

Lyman's Law is active in loanwords and nonce words: Evidence from naturalness judgment studies

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Abstract

Lyman's Law is a general phonotactic restriction in Japanese which prohibits two voiced obstruents within the same morpheme. This law manifests itself, for example, in the blockage of Rendaku, a phenomenon which voices the initial consonant of the second member of a compound. Lyman's Law blocks Rendaku when the second member already contains a voiced obstruent. Lyman's Law has been formulated as a general phonotactic restriction against two voiced obstruents (Itô and Mester, 1986), and believed to hold only in native words, not in loanwords, because there are many loanwords that violate this restriction (e.g. [gaado] 'guard' and [bagu] 'bug': Itô and Mester, 2003, 2008).

Building on Vance (1980), Tateishi (2003) and Nishimura (2003, 2006), however, this study shows that Lyman's Law is active even in loanwords, and nonce words more generally. In Experiments I and II, native speakers of Japanese judged Rendaku in nonce words to be less natural when it resulted in a violation of Lyman's Law. In Experiment III, native speakers of Japanese judged devoicing of real loanwords and nonce words to be more natural when devoicing was caused by Lyman's Law. Therefore, the three experiments, as a package, show that Lyman's Law is active both as a blocker and a trigger of phonological alternations. A general implication of this study is that a restriction with many lexical exceptions can still impact native speakers' treatment of loanwords and nonce words, as predicted by theories that posit that constraints are violable (Legendre et al., 1990a,b; Prince and Smolensky, 1993/2004).

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1. Introduction

Perhaps one of the most well-known phonological alternations in Japanese is Rendaku (also known as “sequential voicing”), in which the first consonant of the second member of a compound becomes voiced, as in (1) (see Haraguchi, 2001; Itô and Mester, 1986, 1995, 1999, 2003, 2008; Kubozono, 2005; Labrune, 2012; McCawley, 1968; Otsu, 1980; Vance, 1980, 1987 among many others).¹ Also well known is Lyman's Law (Lyman, 1894; Vance, 2007), one of the factors which blocks Rendaku. This law states that Rendaku is blocked when the second member already contains a voiced obstruent, as in (2). (Lyman's Law is not the only restriction that blocks Rendaku; for example, Rendaku applies mainly to native words: e.g. Itô and Mester, 1986, 1995, 2008; Labrune, 2012; McCawley, 1968.)

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¹ [h] is arguably underlyingly—or at least historically—/p/ (McCawley, 1968:124 Rule 9), and becomes [b] as a result of Rendaku. The status of /p/ as an underlying form of [h] is not universally accepted (see e.g. Fukazawa et al., 2002; Labrune, 2012; Shibatani, 1990). It is beyond the scope of this paper to explicate why [h] becomes a bilabial voiced stop as a result of Rendaku. It could be that this labiality comes from an underlying /p/, or that this “crazy rule” (Bach and Harms, 1972) came about as a result of a sequence of historical changes.

- (1) Rendaku
- /nise+**tanuki**/ → [nise**danuki**] ‘fake raccoon’
 - /nise+**karasu**/ → [nise**garasu**] ‘fake crow’
 - /nise+**sakura**/ → [nise**zakura**] ‘fake cherry trees’
 - /nise+**hajira**/ → [nise**hajira**] ‘fake pillar’
- (2) Lyman’s Law blocks Rendaku
- /nise+**tamago**/ → [nise**tamago**], *[nise**damago**] ‘fake egg’
 - /nise+**kagi**/ → [nise**kagi**], *[nise**gagi**] ‘fake key’
 - /nise+**sawagi**/ → [nise**sawagi**], *[nise**zawagi**] ‘fake fuss’
 - /nise+**hanabi**/ → [nise**hanabi**], *[nise**banabi**] ‘fake firework’

Lyman’s Law has been formalized as a general phonotactic restriction, OCP(voice), which prohibits two voiced obstruents within the same morpheme (Itô and Mester, 1986) (the rest of this paper refers to OCP(voice) as simply the OCP).² The OCP not only blocks Rendaku, but also functions as a general phonotactic restriction: native words do not generally allow two voiced obstruents within the same morpheme ([**ɸuda**] ‘amulet’, [**buta**] ‘pig’, *[**buda**]: Itô and Mester, 1986, 2003). The OCP, however, is believed to hold only in native words, because many loanwords do not obey the OCP (e.g. [**bagu**] ‘bug’, [**bobu**] ‘Bob’, and see (7) below for more examples).

