussed in the preceding subsection fall between these two extremes. A closer examination of compound nouns may reveal a more general nature of the extended effect of Lyman's Law sketched in (8)-(9) as well as the degree to which *rendaku* voicing is morpheme-dependent.

3. Branching constraint

A second major condition that blocks *rendaku* voicing in Japanese is the so-called ‘branching constraint’ (Otsu 1980, Kubozono 1988). This constraint can be defined as follows.

(15) *Rendaku* is blocked in the second member of a right-branching compound.

Otsu (1980) gives the following pairs to illustrate the effect of this constraint.

- (16) a. Right-branching compounds
 nuri + [hasi + ire] → nuri-hasi-ire
 ‘lacquered, chopstick, case; chopstick case which is lacquered’
 nise + [tanuki + siru] → nise-tanuki-ziru
 ‘pseudo, raccoon dog, soup; raccoon dog soup that is not authentic’
- b. Left-branching compounds
 [nuri + hasi] + ire → nuri-basi-ire
 ‘lacquered, chopstick, case; case for lacquered chopsticks’
 [nise + tanuki] + siru → nise-danuki-ziru
 ‘pseudo, raccoon dog, soup; soup made from a pseudo raccoon dog’

In (16a), the second member forms a constituent with the third rather than the first member. Corresponding to this morphosyntactic structure, *rendaku* voicing is blocked between the first and second members although it is not blocked between the second and third. In contrast, *rendaku* is not blocked in (16b), where the second as well as the third member can undergo the process. Sato (1989) adds the following pair to illustrate this same effect.

- (17) a. mon + [siro + tyoo] → mon-siro-tyoo, *mon-ziro-tyoo
 ‘white, armorial bearing, butterfly; white cabbage butterfly’
- b. [o + siro] + wasi → o-ziro-wasi ‘tail, white, eagle: white-tailed eagle’

The reality of the branching constraint may be questioned despite the examples in (16) and (17). For one thing, it is difficult to find clear cases showing its effect. The compound nouns in (16) are novel compounds for many native speakers of Japanese, who do not necessarily have clear-cut intuitions about the presence or absence of voicing in the pairs of expressions. The compounds in (17) are existing expressions, but it is difficult to find more examples showing a similar effect. Moreover, the branching constraint may be questioned by the existence of expressions that apparently defy its effect. Some of these counterexamples are given in (18).

- (18) oo + [huro + siki] → oo-buro-siki ‘big, bath, carpet; big talk’
 mati + [hi + kesi] → mati-bi-kesi
 ‘town, fire, to extinguish; fire brigade for common people’

While the reality of the branching constraint may thus be questioned, it can be supported by more general phonological considerations. Kubozono (1988) provided evidence that the process of accentual phrasing characteristic of compound formation exhibits essentially the same prosodic asymmetry between right-branching and left-branching structures. This is illustrated in (19), where /’/ denotes a lexical accent and is placed immediately after the accented mora. Words without this mark are so-called unaccented words, which involve no abrupt pitch fall at the phonetic output. { } indicates an accentual phrase, or a prosodic word (PrWd).

- (19) a. Right-branching compounds
do'itu + [bu'gaku + kyookai] → {do'itu} {bungaku-kyo'okai}
'Germany, literature, association; German Association of literature'
- b. Left-branching compounds
[do'itu + bu'ngaku] + kyookai → {doitu-bungaku-kyo'okai}
'Association of German literature'

In right-branching compounds, accentual phrasing is blocked between the first and second members with the result that the first member forms an accentual phrase independent of the second and third members. Their left-branching counterparts, in contrast, do not exhibit such an accentual split and, consequently, constitute one unified accentual unit. This contrast between left-branching and right-branching compounds is equivalent to the situation of *rendaku* blocking shown in (16) and (17). Unlike the case of *rendaku* voicing, there are a number of compound nouns in Japanese that exhibit an accentual contrast as shown in (19).

