

Auditory and written perception of Japanese sequential voicing*

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ABSTRACT

Japanese *rendaku* affects second elements (E2s) of compounds, replacing a voiceless obstruent with a voiced obstruent (/tama/ ‘ball’, /me+dama/ ‘eye-ball’). Lyman’s Law is ordinarily stated as a constraint preventing *rendaku* when E2 already contains a voiced obstruent. An alternative proposal is that the constraint is orthographic, preventing a second diacritic in the *kana* representation of an E2 that already contains one. The crucial cases involve E2s with a medial /p/: a voiceless obstruent written with a diacritic. We report two experiments involving compounds with made-up E2s. Speakers chose between forms with and without *rendaku*. In an audio experiment, E2s with medial /p/ patterned with E2s with medial voiceless obstruents, but in a written experiment, E2s with medial /p/ patterned between those with medial voiceless obstruents and those with medial voiced obstruents. These results lend credence to the orthographic version Lyman’s Law, but only when orthographic information is visually present.

Keywords: sequential voicing, voicing, Japanese, perception, orthography

1. INTRODUCTION

Japanese (i.e., modern Tokyo “standard” Japanese) has a well-known set of morphophonemic alternations known collectively as *rendaku* (sometimes translated as ‘sequential voicing’) [8]. Many morphemes have one allomorph that begins with a voiceless obstruent and another allomorph that begins with a voiced obstruent, as in (1).

- (1) a. /tara/ ‘cod’
 b. /tara+ko/ ‘cod roe’
 c. /boH+dara/ ‘dried cod fillet’

The initial voiced obstruent in the /dara/ allomorph in (1c) is an instance of *rendaku*, and the prototypical environment for *rendaku* is the beginning of the second element of a two-element compound. Only the non-*rendaku* allomorph of an alternating morpheme can occur word-initially, as in (1a) and (1b), with /tara/ rather than /dara/.

Although each *rendaku* alternation pairs a voiceless obstruent with a voiced obstruent, the phonetic

difference between the two phonemes in each pair is in many cases more than just the absence vs. presence of voicing [17]. All the Japanese obstruent phonemes except /p/ are involved in these alternations. Each voiceless obstruent phoneme other than /p/ (i.e., /f h t c s č š k/) appears word-initially in at least one pairing, and each voiced obstruent (i.e., /b d z j g/) appears as a *rendaku* partner in at least one pairing.

Lyman’s Law is a constraint on *rendaku*. The now standard formulation is that Lyman’s Law prohibits *rendaku* in the second element (E2) of a compound if that element already contains a medial voiced obstruent (e.g., */umi+gaze/ ‘sea breeze’; cf. /kaze/ ‘wind’). Only a few exceptions to Lyman’s Law are found in the existing vocabulary [6, 9, 14].

The modern Japanese writing system incorporates two parallel subsystems, *hiragana* and *katakana*, each of which makes it possible to represent the pronunciation (i.e., the phonemic form) of any Japanese word accurately. Together, these two subsystems are known as *kana*, and they are basically moraic: for the most part, each symbol represents a short syllable or half of a long syllable, although some moras are written with digraphs. Orthographic norms require a few minor mismatches between *kana* “spelling” and pronunciation [16], but these norms can be violated when the goal is to convey pronunciation. Both *hiragana* and *katakana* use the diacritic (°), known as *dakuten*, to represent moras that begin with a voiced obstruent (as in た for /da/ vs. た for /ta/). As noted, /p/ is the only modern Tokyo phoneme realized as an obstruent that is not involved in a *rendaku* alternation. The phoneme /b/ alternates not with /p/ but with /f/ or /h/. The term *han-dakuon* ‘half voiced sound’ denotes a mora that begins with /p/, and such a mora is written in *kana* with the diacritic (°), known as *han-dakuten*, added to a symbol for a mora that begins with /h/ or /f/ (as in ぱ for /pa/ vs. は for /ha/ and ば for /ba/).

There is one conspicuous difference between Lyman’s own statement of Lyman’s Law [7] and the now standard version: Lyman’s list of E2-medial consonants that inhibit *rendaku* includes /p/ in addition to all the voiced-obstruent phonemes of modern Japanese. The existing vocabulary, however, provides little reason to believe that E2-medial /p/ inhibits *rendaku* [18].

Most present-day linguists simply ignore /p/ when discussing *rendaku* and Lyman’s Law, but it should

be noted that the modern Japanese vocabulary contains very few examples of *rendaku* in an E2 with a medial /p/. The almost total absence of such examples lends plausibility to the notion that an E2-medial /p/ inhibits *rendaku*. It is not far-fetched to imagine that an E2-medial /p/ might have a psychologically real inhibiting effect on *rendaku* for present-day native speakers of Japanese.

