Phonology and orthography:

The orthographic characterization of rendaku and

Lyman's Law

Abstract

This paper argues that phonology and orthography go in tandem with each other to shape our phonological behavior. More concretely, phonological operations are non-trivially affected by orthography, and phonological constraints can refer to them. The specific case study comes from a morphophonological alternation in Japanese, rendaku. Rendaku is a process by which the first consonant of a second member of a compound becomes voiced (e.g., /oo/ + /tako/ → /oo+dako/ 'big octopus'). Lyman's Law blocks rendaku when the second member already contains a voiced obstruent (/oo/ + /tokage/ → */oo+dokage/, /oo+tokage/ 'big lizard'). Lyman's Law, as a constraint which prohibits a morpheme with two voiced obstruents, is also known to trigger devoicing of geminates in loanwords (e.g. /**bedd**o/ → /**bett**o/ 'bed'). Rendaku and Lyman's Law have been extensively studied in the past phonological literature. Inspired by recent work that shows the interplay between orthographic factors and grammatical factors in shaping our phonological behaviors, this paper proposes that Rendaku and Lyman's Law actually operate over Japanese orthography. Rendaku is a process that assigns *dakuten* diacritics, and Lyman's Law prohibits morphemes with two diacritics. The paper shows that various properties of rendaku and Lyman's Law follow from this proposal. However, since some aspects of rendaku are undoubtedly phonological, the ultimate conclusion is that we need to recognize a model of phonology in which it has assess to orthographic information.

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1 Introduction

1.1 Theoretical context

In the traditional view, phonology is strictly about sounds, and orthography has been considered to have nothing to do with phonological theory. This has been the case since linguistics distinguished itself from philology, under the influence of landmark studies like Saussure (1916/1972). However, there are a few recent proposals and observations in the phonological literature that cast doubts on this traditional, strictly orthographic-free versions of phonology theory. Ito et al. (1996) offer an illustrative example. In a Japanese argot language game, known as *zuuja-go*, reversing occurs based bimoraic feet: e.g. /(batsu)+(guN)/ $\rightarrow$ /(gum)+(batsu)/ 'exquisit'. When the first syllable contains a geminate, the reserved segment which corresponds to a geminate marker in the original word appears as /tsu/; e.g. /(bi**k**)+(kuri)/ $\rightarrow$ /(kuri)+(bi**tsu**)/ 'surprised'. The most reasonable conjecture about this conversion of a geminate to /tsu/, according to Ito et al. (1996), is because the gemination is marked with a smaller version of the letter for /tsu/ (   ) in the Japanese orthography. Thus, in terms of orthography, this argot can be expressed as $\rightarrow$, in which the gemination marker   is realized as a full segment   after the reversal. This is an example in which orthography offers a straightforward explanation for the sound pattern under question. This conclusion does not mean, however, that the Japanese argot pattern is entirely dictated by orthography. Ito et al. (1996) show various prosodic factors affect the patterns of the argot system—after all, the pattern is based on a bimoraic foot, which is very phonological. It therefore seems that both phonological and orthographic factors together shape the Japanese argot pattern.

More recently, Nagano & Shimada (2014) proposed that Japanese *kanji*—Chinese characters used in the current Japanese orthography system—should be used as a representation of

lexemes in the Japanese lexicon. More often than not, one *kanji* in Japanese has two readings: for example, can be read as /ɕige/ or /haɴ/, both meaning "prosperous" (see Nagano & Shimada 2014 for extended exemplification). This dual reading creates an apparently extremely complex suppletive morphological patterns, which can be modeled very simply, if *kanji* is a part of linguistic knowledge of Japanese speakers, over which morphological representations can operate. Relatedly, Poser (1990) points out a hypocoristic formation in Japanese which makes sense only in terms of orthography. For example, a person named (/takaɕi/) can be called /kjuu/, because /takaɕi/ and /kyuu/ are two readings of the same kanji . This hypocoristic formation is thus mediated by the *kanji* character. At the same time though, this hypocoristic formation is based on a bimoraic foot (Poser, 1990), as is the case with the argot pattern discussed by Ito et al. (1996).