More significantly, the right-branching structure is subject to a similar branching constraint at the phrasal level, where intonational phrases called 'minor phrases' are formed. This post-lexical process, too, is blocked in right-branching structure, but not in left-branching structure (Kubozono 1988, 1995). All these observations indicate that a branching constraint of the sort in (15) is independently motivated in Japanese phonology. All we need to do is to define the constraint in a more general form as in (20): (20a) and (20b) are synonymous in descriptive terms.[NOTE 4]

- (20) Branching constraint
- a. Phonological unification is blocked in the right-branching structure.
- b. Phonological unification is blocked between two constituents, A and B, if B does not c-command A.

An equally interesting fact about the branching constraint thus redefined is that it also applies to phonological processes in languages other than Japanese. In English, for example, compound nouns exhibit an asymmetry between left-branching and right-branching constructions, with the latter but not the former failing to conform to the general strong-weak pattern of compound stress of the language (Chomsky & Halle 1968, Liberman & Prince 1977). Essentially the same asymmetry is observed in Chinese. In this tone language, right-branching phrases fail to undergo the well-known tone sandhi rule whereby a sequence of two tones 3 (falling-rising tone) is converted into a sequence of tone 2 (rising tone) and tone 3 (falling-rising tone) (Hirose et al. 1994). Thus the string of 3-3-3 tones turns into 2-2-3 via 2-3-3 if it forms a left-branching structure, but the same string tends to yield 3-2-3 in a right-branching structure. A similar effect of branching constraint is observed in the tone sandhi rule in Ewe, an African tone language (Clements 1978). Moreover, it is also reported that consonant lengthening in Italian is blocked in right-branching constructions (Napoli & Nespor 1976). It is an open empirical question if this structural constraint is observed in a wider range of languages, but it obviously represents a rather general constraint on phonological processes that has a cross-linguistic significance.

One last question that remains unanswered is why phonological processes in Japanese and other languages are subject to the structural constraint formulated in (20)—or, equivalently, why right-branching structure exhibits such a marked phonological pattern. Kubozono (1995) proposed two hypotheses. One is that the right-branching structure displays irregular phonological behavior in languages where the right-branching structure is syntactically/morphologically marked. This interpretation is consistent with the fact that the left-branching structure is unmarked, at least statistically, in Japanese compounds and phrases as well as in English compounds. If this interpretation is correct, it is

expected that the left-branching rather than right-branching structure will show marked, exceptional behavior in right-branching languages. A second hypothesis put forward by Kubozono (1995) is that the right-branching constraint in (20) is universal and applies to compound nouns irrespective of whether the left-branching or right-branching structure is syntactically/morphologically unmarked in a particular language. These two hypotheses must be compared and evaluated by examining phonological markedness in a wider range of languages. This is certainly another interesting topic for future work that will require detailed cross-linguistic comparisons.

4. Mora condition on *rendaku*

4.1 Alternation between /hon/ and /bon/

We have seen in the preceding section that the constituent structure of a compound noun can serve as a condition on *rendaku* voicing and, accordingly, determine the domain of this productive process. In addition to this, there are cases where the domain of the rule is determined by the phonological length of the compound. One such case is compounds that contain the morpheme //hon// ‘book’ as their second member. According to Ohno (2000), this morpheme exhibits an alternation between the underlying form /hon/ and the *rendaku* form /bon/, depending on the phonological length of the element with which it is combined, or N1. [NOTE 5] A crucial boundary lies between bimoraic and trimoraic N1. If the N1 is monomoraic or bimoraic, //hon// fails to undergo *rendaku* and manifests itself as /hon/. If the N1 is three moras long or longer, on the other hand, //hon// undergoes the voicing rule and yields /bon/. These two patterns are formulated in (21) and illustrated in (22). [NOTES 6, 7]

(21) N1+//hon// undergoes *rendaku* voicing if N1 is longer than two moras.