Recent work by [5] shows that native speakers seem to treat /p/ and voiced obstruents alike in triggering the optional devoicing of underlyingly voiced “geminates,” that is, sequences of the moraic obstruent /Q/ followed by a voiced obstruent within the same element. Such sequences are confined to recent loans [15], and the examples below in (2) illustrate the putative pattern.

- (2) a. /beQdo/ ベッド ‘bed’ [bed:o]~[bet:o]
 b. /paQdo/ パッド ‘pad’ [pad:o]~[pat:o]
 c. /heQdo/ ヘッド ‘head’ [hed:o] (*[het:o])

Given the optional devoicing pattern in (2), [4] suggests that it might be better to view *rendaku* as an orthographic phenomenon rather than as a phonological phenomenon. Their evidence is that /p/ seems to depress the acceptability of forms with more than one “marked” segment just as a voiced obstruent does, but their experimental data is not from forms with/without *rendaku* but from forms with/without an initial voiced obstruent (i.e., the idea that /gaQta/ is better than /gaQda/ but also better than /gaQpa/). In other words, (supposedly) /p/ patterns like a voiced obstruent in such cases.

Our study provides a straightforward test of the effect of /p/ and voiced obstruents in inhibiting *rendaku*. If the *rendaku* rate is lower when the test item’s E2 contains a medial voiced obstruent than when it contains a medial voiceless obstruent other than /p/, the results corroborate the usual version of Lyman’s Law. If test items with E2s that contain a medial /p/ pattern like test items with E2s that contain a medial voiced obstruent, then the results support the orthographic interpretation of Lyman’s Law: E2 cannot contain more than one diacritic (゚ or ゝ) in *kana* representation. If the test items with E2s that contain medial /p/ pattern like test items with E2s that contain a medial voiceless obstruent other than /p/, then the results support the usual version of Lyman’s Law: E2 cannot contain more than one voiced obstruent.

2. METHODOLOGY

In order to test whether Lyman’s Law is an orthographic effect rather than a phonological effect, in particular the possible interaction of Lyman’s Law and /p/, we conducted two perception experiments,

one with aural stimuli (without presenting *kana* orthography) and the other with written stimuli (including *kana* orthography).

2.1. Stimuli

Table 1 shows examples of the 38 test words we prepared. These were all non-existing Sino-Japanese words, so their familiarity scores were controlled for.¹ We chose to use Sino-Japanese words, although they often do not undergo *rendaku*, to obviate possible interaction with lexical-stratum factors involving /p/ and *rendaku*. The test words were compounds with the first element (E1) *nise-* (偽“fake”) (e.g., /nise+soNpei/). If E2 undergoes *rendaku*, the first segment of E2 becomes voiced (e.g., /nise+zoNpei/).

E2 medial	Word	Orthography
/p/	/soNpei/	村兵 (そんぺい)
voiced obstr.	/soNguu/	村宮 (そんぐう)
voiceless obstr.	/soNkuu/	村空 (そんくう)

Table 1: Examples of test words

Participants were asked to choose whether the form with *rendaku* or the form without *rendaku* (e.g., /nise+zoNpei/ or /nise+soNpei/) was more natural. Half of the participants in each experiment were presented with the form undergoing *rendaku* first, and the other half were presented with the form not undergoing *rendaku* first, thereby counterbalancing the presentation order.

2.2. Participants

Fifty-three native Japanese speakers participated in the audio experiment, and 46 native Japanese speakers participated in the written experiment. All participants were from the Tokyo area (Tokyo, Chiba, Kanagawa and Saitama prefectures). Participants received a small monetary compensation upon completion of the experiment.

The participants for the two experiments were recruited via the online crowdsourcing platform Crowdworks. In both the audio and the written experiments, the participants were first presented with a consent form and with instructions, and they completed two practice trials before proceeding to the main section of the experiment.

2.3. Audio and written experiments

The audio experiment was a binary forced-choice test coded with jsPsych and conducted via a web-based test implemented using Cognition.run. The participants were asked to wear either headphones or earphones. The participants were visually presented with the non-existing test word in *kanji* and its “meaning”

in Japanese on the computer screen and auditorily presented with the forms undergoing and not undergoing *rendaku* (the choice between /nise+zoNpei/ and /nise+soNpei/, etc.) and asked to choose the more natural form. The *kanji* orthography uses Chinese characters and thus, unlike *kana*, does not directly encode the voicing contrast; participants were given the voicing information aurally but not visually. The participants were able to listen to the audio stimuli repeatedly, as many times as they wanted.