Shaw et al. (2014) found essentially something similar: in order to account for compound truncation patterns in Chinese, it is essential to consider Chinese characters as part of lexical representations. Shaw et al. (2014) demonstrates, moreover, that what survives in truncation is affected by predictability of each compound member, and "predictability" is arguably an essential part of our linguistic knowledge (Hall et al. 2016 for a recent overview). Again, this example illustrates the importance of considering the interplay of orthographic knowledge and lexical/phonological knowledge.

Finally, many studies of loanword adaptation have shown that the role of orthography is non-negligible (Daland et al., 2015; Silverman, 1992; Smith, 2007; Vendelin & Peperkamp, 2006). To take an example from Japanese, the English word *manager* is borrowed as /maneeʑaa/ in Japanese. Note that the second vowel in the original word *manager* is a schwa, and there is no reason that it had to be borrowed as a long vowel, /ee/ (p.c. Junko Ito, Oct. 2016). In this example, the orthography "a" in the original English word, and knowledge that it sometimes represents a diphthong in English may have led Japanese speakers to borrow it as a long vowel. See Smith (2007) for other examples of the influence of orthography in

loanword adaptation in Japanese.

Importantly, these proposals do not undermine the importance of phonology or morphology as an explanation of our linguistic behavior. To the extent that orthography offers a simple explanation of our linguistic behavior, and to the extent that that behavior is also dictated by phonological and other grammatical considerations, it seems that the most natural conclusion is that phonological and morphological grammar has assess to orthography knowledge. More concretely, in current theoretical frameworks using (violable) constraints (e.g. Optimality Theory: Prince & Smolensky 2004), constraints should be able to refer to orthographic information. This paper further explores this sort of grammar-orthography interaction, by studying rendaku and Lyman's Law in detail from this fresh perspective.

1.2 The current case study: rendaku

Rendaku and Lyman's Law are probably some of the most well-studied phenomena in the phonological studies of Japanese (Irwin, 2016a; Vance & Irwin, 2016). A traditional description of rendaku is that "the first consonant of a second member of a compound becomes voiced"; e.g., /oo/ 'big' + /**t**ako/ 'octopus' → /oo+**d**ako/ 'big octopus'. Lyman's Law (Lyman, 1894; Vance, 2007) blocks rendaku when there is already another voiced obstruent in the second member of the compound; for example, /oo/ 'big' + /**t**oka**g**e/ 'lizard' → **/oo+**d**oka**g**e/, /oo+**t**oka**g**e/ 'big lizard'. Rendaku and Lyman's Law were studied extensively by the traditional grammarians (see Irwin 2016a), and were brought to the attention of theoretical linguists by Otsu (1980), who presented the first analysis of rendaku in the SPE-style (Chomsky & Halle, 1968).[*1] Ito & Mester (1986) made rendaku and Lyman's Law famous in the field of theoretical phonology, as they analyzed rendaku and Lyman's Law using theoretical devices that were being developed at that time: autosegmental spreading, underspecification,

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[*1] The first comprehensive generative treatment of Japanese phonology appeared in McCawley (1968), but he gave up on the analysis of rendaku because he could not make sense of its irregularity. He states that the behavior of rendaku is "completely bewildering" (p. 87, note 18).

and OCP (Obligatory Contour Principle). Later, Ito & Mester (2003a) developed a comprehensive reanalysis of rendaku and Lyman's Law within the framework of Optimality Theory (OT: Prince & Smolensky 2004). Reflecting the fact that they are now well-known in the field of theoretical phonology, rendaku and Lyman's Law appear in a number of introductory phonology textbooks (Gussenhoven & Jacobs 2011, p. 58; Kenstowicz 1994, p. 493, pp. 511-512; Roca 1994, pp. 75-76; Spencer 1996, pp. 60-61). Most generative studies on rendaku and Lyman's Law consider them to be purely phonological or morphophonological (see Kawahara 2015a and Vance 2014 for critical assessment of this common assumption).

Building on some previous work (Kawahara, 2015a; Vance, 2015, 2016), this paper presents an alternative conception of rendaku and Lyman's Law, which explains their properties better than the purely phonological view. In essence, this paper proposes the following:

(1)   Orthographic interpretations of rendaku and Lyman's Law.

     a.   Rendaku is a process that adds a *dakuten* mark, an orthographic diachritic to represent obstruent voicing.

     b.   Lyman's Law prohibits two occurrences of diacritics within a single morpheme.