To capture this observation, Itô and Mester (2003, 2008) propose that a faithfulness constraint that protects underlying voicing for loanwords is ranked above the markedness constraint OCP, implying the inactivity of the OCP in loanwords (cf. Fukazawa and Kitahara, 2005). They claim that the OCP is not active in loanwords, as we can observe from the following quote³: “[a] quick glance at the data in (47)–(49), which include examples like *dibaidaa* ‘divider’ and *bagabondo* ‘vagabond’, is sufficient to dispel any notion that a restriction against co-occurrence of voiced obstruents could be at work in the foreign vocabulary (Itô and Mester, 2003:41).” See also Itô and Mester (1995) where the domain of Lyman’s Law (as well as Rendaku) is restricted to the native vocabulary.⁴

However, despite the existence of many loanwords violating the OCP, there are three pieces of evidence that the OCP may still be active in loanwords, and nonce words more generally. One note is in order here before proceeding. This paper assumes that loanwords and nonce words are treated alike by the grammar, at least in Japanese (Kubozono, 1996). For example, both loanwords and nonce words show default accentuation patterns in Japanese (e.g. Katayama, 1998; Kawahara and Kao, 2012; Kubozono, 1996, 2006, 2008; Labrune, 2012; McCawley, 1968; Shinohara, 2000); neither native words nor Sino-Japanese words allow voiced geminates, while both loanwords and nonce words allow them (Itô and Mester, 1995, 1999, 2008).

The first piece of evidence for the activity of the OCP in nonce words comes from experiments reported in Vance (1980). Vance (1980) shows by way of wug-experiments (Berko, 1958 *et seq.*) that given nonce words, Japanese speakers apply Rendaku less often when the second morpheme already contains a voiced obstruent. In this regard, Lyman’s Law seems to affect the application of Rendaku to nonce words.

Second, Tateishi (2003) points out that when the English plural suffix *-s* is used in Japanese, it is usually pronounced as [zu], as in (3). However, it tends to be pronounced as [su] when the stem already contains a voiced obstruent, as in (4) (see also Fukazawa and Kitahara, 2005; Itô and Mester, 2006; Kurisu, 2007; Mutsukawa, 2007; Oshita, 2010 for further data, discussion, and analyses of this pattern).⁵

- (3) *-s* pronounced as [zu]
- [**ʃu-zu**] ‘shoes’
 - [**suwaroo-zu**] ‘Swallows’
 - [**ɸaitaa-zu**] ‘Fighters’

² This paper uses the two terms “Lyman’s Law” and “OCP” interchangeably, although it may be more accurate to consider Lyman’s Law as a blockage effect of Rendaku, and the OCP as a phonotactic markedness restriction which is responsible for the blockage effect. I also note that the restriction against two voiced obstruents within the same morpheme is not the only restriction on Rendaku that Lyman found (Vance, 2007).

³ While Itô and Mester (2003) are quite explicit about the inactivity of Lyman’s Law in loanwords, later in the book they do note one of the pieces of evidence for the activity of the OCP in loanwords, discovered by Nishimura (2003, 2006), which is discussed in (5) below of this paper.

⁴ Ohno (2000) argues that Rendaku is determined lexically (not phonologically), and suggests also that “[t]his view questions Lyman’s Law as a synchronic factor as well” (162 fn. 7). Although this view is different from Itô and Mester’s in that it denies Rendaku and Lyman’s Law as phonological altogether, it shares the basic idea that Lyman’s Law is inactive in the mind of Japanese speakers.