- (22) a. e-hon ‘picture book’, aka-hon ‘red book, or a brand name of a publisher’s books for entrance examinations’, ero-hon ‘erotic book’, huru-hon ‘secondhand book’
 b. bunko-bon ‘paperback book’, manga-bon ‘comic book’, tyuuko-bon ‘secondhand book’, tankoo-bon ‘independent book’, pinku-bon ‘pink, book; pornographic book’, karaa-bon ‘colored book’

Two additional points should be emphasized here. First, the phonological length of N1 must be defined in terms of the mora and not the syllable. This is clearly shown by compounds such as /pinku-bon/ and /karaa-bon/ whose N1 consists of three moras but two syllables. These bisyllabic morphemes do not pattern with bimoraic and bisyllabic morphemes like /aka/ ‘red’ and /ero/ ‘erotic’. Another noteworthy point is that the morphological complexity of N1 does not matter. The monomoraic and bimoraic N1s in (22a) are all monomorphemic while N1 in (22b) consists of more than one morpheme in most cases. This reflects the fact that //hon//, a Sino-Japanese (SJ) morpheme, tends to be combined with another SJ morpheme (or morphemes) and that each SJ morpheme is up to two moras long. However, the morphological structure of the N1 does not directly concern the boundary between /hon/ and /bon/. This is shown by monomorphemic N1s such as /pinku/ ‘pink’ and /karaa/ ‘color’, which clearly pattern with bimorphemic words like /bunko/ ‘bibliotheca, papeterie’ and /manga/ ‘cartoon’ and not with monomorphemic words like /aka/ ‘red’ and /ero/ ‘erotic’.

Having justified the generalization in (21), it is necessary to point out that this rule applies specifically to compound nouns with //hon//, and not to other compounds. Indeed, many morphemes other than //hon// do not conform to the pattern in (21). We saw in section 2 above that the morpheme //ta// ‘rice field’ can undergo voicing even when it is combined with a bimoraic noun. Moreover, some morphemes like //ha// ‘tooth’ and //kame// ‘turtle’ undergo *rendaku* even when they are combined with

bimoraic nouns as in (23a), while others are not subject to voicing whether they are combined with bimoraic or trimoric nouns, as shown in (23b).

- (23) a. musu + ha → musu-ba ‘a decayed tooth’
 umi + kame → umi-game ‘sea, turtle; turtle’
 mayu + ke → mayu-ge ‘eyebrow, hair; eyebrow’
 b. migi + te → migi-te ‘right, hand; the right hand’
 hidari + te → hidari-te ‘left, hand; the left hand’
 kasegi + te → kasegi-te ‘to earn, hand; bread winner’

While the rule in (21) is not a general constraint on *rendaku* in Japanese compound nouns, it does not follow that the mora-based generalization represents an idiosyncratic rule in Japanese phonology. The rule in (21) can be reinterpreted as follows, if we consider the phonological length of the whole word rather than the length of individual components.

- (24) //hon// undergoes *rendaku* if the entire word consists of more than four moras.

This generalization means that *rendaku* does not occur in //Noun-hon// if this whole word is up to four moras long. In other words, the morpheme //hon// preserves its underlying form /hon/ in four-mora or shorter words, while it undergoes some phonological process characteristic of compounds in five-mora or longer words. Interestingly enough, essentially the same contrast between words up to four moras and those composed of five or more moras is observed in several other phonological processes independent of *rendaku* voicing in Japanese. Let us first consider the process that Itô and Mester (1996) called ‘contraction’ in SJ compounds.

4.2 Contraction in SJ compounds

One type of SJ morpheme has a (C)VC structure with an optimal onset. Morphemes of this type can only take a voiceless obstruent, /t/ or /k/, in the coda position, and exhibit two phonological patterns in SJ compounds, depending on the initial segment of the following morpheme. In many cases, they undergo vowel epenthesis in order to avoid closed syllables or voiced geminates. This is illustrated in (25), where < > and // denote an epenthetic vowel and a syllable boundary, respectively.