Consider Table 1, which illustrates the basic Japanese *kana*-orthographic system, in which one letter generally corresponds to a (C)V mora. As shown in rows (a1-3), Japanese orthography marks voiced obstruents by putting two dots (called *dakuten*) on the upper right corner of the letter for the corresponding voiceless obstruents. As shown in (b), /b/ is written with *dakuten* on the letter for /h/. /p/ is represented by putting a little circle—known as *han-dakuten* 'half *dakuten*'—on the upper right corner of the letter for /h/, as in (c). Sonorant consonants and vowels, despite being phonetically voiced, are not written with *dakuten*, as in (d1-3).

Table1   Basic Japanese *kana*-orthography systems.

	Sounds	Letters	Sounds	Letters
(a1)	ta		da	
(a2)	ka		ga	
(a3)	sa		za	
(b)	ha		ba	
(c)	ha		pa	
(d1)	na		ma	
(d2)	ja		wa	
(d3)	na		a	

This paper proposes that (i) rendaku is a process that assigns *dakuten*, and that (ii) Lyman's Law prohibits two diacritics (*dakuten* or *han-dakuten*) within a morpheme. In this view, Lyman's Law can be considered as orthotactics (Bailey & Hahn, 2001) rather than purely phonotactics. Although this proposal may seem rather radical, it did not come out of the blue—Vance (2007, 2015, 2016) repeatedly alerted the relevance of Japanese orthography in the patterning of rendaku, as we will see below. This proposal is also inspired by other work showing the interplay between orthographic and linguistic knowledge in shaping our phonological behaviors, which was reviewed in the introduction of the paper (Ito et al., 1996; Nagano & Shimada, 2014; Shaw et al., 2014; Smith, 2007). Under the current proposal, formally speaking, rendaku can be understood as follows. The compound junction morpheme postulated by Ito & Mester (2003a) is actually *dakuten* diacritic, instead of [+voice], and the morpheme realization constraint requires this *dakuten* to realize on the surface. Lyman's Law can be understood as OCP(diacritic), which prohibits two *(han)-dakuten* diacritics within a morpheme.

2   Some properties of rendaku and Lyman's Law

Before developing this orthographic theory of rendaku and Lyman's Law, let us first review some crucial properties of rendaku (Kawahara & Zamma, 2016). As stated in the introduction, rendaku was first formalized in the SPE format by Otsu (1980), and later analyzed by a series of work by Ito and Mester (1986; 1996; 1997b; 2003a; 2003b). There are a number of theoretical contributions that they have made over the years, but this section focuses on those aspects that will become relevant later. First, rendaku has been treated as a manifestation of several grammatical operations, including a feature-changing SPE-style rule (Otsu, 1980), an autosegmental spreading rule (Ito & Mester, 1986), morphophonologized intervocalic voicing (Ito & Mester, 1996), and morpheme realization requirement of a compound juncture morpheme (Ito & Mester, 2003a).

Second, rendaku has been discussed in the context of the internal organization of the Japanese lexicon (Ito & Mester, 1995, 1999, 2008) in that rendaku mainly occurs in native words, but very rarely occurs in loanwords. Third, Ito & Mester (1986) proposed that Lyman's Law is an instantiation of a universal constraint schema, the OCP on the [+voice] feature (Goldsmith, 1976; Leben, 1973; McCarthy, 1986). They further argued that OCP(+voice) acts as a morpheme structure condition on the Japanese lexicon as well, in that there are only a few native morphemes that contain two voiced obstruents.

Fourth, Lyman's Law is not triggered by [+voice] on sonorants, and hence Ito & Mester (1986) argued that the [+voice] feature is underspecified for sonorants. Mester & Ito (1989) argue instead that [voice] is a privative feature and sonorants do not bear that feature at all throughout the phonological derivation. Rice (1993) instead argues that sonorant voicing and obstruent voicing are represented by different features, and Lyman's Law targets only the latter. Alderete (1997) and Ito & Mester (2003b) formulated Lyman's Law as a result of self-conjunction of an OT constraint *VOICEOBS (=*D^2), which allows one not to commit

themselves to a particular representation of [voice] for sonorants. This short review shows that rendaku and Lyman's Law have been extensively discussed in multiple theoretical frameworks (see Kawahara & Zamma 2016 for more details).