The written experiment was a binary forced-choice test conducted via a web-based test implemented using PsyToolKit [12, 13]. The presentation for each test word consisted of two pages: a first page that explained the “meaning” of the non-existing word (in Japanese), and a second page asking the preference for the form undergoing *rendaku* or the form not undergoing *rendaku* (e.g., the choice between /nise+zoNpei/ and /nise+soNpei/, presented in Japanese orthography). The participants were given the information about voicing and about /p/ visually, i.e., with and without the diacritics (゛) and (゜), as in にせきんぼん /nise+kiNboN/ vs. にせぎんぼん /nise+giNboN/ and にせとんぴん /nise+toNpiN/ vs. にせどんぴん /nise+doNpiN/.

3. RESULTS

Figure 1 gives the mean rates of the preference for *rendaku* in the two experiments. The numbers indicate the percentage of participants in each experiment that chose the forms with *rendaku* as more natural.² The y-axis is the response rate, and the x-axis is the category of E2-medial consonants. Overall, the rates are not very high even for test words with voiceless E2-medial obstruents other than /p/ (0.21 in the audio experiment and 0.26 in the written experiment). This is the condition most likely to elicit *rendaku*, but the low rates can be explained by the general fact that Sino-Japanese E2s often do not undergo *rendaku*.

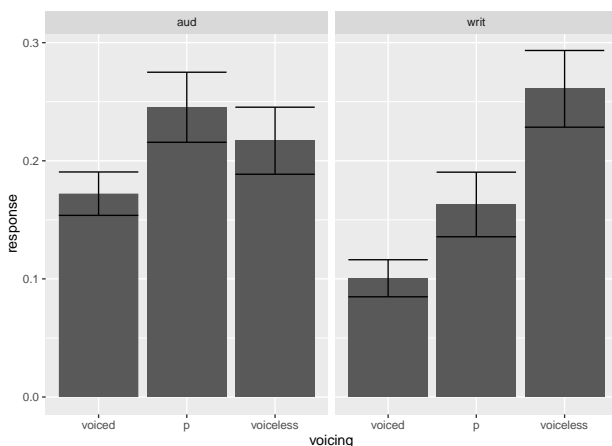


Figure 1: Mean *rendaku* preference rates; Left panel: audio data, Right panel: written data

To examine the effects of the E2 consonants, a mixed-effects logistic regression analysis was carried out with *rendaku* preference response as the dependent variable. The predictors included the voicing (three levels: /p/, voiceless consonants other than /p/, voiced consonants), the mode (two levels: audio and written) and the interaction of these two. Speaker and item were included in the model as random effects (a random intercept and a random slope for speaker and a random intercept for item). The analysis used the software R [11] with R package *lme4* [1].

Type II Wald chi-square tests, with the *Anova* function of the *car* package [2], determined that the main effect of voicing is overall statistically significant (Table 2).

	χ^2	df	p-value
voicing	11.9457	2	< 0.01 **
mode	1.7454	1	0.186
voicing:mode	9.5157	2	< 0.01 **

Table 2: Wald chi-square test of predictors in the mixed-effects logistic regression analysis

The results of the mixed-effects logistic regression analysis (Table 3) reveal that in the audio data, E2 /p/ is significantly different from E2 voiced consonants but not different from other voiceless consonants.

	Estimate	S.E.	z-value	Pr(> z)
Intercept	-1.502	0.288	-5.208	< 0.001 ***
Voiced	-0.636	0.287	-2.215	< 0.05 *
Voiceless	-0.322	0.319	-1.009	0.312
Modewritten	-0.637	0.403	-1.579	0.114
Voiced:writ	-0.108	0.378	-0.286	0.774
Voiceless:writ	0.968	0.404	2.397	< 0.05 *

Table 3: Mixed-effects logistic regression analysis

Follow-up pairwise comparisons were made for the three levels of voicing within each mode. This was done using the *testInteractions* function of the *phia* package with no adjustment. The results reveal that (a) in the audio data, in addition to the above-reported significance (/p/ vs. other voiceless obstr., /p/ vs. voiced obstr.), voiceless obstruents other than /p/ and voiced obstruents are not significantly different ($p=0.29$) and (b) in the written data, all three pairwise comparisons were significant (/p/ vs. voiced: $p=0.039$, voiced vs. voiceless except /p/: $p<0.001$), although the difference between /p/ and other voiceless obstruents was only marginally significant ($p=0.068$).

To summarize, /p/ patterns differently in the audio and written data. In the audio data, /p/ patterns with other voiceless obstruents and not with voiced obstruents: the *rendaku* rate is higher in E2s with medial /p/ or another voiceless obstruent than in E2s with a medial voiced obstruent. In the written data, /p/ patterns neither with other voiceless obstruents nor with voiced obstruents: the *rendaku* rate increases in the

order voiced obstruents < /p/ < voiceless obstruents excluding /p/, positioning /p/ between voiced and voiceless excluding /p/.

4. DISCUSSION

The results of the audio experiment are consistent with the standard version of Lyman's Law, according to which an E2-medial voiced obstruent inhibits *rendaku*. E2-medial /p/ patterned with other voiceless obstruents and not with voiced obstruents.