- (25) gak + bu → ga.k<u>.bu, *gak.bu, *gab.bu ‘learning, part; faculty’
 but + ri → bu.t<u>.ri, *but.ri, *bur.ri ‘substance, law; physics’

On the other hand, (C)VC morphemes do not undergo epenthesis if the following morpheme begins with a voiceless consonant. This is the pattern that Itô and Mester (1996) termed ‘contraction’. The only minor change that the morphemes in question undergo is a place assimilation, whereby the morpheme-final consonant becomes homorganic with the initial consonant of the following morpheme.[NOTE 8] This is illustrated in (26).

- (26) gak + kai → gak.kai, *ga.k<u>.kai ‘learning, party; academic society’
 but + si → bus.si, *bu.t<u>.si ‘Buddha, teacher; a sculptor of Buddhist images’
 gak + ka → gak.ka, *ga.k<u>.ka ‘learning, department; department’
 but + ka → buk.ka, *bu.t<u>.ka ‘thing, price; commodity prices’

The contraction process in (26) has the effect of combining the two morphemes in a straightforward manner. This process, however, is blocked if there is a word boundary between the two morphemes. In other words, the ‘contraction’ in (26) occurs only if the two adjacent morphemes form a constituent. This is illustrated in (27a), where the constituency is shown by []. SJ compounds in (27b), in contrast, readily undergo contraction since they do not involve a word boundary between the second and third elements.

- (27) a. [dai + but] + si → dai.bu.t<u>.si, *dai.bus.si
 ‘great, Buddha, teacher; a sculptor of big Buddhist images’
 [sin + gak] + ka → sin.ga.k<u>.ka, *sin.gak.ka
 ‘god, learning, department; department of religion’
 b. dai + [but + si] → dai.bus.si, *dai.bu.t<u>.si
 ‘great, Buddha, teacher; a great sculptor of Buddhist images’
 sin + [gak + ka] → sin.gak.ka, *sin.ga.k<u>.ka
 ‘new, learning, department; a new department’

Itô and Mester (1996) interpret the constituency effect illustrated in (27) as a constraint on the domain of the contraction process: contraction occurs within a PrWd, which consists of one or two morphemes. Since every SJ morpheme is at most two moras long, this domain constraint can be reinterpreted as in (28).

- (28) Contraction occurs in the domain of up to four moras.

Contraction has taken place in (26) and (27b) since the (C)VC morphemes in question are embedded in a word of up to four moras. In (27a), by contrast, (C)VC morphemes are combined with the following CV(C) morphemes in a larger word. In terms of phonological length, this fact can be reduced to a constraint requiring that the maximal domain of contraction be a constituent consisting of four moras. In other words, two morphemes can be combined without undergoing vowel epenthesis if they form a four-mora or shorter word. This is precisely the same domain constraint that we saw for //hon// above, which does not undergo the compound rule of *rendaku* voicing if it is embedded in a four-mora or shorter word.

4.3 /p/-/h/ alternation in SJ compounds

The /p/-/h/ alternation shows the same domain effect as the process of vowel epenthesis. This is illustrated with the morpheme //hitu// ‘pencil’ here. It is generally assumed that the underlying form of this alternation is /p/, which alternates with /h/ in a predictable way. Itô and Mester (1996) showed that morphemes involving this alternation preserve the underlying form with /p/ when they follow a morpheme ending in a moraic nasal /N/:

- (29) eN + pitu → em-pitu ‘lead, pen; pencil’
 haN + patu → ham-patu ‘opposite, start; rebel’

However, this does not happen in the two environments in (30) even if they are preceded by a moraic nasal. In (30a), the /p/-morpheme is combined with a SJ compound; in (30b), it forms a constituent with the following morpheme before it does with the preceding one. In these two cases, /p/-initial morphemes do not keep their underlying /p/ and, hence, take /h/ instead: [] denotes a constituent.

- (30) a. [maN + neN] + pitu → mannen-hitu, *mannem-pitu ‘one thousand, year, pen; fountain pen’
 b. siN + [patu + mei] → sin-hatumei, *sim-patumei ‘new, invention; new invention’

Since SJ morphemes are maximally bimoraic, the boundary between the /p/ pattern in (29) and the /h/ pattern in (30) can be defined as follows:

- (31) /p/ is preserved if it is in the non-initial position of words consisting of up to four moras; otherwise, it turns into /h/.