3 Arguments for orthographic explanations

3.1 Phonetic diversity, orthographic unity

Let us now turn to the orthographic theory of rendaku and Lyman's Law. The first argument to treat rendaku as a matter of orthography comes from the fact that when viewed from the phonetic point of view, rendaku is not simply a matter of "voicing of initial consonants", but instead involves more complicated parings of sounds. This observation was reiterated in a series of work by Timothy Vance (Vance, 2007, 2015, 2016), but did not seem to have received serious attention from formal phonologists. The surface phonetic pairs that are related by rendaku are shown in Table 2. In the left column, for each pair, the original sound is shown on the left, and the one that appears after the application of rendaku is shown on the right. The middle column shows examples. The right column shows how these sounds are written before and after rendaku.

Table2　Phonetic diversity, orthographic unity

	Phonetic pair	Example	Orthographic paring
(a)	[ɸ]–[b]	[ɸue]–[bue] 'flute'	vs.
(b)	[ç]–[b]	[çi]–[bi] 'fire'	vs.
(c)	[h]–[b]	[ha]–[ba] 'tooth'	vs.
(d)	[t]–[d]	[ta]–[da] 'field'	vs.
(e)	[ts]–[z]	[tsuma]–[zuma] 'wife'	vs.
(f)	[tɕ]-[ʑ]	[tɕikara]–[ʑikara] 'power'	vs.
(g)	[k]–[g]	[ki]–[gi] 'tree'	vs.
(h)	[s]–[z]	[sora]–[zora] 'sky'	vs.
(i)	[ɕ]–[ʑ]	[ɕima]–[ʑima] 'island'	vs.

Table 2 highlights the fact that rendaku is not simply a matter of "voicing the target consonant." Among those in Table 1, (d, g, h, i) are straightforward minimal pairs that differ in voicing, but the others are not; for example, in (b), [ç] is a voiceless palatal fricative, but [b] is a voiced labial stop; in (c), [h] is a glottal fricative, but [b] is a labial stop; in (e) and (f), the original sounds are affricates, but the resulting sounds are fricatives. This complexity is not impossible to solve with a phonological analysis; for example, for (a-c), it is possible to posit an underlying labial stop /p/ (McCawley, 1968), which is realized as /h/ in non-voicing contexts and as /b/ in voicing contexts; /h/ further undergoes allophonic changes before /i/ and /u/, realizing as [çi] and [ɸu]. The deaffrication in (e, f) can be attributed to independently motivated intervocalic deaffrication (see Maekawa 2010 for details), because rendaku usually occurs in intervocalic contexts.

It is not impossible to construct a phonological analysis of the complicated patterns in Table 2 in this way. However, it does face some problems. Most importantly, positing underlying /p/ for surface [h] can be problematic, because /p/ realizes faithfully in native words as well, as in *tampopo* 'dandelion' and *paipan* 'shaved genitalia' (Fukazawa & Kitahara, 2002). Moreover, a reversing argot pattern in Japanese (Ito et al., 1996) shows that the process that turns un-

derlying /p/ to [h] is not active even for native items; e.g. /kappa/ → /**p**akka/, */**h**akka/ 'river imp' and /oppai/ → /**p**aiotsu/, */**h**aiotsu/ 'breast'. The purported rule that turns underlying /p/ to [h] does not seem to be active even in the native phonology of Japanese.

More crucially, it is important to note that from the view point of orthography, all the pairings in Table 1 can be treated very simply as a unitary rule—an addition of the same diacritic mark (*dakuten*) (Vance, 2015, 2016). All the letters for the sounds that appear on the right are identical to those letters that represent the sounds on the left, with addition of the *dakuten* diacritic mark. Rendaku therefore can simply be understood as "the addition of a *dakuten* mark". As Vance (2016) says, "the Japanese writing system represents all the [rendaku] alternations in a uniform way" (p.3 of the manuscript version).[*2] In the discussion of Japanese argot in which /tsu/ appears as the argot correspondent of a gemination marker, Ito et al. (1996) entertain some possible phonological analyses, but conclude that "such proposals have a ring of artificiality in comparison with the perfectly straightforward kana account." The same argument can be made for the case of rendaku.