⁵ Post-nasal environments tend to encourage voicing in the pronunciation of this suffix, even at the cost of violating the OCP (e.g. [**doragon-zu**] ‘Dragons’) (Fukazawa and Kitahara, 2005). This voicing can be attributed to a general post-nasal voicing effect found in many languages (Hayashi and Iverson, 1998; Hayes and Stivers, 1995; Pater, 1999, 2001), which can be attributed to the articulatory difficulty of stopping voicing after nasals. See also Vance (2007) and references cited therein (fn. 28) as well as Labrune (2012:116) for the claim that nasals encourage Rendaku of the following consonants.

- (4) -s pronounced as [su]
- [taigaa-su] 'Tigers'
 - [kabu-su] 'Cubs'
 - [reidii-su] 'ladies'
 - [daburu-su] 'doubles'

Although there are a number of exceptions to these generalizations (e.g. [sokku-su] 'socks', [jankii-su] 'Yankees', [kaadinaru-zu] 'Cardinals' and [buru-zu] 'Bulls') and this "devoicing" of [zu] is a suffix-specific phenomenon (Mutsukawa, 2007), the data in (3) and (4) indicate that the OCP may be active in loanwords.

Third, cross-linguistically, the OCP is well known for not only blocking phonological patterns (McCarthy, 1986) but also triggering phonological alternations (Yip, 1988), and this dual nature of the OCP is observed in Japanese as well. Nishimura (2003, 2006) argues that the devoicing of OCP-violating geminates is grammatical in loanwords, as in (5), but the devoicing of non-OCP-violating geminates is ungrammatical, as in (6). Therefore, it is the OCP that is responsible for the devoicing of geminates (see also Kawahara, 2006). An interesting twist, which Experiment III below will address, is that according to Nishimura (2003, 2006), devoicing is ungrammatical for singleton consonants, even when they violate the OCP, as in (7).

- (5) (Optional) grammatical devoicing of OCP-violating geminates
- /baddo/ → [batto] 'bad'
 - /bagger/ → [bakku] 'bag'
 - /doggu/ → [dokku] 'dog'
- (6) Ungrammatical devoicing of non-OCP-violating geminates
- /sunobbu/ → *[sunoppu] 'snob'
 - /reddo/ → *[retto] 'red'
 - /eggu/ → *[ekku] 'egg'
- (7) Ungrammatical devoicing of OCP-violating singletons
- /gibu/ → *[gipu] 'give'
 - /bagu/ → *[baku] 'bug'
 - /dagu/ → *[daku] 'Doug'

To summarize, on the one hand, there are many loanwords that violate the OCP, or Lyman's Law, as in (7). On the other hand, there are some pieces of evidence that suggest that the OCP may nevertheless be active in loanwords and nonce words.

Given this evidence, and in response to the claim that Lyman's Law is inactive in loanwords (Itô and Mester, 2003, 2008), this paper follows up on Vance (1980), Tateishi (2003) and Nishimura (2003, 2006) to test whether the OCP is active or not in loanwords and nonce words in Japanese, using a phonological judgment paradigm. This experimental methodology has been shown to reveal subtle aspects of native speakers' phonological knowledge (see e.g. Berent and Shimron, 1997; Daland et al., 2011; Frisch and Zawaydeh, 2001; Greenberg and Jenkins, 1964; Hayes, 2000; Kawahara, 2011a,b; Kawahara and Kao, 2012; Pertz and Bever, 1975; Shademan, 2007). The three experiments reported in this paper show that indeed, the OCP is active in real loanwords as well as in nonce words.

Experiments I and II replicate Vance's (1980) experiment with a naturalness rating experiment. They expand on Vance (1980) by including a larger set of controlled stimuli and by gathering data from many more speakers. The results show that Lyman's Law is active in making Rendaku less natural even in nonce words. Experiment III shows that Japanese speakers judge devoicing of voiced stops more natural when devoicing resolves violations of the OCP in both real loanwords and nonce words. The results provide experimental support for Nishimura's (2003, 2006) contention that Lyman's Law is active in loanwords, as a trigger of devoicing. Taken as a package, the experiments suggest that the OCP is active both as a trigger and a blocker of phonological patterns in the nonce word phonology of Japanese. More generally, this study shows that a phonotactic restriction with many lexical exceptions can impact native speakers' judgment patterns.