This domain effect is identical to the one we saw in the preceding section as well as the ones we will see in the next sections.

4.4 Accent of mimetics

Japanese exhibits some accentual processes that are sensitive to the four-mora domain. One of them is the accentuation of reduplicative mimetic expressions. The base form of Japanese mimetic expressions is largely bimoraic and accented on its initial syllable. When these bimoraic bases are reduplicated to form four-mora words, they are usually accented on their initial syllable. In other words, only the first member of the reduplicated form preserves its accent. This is an accent pattern characteristic of reduplicative mimetics (32), reduplicative nouns (33), as well as dvandva, i.e. coordinate, compound nouns (34) (Nasu 2001).

- | | | |
|------|----------------------------|---|
| (32) | yu'ra + yu'ra → yu'ra-yura | ‘(to sway) gently’ |
| | su'ru + su'ru → su'ru-suru | ‘(to climb) smoothly’ |
| | ba'ta + ba'ta → ba'ta-bata | ‘(to fall) noisily, one after another’ |
| (33) | mura' + mura' → mura'-mura | ‘village, village; villages’ |
| | ka'zu + ka'zu → ka'zu-kazu | ‘number, number; in a great number, numerous’ |
| (34) | yo'ru + hiru' → yo'ru-hiru | ‘night and day’ |
| | hiru' + yo'ru → hiru'-yoru | ‘day and night’ |
| | a'sa + ban → a'sa-ban | ‘morning and evening’ |

Accent deletion of the second member does not seem to occur, however, if the bimoraic base is reduplicated after being combined with a mimetic ending such as /ri/ or the moraic nasal /N/. [NOTE 9]

- | | | |
|------|-------------------------------------|----------------------------|
| (35) | yura'ri + yura'ri → yura'ri yura'ri | ‘(to sway) in slow motion’ |
| | suru'ri + suru'ri → suru'ri suru'ri | ‘(to dodge) swiftly’ |
| | bata'N + bata'N → bata'N bata'N | ‘thumpety thump’ |

The contrast between (32) and (35) indicates that four-mora mimetics constitute a prosodic word (PrWd), or one accentual unit, whereas six-mora mimetics form two PrWds. This provides further support to the claim that the maximal length of a PrWd is four moras.

4.5 Accent of numeral sequences

Similar accentual evidence can be found with the pronunciation of numeral sequences. SJ morphemes for numbers are underlying monomoraic or bimoraic, but they are invariably pronounced with bimoraic length when enumerated in a string of numbers (Itô 1990). Thus, monomoraic morphemes, /ni/ ‘two’ and /go/ ‘five’, are pronounced with a long vowel: [ni:] and [go:]. What is interesting here is that

numeral sequences are divided into prosodic words each consisting of two morphemes, or four moras. This shows up very clearly in citing telephone numbers, as exemplified in (36). { } denotes the domain of PrWd, while H and L stand for high and low tones, which are assigned to every mora here for the sake of description.

- (36) a. 03-6825-7194 {re'esan} {rokuha'ti} {niigo'o} {nanai'ti} {kyuuyo'n}
 LHHL LHHL LHHL LHHL LHHL
 b. 721-2875 {nanani'i} {iti'} {niiha'ti} {nanago'o}
 LHHL LH LHHL LHHL

In (36b), the string of three numbers, 721, is realized in two PrWds, with the first two numbers forming a four-mora unit, and the last number constituting a separate PrWd. This clearly demonstrates that the optimal length of PrWds is maximally four moras.

Interestingly, the same maximality constraint operates in other dialects, too. (37) shows how the string in (36b) is pronounced in Kinki (Kyoto/Osaka) dialects (Fukui 1990). In fact, Tokyo and Kinki dialects differ only in the tonal pattern of four-mora PrWds: four-mora strings are pronounced with the tonal pattern of LHHL in Tokyo, and with the pattern of LLHL in Kinki. [NOTE 10] Two-mora PrWds are pronounced with the original (or lexical) accentual pattern of the relevant morpheme in both dialects.