3.2 /p/-driven geminate devoicing

The second argument comes from the patterns of geminate devoicing found in loanwords, which is demonstrably caused by Lyman's Law. In Japanese loanwords, geminates can devoice when they co-occur with another voiced obstruent (e.g. /**bedd**o/ → /**bett**o/ 'bed'), but not when voiced geminates do not appear with an additional voiced obstruent (/**hedd**o/ → /**hedd**o/, */**hett**o/ 'head') (Kawahara, 2006, 2011, 2015b; Nishimura, 2006). As Nishimura (2006) and Kawahara (2006) argue, this devoicing can be understood as an effect of Lyman's Law, because devoicing avoids morphemes with two voiced obstruents. Interestingly, /p/

[*2] This view of rendaku is strictly about rendaku in Modern Japanese. Japanese *dakuten* system was not systematically used in the Japanese orthographic system until the Meiji period, which started in the middle of the 19th century. This does not mean, however, that the contemporary speakers of Japanese speakers do not have knowledge of *dakuten* and use it to characterize rendaku. I also have nothing to say about how rendaku and Lyman's Law were mentally represented before *dakuten* entered into the Japanese orthographic system.

seems to cause devoicing of geminates as well (e.g. **/p**irami**dd**o/ → **/p**irami**tt**o/ 'pyramid';
/kjuu**pidd**o/ → /kjuu**pitt**o/ 'cupid').

Since this /p/-driven devoicing of geminates seems counterintuitive, Kawahara & Sano (2016) ran a judgment experiment to investigate whether this devoicing is real. In this experiment, they presented native speakers of Japanese with a list of words that contain particular sorts of structures: (i) geminates that appear with /p/ (e.g. **/p**a**dd**o/ 'pad'), (ii) Lyman's Law-violating geminates (e.g. **/b**a**dd**o/ 'bad'), (iii) non-Lyman's-Law-violating geminates (e.g. /he**dd**o/ 'head'), (iv) Lyman's Law-violating singletons (e.g. **/b**aa**d**o/ 'bird'), and (v) non-Lyman's Law-violating singletons (e.g. /haa**d**o/ 'hard'). In that experiment, for each word, they presented to the participants two forms, one "faithful form" (e.g. /be**dd**o/) and one "devoiced form" (e.g. /be**tt**o/), and asked them which pronunciation they would use. The results, reproduced in Figure 1, show that geminates are indeed pronounced as devoiced 40% or 30% of the time when they co-occur with /p/ or another voiced obstruent; the results also show, on the other hand, that other conditions show very few devoiced responses—most importantly, context-free devoicing of geminates rarely occurs. See Kawahara & Sano (2016) for the corpus data, which generally suggests the same pattern.
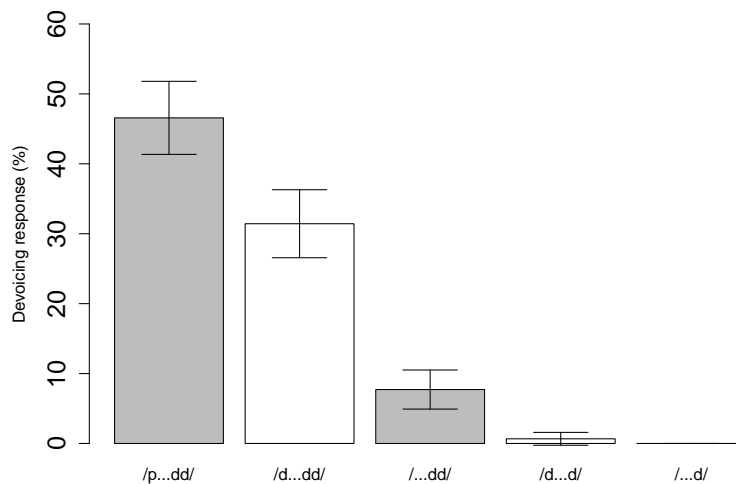
Figure1: Devoicability of each type of consonant. Based on Kawahara & Sano (2016).