2. Experiment I: Lyman's Law and Naturalness of Rendaku

2.1. Introduction

The first experiment builds on Vance (1980) to investigate whether Lyman's Law manifests itself in the blockage of Rendaku in nonce words. Vance (1980) showed through wug-testing (Berko, 1958) that native Japanese speakers apply Rendaku to nonce words less often when Rendaku results in a violation of the OCP. Moreover, he showed that this

Table 1

The list of the stimuli in Experiment I. The stimuli used in Vance (1980) are shown with an asterisk next to them.

No-OCP violation	Local OCP-violation	Non-local OCP-violation
tamura*	taguta*	tatsuga*
tatsuka*	tozumi	tenago
taruna	tegura	tomiba
kimane*	kidake*	kitage*
kikake*	kobono	koriga
katoni	kabomo	kamagi
semaro*	sebato*	sekabo*
sekato*	segeha	soyoga
sutane	sozumo	sukaza
honara*	hobasa*	hokada*
hotaka*	haboke	hekazu
hinumi	hogore	hemiga

blockage of Rendaku is more likely when the blocker consonant is closer to the potential undergoer of Rendaku. Ihara et al. (2009) also found the locality effect of the OCP, although its observed locality effect decreased from 1984 to 2005 in their study.⁶ (See also Oshita, 2010 and Tanaka, 2008 for relevant discussion on the locality effect of Lyman's Law.)

The current experiment aims to replicate the two findings of Vance (1980)—the activity of Lyman's Law and its locality effect—using a larger pool of stimuli by way of a naturalness judgment paradigm. While Vance (1980) had 50 stimuli in total, the set of stimuli contained words with various syllable structures, and thus had only 4 items for particular conditions, as shown in Table 1. The current experiment includes a larger set of stimuli by controlling syllable structures. The current experiment also gathered many more participants using an internet-based experimentation technique (Reips, 2002; Sprouse, 2011). The current experiment, in short, aims to quantitatively reexamine a conflict between the finding by Vance (1980) and the claim that Lyman's Law is inactive in loanwords (Itô and Mester, 2003, 2008), using a large set of experimental data.

2.2. Method

2.2.1. Stimuli

Table 1 lists the stimuli for Experiment I. There were three conditions: no-OCP-violation condition, local OCP-violation condition, and non-local OCP-violation condition. All of the stimuli were trisyllabic nonce words with only light, CV syllables. For each condition, there were three items with initial [t], three items with initial [k], three items with initial [s], and three items with initial [h] (hence a total of 12 items per each condition). These four consonants are all of the potential undergoers of Rendaku. Initial [p] was not included, because no native words start with a (singleton) [p] (Itô and Mester, 1995, 1999, 2008), and Rendaku applies mainly to native words (e.g. Itô and Mester, 1986, 1995, 2008; Labrune, 2012; McCawley, 1968). The stimuli contained all Vance's (1980) relevant stimuli to replicate his results. The stimuli in Table 1 with an asterisk next to them are those taken from Vance (1980).⁷

2.2.2. Task

In this experiment Japanese speakers rated the naturalness of Rendaku. Following Vance (1980), in this experiment, the participants were told that the stimuli were old Japanese words, which used to exist in Old Japanese.⁸ The *hiragana* orthography was used to convey the idea that the stimuli are old native words, because this type of orthography is used to write native words in Japanese orthographic convention (see e.g. Labrune, 2012). The current experiment used these procedures because if the participants considered the stimuli as non-native words, they could judge all Rendaku patterns to be unnatural, because loanwords do not undergo Rendaku. Experiment II below will address the question of whether this specific instruction affected the results or not.

⁶ Ihara et al. (2009) did not compare OCP-violating items and non-OCP violating items; all of their stimuli violate the OCP.

⁷ For *tamura*, Vance (1980) actually used *tanuma*, but *tanuma* was avoided because it is an existing family name. An anonymous reviewer pointed out that *hotaka* is a place name that exists in Japan. Post-hoc analyses showed that this item and the other two [h]-initial items received similar ratings (3.16 vs. 3.22 in Experiment I and 3.33 vs. 3.13 in Experiment II).

⁸ See also Zuraw (2000, 2010) who used a similar technique for Tagalog.