- (37) 721-2875 {nanani'i} {it'i} {niiha'ti} {nanago'o}
 LLHL HL LLHL LLHL

The facts in (36) and (37) clearly show that the maximal size of a PrWd is four moras in number enumerations. Compound nouns can form a longer PrWd, as exemplified in (19), but this is due to a morphological requirement demanding the correspondence between morphological and prosodic words (or edges). The facts discussed in this and the preceding sections reveal an emergence of the unmarked, or an optimal phonological shape of PrWds in Japanese.

4.6 Morphological evidence

Finally, morphological evidence reinforces our claim that the optimal form of a PrWd in Japanese is up to four moras long and, hence, that the mora condition on the voicing of /hon/ in (24) is of a rather general nature in Japanese phonology. Let us consider truncation, first. One of the most basic characteristics of loanword truncation in Japanese is that long words are converted into four-mora or shorter forms: e.g. /irasutoreesyon/ → /irasuto/ 'illustration' (Itô 1990). Truncation of compounds is subject to essentially the same condition to yield four-mora outputs in most cases: e.g. /poketto monsutaa/ → /pokemon/ 'pocket monster, or Poke-mon'. This process admits three-mora outputs in some contexts, but never permits five-mora or longer outputs.

The same maximality constraint applies to other morphological processes such as the formation of *zuya-go*, or jazz musicians' secret language. *Zuya-go* formation involves metathesis by which the final two moras in the input are combined with the initial two moras to yield four-mora outputs. Here again, three-mora outputs are allowed in some contexts, but five-mora or longer outputs are absolutely illicit (Itô et al. 1996, Kubozono 2002b). This input-output correspondence, too, reveals a tremendous gap between four and five moras. All in all, the fact that five-mora or longer outputs are never tolerated in these morphological processes supports the idea that the optimal word form in Japanese is up to four moras long.

There are, of course, quite a few words, mostly loanwords, that are morphologically simplex but phonologically longer than four moras: e.g. /irasutore'esyon/ 'illustration', /anime'esyon/ 'animation'.

But there is some accentual evidence suggesting that five-mora or longer loanwords are processed as phonological compounds, i.e. that five-mora or longer words are split into two four-mora or shorter substrings to which accent is assigned by the compound accent rule (Sato 2002, Kubozono 2002a). This, too, lends support to the idea that PrWds in Japanese are optimally up to four moras long.

5. Concluding remarks

In this paper I have first considered Fukuda & Fukuda's (1999) neurolinguistic data suggesting that *rendaku* voicing falls into two kinds: voicing in some words are lexicalized, while voicing in other words is due to a productive synchronic process of voicing. In the rest of the paper, I have discussed three constraints on *rendaku* voicing: an extended version of Lyman's Law, a branching constraint and a mora constraint. These three constraints define the domain in which the productive process of *rendaku* voicing occurs in contemporary Japanese. The extended version of Lyman's Law and the mora constraint apply only to a specific type of compound nouns, while the branching constraint applies in a wider context. Despite this difference, all these constraints represent quite general conditions on phonological and morphological processes in Japanese. In this sense, the constraints on *rendaku* voicing should be interpreted in a wider context. These constraints, if examined in more detail, might uncover more interesting aspects and principles of (Japanese) phonology.