The results of the written experiment are less clear-cut. An E2-medial /p/ inhibited *rendaku* more than an E2-medial voiceless obstruent but less than an E2-medial voiced obstruent. If /p/ had patterned with the other voiceless obstruents, the results would be consistent with the standard version of Lyman's Law. If /p/ had patterned with the voiced obstruents, the results would be consistent with the orthographic version of Lyman's Law, according to which a medial diacritic (either *dakuten* or *han-dakuten*) in the *kana* representation of E2 inhibits *rendaku*.

The statistically significant interaction (see Table 2) between mode of presentation (audio vs. written) and voicing (/p/ vs. other voiceless obstruents vs. voiced obstruents in E2-medial position) indicates that mode of presentation affects participant behavior. The "intermediate" results of the written experiment are consistent with the idea that more than one diacritic in the *kana* representation of an E2 is disfavored. On the other hand, the statistically significant difference between /p/ and voiced obstruents contradicts the idea that any combination of two diacritics has the same effect. Recall that the diacritics used for moras beginning with a /p/ (ゑ) and for those beginning with a voiced obstruent (ゑ) differ in Japanese orthography (§1). Thus, one possible explanation for the difference between /p/ and voiced obstruents in *rendaku* inhibition is that although the orthography (in particular diacritic usage) plays a role, its effect is stronger when there are two identical diacritics (i.e., two (ゑ)) than when there are two different diacritics (i.e., one (ゑ) and one (ゑ)). This difference could be understood as a type of OCP effect.

The involvement of orthography in phonological representations has been argued for [4] (§1), and the results of this study support the idea. However, how do we reconcile the difference between the results with aural and written stimuli? The aural results for /p/ are arguably unexpected, since in Japanese morphophonology /p/ often does not pattern with the other phonemes realized as voiceless obstruents. For example, the *rendaku* alternation parallel to /t~/d/, /k~/g/, etc., is /h, f~/b/, not /p~/b/ (§1); /p/ alternates with /h/ and /b/ only in certain environments (e.g., immediately following moraic /N/). It is known that

there are some phonological patterns that are not found elsewhere in the phonology of a language that may be explained by perception or perceptual knowledge [10], e.g., in the rhyming patterns in Japanese rap music [3]. Our results with the aural stimuli may simply reflect the perceptual similarity between /p/ and the other voiceless obstruents in Japanese. These phonemes are all realized phonetically as voiceless consonants, and this perceptual knowledge may have played a role in the participants' responses in the on-line processing. It would be interesting to test the hypothesis with a production experiment. If this perception account is on the right track, the results would be different there. Another possibility for further investigation would be a third presentation mode, providing both audio stimuli and *kana* representation and thus differing in just one respect from each of the other two modes: audio and *kana* vs. audio only vs. *kana* only.³

5. CONCLUSION

This paper has reported the results of two experiments designed to test the suggestion that Lyman's Law can be construed as an orthographic constraint rather than as a phonological constraint.

The phonological construal (standard Lyman's Law) is that an E2-medial voiced obstruent prevents *rendaku*. Since *rendaku* produces an E2-initial voiced obstruent, the phonological construal blocks the addition of a second voiced obstruent to an E2 that already contains one. The orthographic construal of Lyman's Law is that an E2-medial diacritic in *kana* orthography prevents *rendaku*. Since *rendaku* yields a *dakuten* (voicing) diacritic on the initial symbol of the *kana* representation of an E2, the orthographic construal blocks the addition of a second diacritic to the *kana* representation of an E2 that already contains a diacritic (either *dakuten* or *han-dakuten*).

The experimental results show that native speakers of Japanese respond differently depending on whether the test items are presented aurally or visually (i.e., in *kana*). The results of the audio experiment indicate that there is no diacritic effect when response choices are presented aurally. The results of the written experiment indicate that a second diacritic does inhibit *rendaku* when the response choices are presented visually but that the effect is stronger when E2 contains two *dakuten* than when it contains one *dakuten* and one *han-dakuten*, possibly showing an OCP effect involving orthographic representation. The different patterning of /p/ in the aural and written results, in particular the patterning of /p/ in the aural data, might be explained in terms of the perception of surface phonetic forms: [p] is just like other voiceless obstruents.

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¹ The list of words contained three types: (1) those with an E2-medial obstruent preceded by a moraic nasal /N/ (20 words), (2) those with an E2-medial obstruent

preceded by a moraic obstruent /Q/ (12 words), and (3) those with E2-medial /h/ (6 words). This paper discusses only cases with moraic /N/.

² Words with initial /ç/ and medial /š/ and /j/ and those with initial /h/ and medial /p/ and /b/ were excluded from the analysis because they showed unexpectedly lower rates, possibly due to OCP effects.

³ We thank the anonymous reviewer for this suggestion.