After the participants expressed their consent regarding the participation of the experiment, the initial instructions explained what Rendaku is with some actual examples. In the main section of the experiment, for each question, the participants were presented with one stimulus and asked to judge the naturalness of Rendaku when the stimulus is used as a second member of a compound. The first element of the compounds was always *nise* 'fake'. A sample question is therefore: "when you create a compound with *nise* 'fake' and *tamura*, how natural would you find it to pronounce it as [nise+damuma] (as opposed to [nise+tamura])?". The instructions and the stimuli were presented in Japanese orthography. The *hiragana* orthography was used for the stimuli in order to encourage the participants to consider the stimuli as old native words (recall that *hiragana* is usually used for native words). This experiment used a 5-point scale: 5. "very natural", 4. "somewhat natural", 3. "neither natural nor unnatural", 2. "somewhat unnatural", and 1. "very unnatural". The main session was preceded by a practice phase in which they practiced the question format with three real words and three nonce words.

2.2.3. Procedure

Experiment I used SurveyMonkey (<http://surveymonkey.com/>) to run the online experiment. The first page of the experimental website presented a consent form and the instructions of the experiment. After the instructions, each page presented one trial. The order of the stimuli was randomized by hand. At the end of the experiment, the participants were asked if they were familiar with Lyman's Law. Most participants of the experiment were undergraduate students at a Japanese university, and they received extra credit for their class.

2.2.4. Participants

Fifty-four native speakers of Japanese participated in this experiment. Two of them reported that they were familiar with Lyman's Law, and their data was excluded from the following analysis.

2.2.5. Statistics

A general linear mixed model (Baayen, 2008; Baayen et al., 2008) compared the three different conditions. The analysis was implemented using R (R Development Core Team, 1993–2012) with the `lme4` package (Bates et al., 2011). The random factors were items and subjects. The *p*-values were calculated by the Markov chain Monte Carlo method using the `languageR` package (Baayen, 2009).

2.3. Results

Fig. 1 illustrates the average naturalness ratings of the three conditions with the 95% confidence intervals. The participants rated Rendaku most natural when it does not violate Lyman's Law (average rating = 3.42). The difference between the non-OCP violating condition and the two OCP-violating conditions was significant ($t = -10.95$, $p < .001$). Within the two OCP-violating conditions, the participants judged Rendaku less natural when it resulted in local OCP violation (2.76 vs. 2.86), but the difference between the two OCP-violating conditions was not significant ($t = 1.48$, n.s.).⁹

2.4. Discussion

First, the results of Experiment I support Vance's (1980) findings that although Lyman's Law has many lexical exceptions in loanwords, it is still active in nonce words. This finding is inexplicable under the view that Lyman's Law is completely inactive—or "turned off"—in loanwords or nonce words.

Second, the experiment could not replicate the locality effect of the OCP that Vance (1980) and Ihara et al. (2009) found: the distance between the blocker consonant and the potential Rendaku undergoer did not seem to matter (at least not significantly). Ihara et al. (2009) found that the locality effect of the OCP's blockage of Rendaku decreased from 1984 to 2005 in their study, and it may be that this trend continued and that the locality effect has disappeared by 2011 (when the current experiment was conducted).

⁹ An anonymous reviewer raised a concern about using parametric analyses for the data obtained using a 5-point scale. To address this concern, post-hoc non-parametric analyses (Wilcoxon tests) were run, and revealed the same results: the effect of OCP was significant ($p < .001$), while the effect of locality was not.

Also, the consonants differed slightly in their overall naturalness ratings of Rendaku: [h] = 2.86, [s] = 3.00, [t] = 3.06, [k] = 3.14. See Ihara et al. (2011) for an extensive study exploring the segmental effects on Rendaku.