NOTES

1. What counts here is the consonant in the preceding mora, not in the preceding syllable. This is clearly shown by //den// and //goo//, which yield /den-da/ and /goo-da/, not /den-ta/ and /goo-ta/, respectively, even though they contain a voiced obstruent (/d/ or /g/).
2. Sugito was mainly concerned with the relationship between the /ta/-/da/ distribution and the accentual pattern of the whole personal name. She found out that three-mora names ending in /ta/ are usually accented on their initial mora in Tokyo Japanese (e.g. si'ba-ta, ku'bo-ta), while those containing /da/, e.g. /ima-da/ and /sima-da/, tend to be unaccented. This is an interesting fact that needs to be explained.
3. We can add the word /kuro-da/ to Sugito's list of exceptions.
4. Node A c(onstituent)-commands node B if neither A nor B dominates the other and the first branching node which dominates A dominates B (Reinhart 1976: 32). In the right-branching structure [[A][B][C]], [A] c-commands [B], but [B] does not c-command [A] because [B] forms a constituency with [C] rather than with [A]. In the left-branching structure [[[A][B]][C]], on the other hand, both [B] and [C] c-command [A].
5. The morpheme //hon// 'book' should be clearly distinguished from the numeral classifier //hon// which is used to count the number of objects such as fingers and pencils (e.g. /go-hon no yubi/ 'five-hon GEN finger=five fingers'). This numeral morpheme alternates between three phomemic forms, /hon/, /bon/ and /pon/, depending on the phonetic property of the immediately preceding sound (Tanaka & Kubozono 1999).
6. An apparent exception to the generalization illustrated in (21) is the word /bini-bon/ 'vinyl book, a book enclosed in vinyl'. This particular instance will not count as an exception since /bini-bon/ does not come directly from /bini-hon/, but from /buniiru-bon/ via shortening: namely, /buniiru + hon/ → /buniiru-bon/ → /bini-bon/.
7. There are some compounds which contain the morpheme //hon// but have lost its original meaning 'book' e.g. /mi-hon/ 'a sample for sale', /syoo-hon/ 'an extract', hyoo-hon 'a sample'. Interestingly, these lexicalized compounds conform to the generalization in (21).

8. Contraction is generally blocked if the first morpheme ends in /k/. In this case, vowel epenthesis instead of contraction occurs except when the second morpheme also begins with /k/. Thus, /hak+ti/ and /hak+sai/ undergo vowel epenthesis and turn into /hakuti/ ‘imbecility’ and /hakusai/ ‘Chinese cabbage’, respectively, while /hak+kyuu/ turns into /hakkyuu/ ‘white ball’. The fact that the morpheme-final /k/ blocks contraction reveals an interesting asymmetry between /t+k/ and /k+t/, which is called ‘coronal asymmetry’ by Itô & Mester (1996: 30). Thus, the former but not the latter triggers contraction: e.g. /bet+kak/ → /bekkaku/ ‘different style’ vs. /hak+ti/ → /hakuti/ ‘imbecility’. A similar asymmetry is observed in the morphophonology of native verbs, where a stem-final /k/ triggers vowel epenthesis rather than contraction when it is followed by a /t/-initial ending like the past marker /ta/. Thus, /kak + ta/ ‘to write (PAST)’ turns into /kakita/ (and subsequently /kaita/), whereas /yor + ta/ ‘to approach (PAST)’ and /hasir + ta/ ‘to run (PAST)’ turn into /yotta/ and /hasitta/, respectively.
9. We occasionally observe reduplicative mimetic forms that are five-mora long. These five-mora forms seem to be split into two PrWds: e.g. {yu’ra} {yura’ri} ‘(to sway) gently’.
10. This tonal pattern is different from the typical pattern of nouns. In Tokyo Japanese, nouns are usually accented, if accented at all, on the third mora from the end of the word: the word ‘Nagasaki’, for example, is accented on /ga/ as in /naga’saki/. However, the tonal pattern characteristic of numeral sequences is found in four-mora acronyms consisting of two alphabets. Thus, the words for ‘PC’ (personal computer) and ‘OL’ (office lady) are pronounced with an accent on the penultimate mora: /piisi’i/, /ooe’ru/. Alphabetic acronyms are different from numeral sequences, though, in that three-letter and longer acronyms form one unified PrWd that is longer than four moras: e.g. ‘PTA’ /piitiie’e/, ‘IBM’ /aibiie’mu/, ‘YMCA’ /waiemusii’e/.

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