Why would /p/ cause devoicing of geminates, or in other words, why does /p/ trigger Lyman's Law? OCP(+voice) (Ito & Mester, 1986) or *D² (Ito & Mester, 2003a) cannot be the explanation, because /p/ is not a voiced obstruent—it would turn into /b/ if it were [+voice]. If Lyman's Law prohibits two diacritics within a morpheme, this /p/-driven devoicing makes sense, because /p/ also has a diacritic mark (*han-dakuten*: see Table 1). In summary, the trigger of geminate devoicing in Japanese loanwords includes /p, b, d, ɡ/. There does not seem to be a phonological natural class to characterize this group of sounds. However, all of these sounds have an orthographic diacritic in Japanese:　,　,　,　. In essence, then, it is natural to consider Lyman's Law as OCP(diacritic). It may be that OCP is a general cognitive schema to avoid adjacent similar entities (Frisch, 2004; Pierrehumbert, 1993), which can take both phonological features and orthographic characteristics as its arguments.

Mark Irwin (p.c.) pointed out that this theory makes a certain prediction about geminate devoicing. Since devoicing /bb/ would result in /pp/, which would still have a diacritic mark, /bb/ should not devoice. Loanwords containing /bb/ are rare in the first place (Katayama, 1998; Shirai, 2002), but there is one word that contains both /bb/ and a voiced

stop, **/ge**bb**erusu/** 'Göbbels," and the prediction seems to be borne out. In the naturalness judgment using a 5-point scale reported by Kawahara (2011), the devoicing of this word was rated much less natural than the devoicing of geminates in other Lyman's-Law-violating words: 3.16 vs. 3.86. This score (3.16) is in fact *lower* than the average naturalness of devoicing of non-Lyman's-Law-violating words (3.26), whose devoicing was deemed almost impossible in Kawahara & Sano (2016) (see Figure 1). This result further supports the formulation of Lyman's Law as the orthotactic which prohibits two diacritics.[*3]

3.3 Explaining why sonorants do not cause Lyman's Law

Treating rendaku and Lyman's Law as a matter of orthography comes with additional virtues. Recall that Lyman's Law ignores voicing in sonorants and vowels, and that several theoretical apparatuses were proposed to account for that observation: underspecification (Ito & Mester, 1986), privative feature (Mester & Ito, 1989), or obstruent-specific voicing feature (Rice, 1993). However, there is a simple explanation in terms of orthography: as shown in Table 1, Japanese orthography marks voicing on obstruents with a diacritic mark, but not on sonorants. Therefore, if Lyman's Law were to be understood as a prohibition against two diacritics—or OCP(diacritic)—then the inactivity of sonorant voicing directly follows. No additional theoretical machinery is necessary.[*4]

[*3] Another possible candidate is **/gu**bb**ai/** 'Good bye', which is arguably heteromorphemic, and thus has not been tested in the previous judgment experiments. I have consulted a few native speakers about the possibility of devoicing this /bb/ in **/gu**bb**ai/**—many feel that it is impossible to devoice /bb/ for this word too, to the degree that they laugh at the devoiced form of this word.

[*4] Japanese arguably has a pattern of postnasal voicing, which may require [voice] specification on sonorants (Ito et al., 1995; Rice, 1993). For example, the past tense suffix [ta] is realized as [da] after a nasal consonant (e.g. [tabe-ta] 'ate' vs. [ɕin-da] 'died'). However, the evidence for the *productivity* of postnasal voicing in Japanese phonology is weak at best (Vance, 1987, 1991). Even if post-nasal voicing is productive, it can be attributed to an Optimality Theoretic constraint *NT (Pater, 1999), without assuming that nasals have [+voice] feature (Hayashi & Iverson, 1998).

3.4   Explaining the opacity

Another piece of evidence comes from the interaction of rendaku, Lyman's Law, and yet another phonological process. In some dialects of Japanese, intervocalic [ɡ] becomes [ŋ] (Ito & Mester, 1997a, 2003b; Vance, 1987). This segment [ŋ] is not a voiced obstruent, but it still blocks rendaku, as in [saka-toŋe] 'reverse thorn' and [oo-tokaŋe] 'big lizard'.

This interaction is opaque because the surface [ŋ] acts as if it is a voiced obstruent: it triggers Lyman's Law, although its surface realization is a sonorant. In other words, the blockage of rendaku due to Lyman's Law overapplies and rendaku underapplies, despite the application of velar nasalization. In a derivational sense, velar nasalization needs to occur after rendaku applies; when rendaku occurs, /ɡ/ is still /ɡ/ (Table 3). Ito & Mester (2003b) developed this derivational ordering analysis in OT (Prince & Smolensky, 2004). Ito & Mester (1997b) and Honma (2001) instead proposed analyses based on Sympathy Theory (McCarthy, 1999).