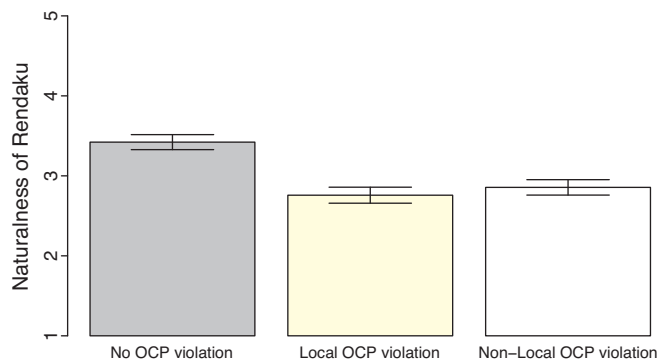


Fig. 1. The average naturalness ratings in the three conditions in Experiment I. The error bars represent 95% confidence intervals.

3. Experiment II: Lyman's Law and Naturalness of Rendaku 2

3.1. Introduction

The previous experiment shows that Japanese speakers find Rendaku to be less natural when it results in a violation of Lyman's Law. A question remains, however, whether Lyman's Law was active in Experiment I because the experimental protocol encouraged the speakers to consider the stimuli as (old) native Yamato words.¹⁰ The second experiment therefore did not encourage the participants to consider the stimuli as old Japanese words, and instead asked them to consider the stimuli as true nonce words.

3.2. Method

The method was almost identical to Experiment I, except that the instructions did not say that the stimuli were old Japanese words. Instead the stimuli were presented as nonce words (*muimigo* in Japanese). Also, the stimuli were written with *katakana* orthography to convey the idea that the stimuli were nonce words (loanwords and nonce words are usually written with *katakana* in the Japanese orthographic convention: see e.g. Labrune, 2012). A total of forty-eight native speakers, again mainly undergraduate students from a Japanese university, completed the experiment, but three of them reported that they were familiar with Lyman's Law. There was no overlap between the remaining forty-five speakers and those who participated in Experiment I.

3.3. Results

Fig. 2 illustrates the average naturalness ratings of the three conditions in Experiment II. Again the participants rated Rendaku most natural when it does not violate the OCP (average rating = 3.35), and this difference between the non-OCP violating condition and the two OCP-violating conditions was significant ($t = -10.82$, $p < .001$). In this experiment, the participants judged Rendaku to be more natural when it resulted in local, rather than non-local, OCP-violation (2.79 vs. 2.67); however, the difference between the two OCP-violating conditions was not significant ($t = -1.87$, n.s.).¹¹

3.4. Discussion

Experiment II shows that even when the stimuli are presented as true nonce words, rather than old Japanese words, Lyman's Law is still active. The results thus extend on Experiment I and Vance (1980), in which the stimuli were presented

¹⁰ As an anonymous reviewer points out, it may be interesting to compare the results of Experiment I with a new experiment using real Yamato words in a future study. Such a study may address the question of whether the instructions in Experiment I indeed forced the participants to use their knowledge of the native phonology (although a difference between real Yamato words and "nonce Yamato words" still remains).

¹¹ Again post-hoc non-parametric Wilcoxon tests were run inspired by a suggestion from an anonymous reviewer. The analyses revealed the same results: the effect of OCP was significant ($p < .001$), but not the effect of locality.

Also, as in Experiment I, the consonants differed slightly in their overall naturalness ratings of Rendaku: [h] = 2.79, [s] = 2.94, [t] = 3.03, [k] = 2.99. The fact that Rendaku of [h] was judged to be most unnatural both in Experiments I and II may be because it involves a change in place of articulation as well; i.e. speakers disprefer phonological alternations that involve more featural/perceptual changes (Prince and Smolensky, 1993/2004; Steriade, 2001/2008). See also Ihara et al. (2011) for related discussion.

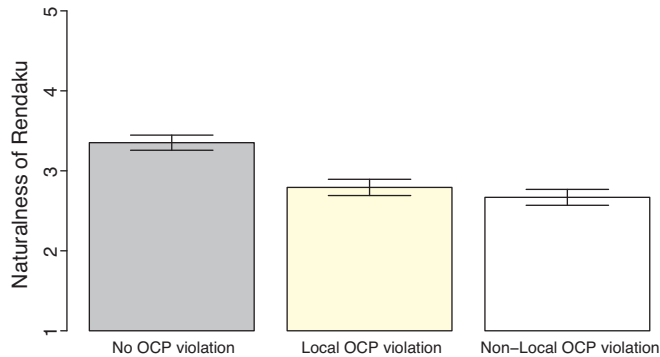


Fig. 2. The average naturalness ratings in the three conditions in Experiment II. The error bars represent 95% confidence intervals.

as old Japanese words. The results show that the effects of the OCP are not limited to native words, but extend to nonce words in general, regardless of whether they are considered to be old native words or true nonce words. On the other hand, the current experiment did not find evidence for the locality effect between the blocker consonant and the potential undergoer of Rendaku.