Table3   Derivational analysis of the opacity.

	The right order		The wrong order	
UR	/saka+toge/		UR	/saka+toge/
rendaku	—blocked by Lyman's Law—		velar nasalization	/saka+toŋe/
velar nasalization	/saka+toŋe/		rendaku	/saka+doŋe/
SR	[saka+toŋe]		SR	*[saka+doŋe]

One particular challenge that this opaque pattern presents is as follows. Since [ɡ] and [ŋ] are in an allophonic relationship Ito & Mester (1997a), the Richness of the Base hypothesis (Prince & Smolensky, 2004; Smolensky, 1996) makes us consider a case in which [ŋ] appears in the input; e.g. /toŋe/. In order for this form to block rendaku, the underlying /ŋ/ has to be changed to /ɡ/, and then has to turn back to /ŋ/. This pattern would thus instantiate a "Duke-of-York" derivation (Pullum, 1976) (schematically, /A/ → /B/ → [A]). However, the existence

of such derivation is debatable (McCarthy, 2003; Rubach, 2003; Wilson, 2000); granting phonological theory enough power to allow such type of derivation may overgenerate.

The orthographic formulation of Lyman's Law explains why /g/, after becoming [ŋ], would still block rendaku, because [ŋ] is still written with a *dakuten* mark (velar nasalization is not reflected in the Japanese orthography). No theoretical machinery is necessary, and in fact, there is no opacity in this analysis. In other words, this view does away with the derivational ordering analysis. See arguments by Hooper (1976), Sanders (2003), Green (2004) and Padgett (2010) that there are perhaps no productive synchronic cases of opacity.[*5]

One may argue that devices such as underspeficication, privative features, derivational opacity, or a Duke-of-York derivation are independently necessary, so the last two arguments developed in this section are not as strong. It may actually turn out that these notions are indeed necessary in phonological theory. However, it is important to emphasize here that the orthographic theory of rendaku and Lyman's Law explains the clustering of their properties without further additional machineries.

4   Discussion

4.1   Summary of arguments

In summary, many properties of rendaku and Lyman's Law make sense, once we consider them from the viewpoint of Japanese orthography. When viewed at the surface phonetic level, rendaku is not a simple matter of "voicing the target consonant", but involves different sets of more complicated pairings. However, in terms of orthography, rendaku is simply an addition of *dakuten*. Treating Lyman's Law as orthotactics comes with three additional virtues: (i) it

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[*5] Bruce Hayes also mentions some statement to this effect in his lecture at "50 Years of Linguistics at MIT", which succinctly summarizes the problem: "We don't understand the opaque languages well enough. In particular, I don't think we fully understand the degree to which the opaque pattern is internalized by language learners, and it is time to do more checking" (viewable on Youtube).

explains why /p/ can cause devoicing of geminates; (ii) it explains why Lyman's Law ignores [+voice] of sonorants; and (iii) it explains why /g/ blocks rendaku, even after it turns into /ŋ/.

The orthographic theory of rendaku and Lyman's Law makes one more prediction, which is unfortunately not easy to test—/p/ should block rendaku, because it should trigger Lyman's Law. Unfortunately, rendaku applies mainly to native items, and native items rarely contain /p/, because Japanese lost this phoneme at some point in its history (Ito & Mester, 1995, 1999, 2008).*6 In the rendaku database (Irwin, 2016b; Irwin & Miyashita, 2016), there is one monomorphemic native word that contains /p/ or /pp/, *suppai* 'sour', which undergoes rendaku. This word would have to be treated as an exception. There are two more relevant native words *happa* 'leaves' and *sippo* 'tail', neither of which undergoes rendaku (Vance, 2007) . Another relevant word *kappa* 'coat' undergoes rendaku, contra the prediction of the orthographic theory of Lyman's Law. This word, however, is doubly exceptional, because this word is a loanword (recall that rendaku is usually limited to native words). Overall, there are exceptions for the original formulation of Lyman's Law based on [+voice] as well (e.g. *hasigo* and *saburoo*, which undergo rendaku)—I thus contend that these exceptions are not detrimental to the orthographic theory of Lyman's Law.

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*6 Interestingly, though, Lyman (1894) himself argues that /p/ blocks rendaku: "the second part of a compound word takes the nigori [=rendaku]; that is if beginning with ch, f, h, k, s, sh, or t, those consonants are changed into the corresponding sonant [=voiced] ones ... the general rule does not apply ... when b, d, g, j, p, or z already occurs anywhere in the second part of the compound" (p.2). See also Vance (2007).

Table4　Summary.

	Triggering devoicing	Blocking rendaku	[+voice]	[+voice, -son]	diacritic
/b/	yes	yes	+	+	+
/d/	yes	yes	+	+	+
/g/	yes	yes	+	+	+
/p/	yes	?	-	-	+
/t/	no	no	-	-	-
/k/	no	no	-	-	-
/m/	no	no	+	-	-
/n/	no	no	+	-	-
/ŋ/	?	yes	+	-	+

Table 4 provides a summary of what has been discussed in the paper. The leftmost column shows whether each segment triggers devoicing of geminates or not. Whether /ŋ/ triggers devoicing of geminates is unclear, because there are no words with a voiced geminate and an intervocalic /g/ (and no other potential trigger).[*7] The second column shows whether each segment blocks rendaku or not. The third column shows whether they are phonetically voiced or not. The fourth column shows voicing in obstruents (which would be "plus" under the underspecification theory, for example). The last column shows whether each sound is written with a diacritic mark or not. It seems that the last column matches the first two columns best.

4.2　Rendaku is also sensitive to phonology

Even if the current proposal is on the right track, we need to make sure not to throw the baby out with the bathwater; i.e. banishing rendaku and Lyman's Law from the field of phonology entirely. Recent work shows that orthographic knowledge may have a deep con-

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[*7] The word /bagudaddo/ 'Bagdad' contains an intervocalic /g/ and a voiced geminate, but it also contains other voiced obstruents.

nection with our linguistic knowledge (Ito et al., 1996; Nagano & Shimada, 2014; Shaw et al., 2014). Likewise, it is unlikely that every aspect of rendaku can be reduced to orthography. Rendaku for instance interacts with several kinds of linguistic information, such as branching structures and morphosyntactic categories (Kubozono, 2005; Vance & Irwin, 2016), which cannot be reduced to orthography. Rendaku is also blocked by Identity Avoidance constraints (Kawahara & Sano, 2014a,b), as well as by OCP(labial) (Kawahara et al., 2006). It also interacts with pitch accent, in such a way that rendaku often correlates with unaccentedness in compounding (Kurisu, 2010; Sugito, 1965; Zamma, 2005).

It is also important to note that in the loanword devoicing pattern, only voiced geminates, not singletons, can get devoiced in response to Lyman's Law, as shown in Figure 1—i.e. devoicing due to Lyman's Law is delineated by a grammatical distinction like singletons vs. geminates (Kawahara, 2006, 2016). It thus seems most productive to consider the interplay of orthography and other grammatical principles to explain our linguistic behavior. Japanese speakers should have an orthographic representation as a part of their linguistic knowledge (cf. Nagano & Shimada 2014), and that representation can affect their speech behavior, in tandem with phonological and other linguistic representations.

4.3   Overall conclusion

Recent work has shown that phonological knowledge and orthographic knowledge both influence our linguistic behavior. This paper has shown that many properties of rendaku and Lyman's Law automatically follow, if we take the orthographic patterns of Japanese into consideration. First, at the surface phonetic level, rendaku is not a simple matter of "voicing the target consonant", but involves different sets of more complicated pairings. However, in terms of orthography, rendaku is simply an addition of *dakuten*. Second, postulating Lyman's Law as OCP(diacritic) explains why /p/ can cause devoicing of geminates. Third, this theory explains why Lyman's Law ignores [+voice] of sonorants. Fourth, it explains why /g/ blocks

rendaku, after it turns into /ŋ/. However, some aspects of rendaku are undoubtedly phono-logical, which suggest that rendaku is phonological as much as it is orthographic. Taken together, then, we should develop a model of phonology in which phonological operations and constraints can refer to orthographic information. One interesting prediction that the current proposal makes is that pre-literate children cannot apply rendaku productively. This prediction has to be tested independently.

Acknowledgments

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