The similarity between the results of Experiment I and those of Experiment II shows that Lyman's Law is active regardless of whether the Japanese speakers conceive the stimuli as old Yamato Japanese, as in Vance (1980), or pure nonce words as in the current experiment; i.e. the difference in the experimental instructions does not seem to matter. The current results therefore show that the activity of Lyman's Law in the minds of Japanese speakers is more general than what was found in Vance (1980)—it is active even when Japanese speakers consider the stimuli to be nonce words. More generally, as a methodological point, it shows that it is possible to use nonce words to test aspects of Rendaku, even though in actual production, Rendaku is mainly limited to native words. In turn, it also shows that nonce word experiments may reveal interesting aspects of Rendaku; i.e. just because Rendaku is limited to real words, it does not mean that we cannot use nonce words to experimentally test aspects of Rendaku (see also Ihara et al., 2009, 2011; Tamaoka et al., 2009 for recent experiments on Rendaku using nonce words).

4. Experiment III: Naturalness of devoicing

4.1. Introduction

The previous two experiments have shown that Lyman's Law is active as a blocker of Rendaku even in nonce words. Recall now that Nishimura (2003, 2006) argues that devoicing of geminates is grammatical in OCP-violating real words, but it is impossible with singletons and OCP-violating singletons.¹² The relevant examples are repeated in (8)–(10).

- (8) Grammatical devoicing of OCP-violating geminates
- /baddo/ → [batto] 'bad'
 - /baggū/ → [bakku] 'bag'
 - /doggu/ → [dokku] 'dog'
- (9) Ungrammatical devoicing of non-OCP-violating geminates
- /sunobbu/ → *[sunoppu] 'snob'
 - /reddo/ → *[retto] 'red'
 - /eggu/ → *[ekku] 'egg'
- (10) Ungrammatical devoicing of OCP-violating singletons
- /gibu/ → *[gipu] 'give'
 - /bagu/ → *[baku] 'bug'
 - /dagu/ → *[daku] 'Doug'

¹² The pattern of obstruent devoicing in Japanese loanwords has received much attention in the recent phonological literature (Coetzee and Pater, 2011; Crawford, 2009; Farris-Trimble, 2008; Haraguchi, 2006; Hayes, 2009; Itô and Mester, 2008; Kaneko and Iverson, 2009; Kawahara, 2008; McCarthy, 2008; Pater, 2009; Pycha et al., 2006; Rice, 2006; Steriade, 2004; Tanaka, 2010; Tateishi, 2002; Tesar, 2007). See Kawahara (2011a) for a review of theoretical discussion based on this phenomenon.

By way of a naturalness judgment experiment, Experiment III tests the productivity of this OCP-induced devoicing to further verify the activity of Lyman's Law in Japanese loanwords. A crucial difference between the current experiment and the previous two experiments is that the current experiment tests the activity of the OCP as a trigger (Yip, 1988), not as a blocker (McCarthy, 1986), of a phonological pattern.

Experiment III builds on naturalness judgment experiments of several types of consonants in Japanese loanwords previously reported in Kawahara (2011a,b), but there are several important differences between these two experiments and the current experiment. First, the current study extends on these studies in addressing whether OCP is active in real loanwords as well as in nonce words (Kawahara, 2011a,b used only real loanwords). Second, unlike Kawahara (2011b), this experiment tests whether the OCP affects the naturalness of devoicing of singleton consonants as well, in order to make the comparison with geminates symmetric (Nishimura argues that devoicing is possible only for geminates) (see also Kawahara, 2011a). Third, this study controls for syllable structures and syllable length unlike the previous two studies. Finally, the focus here is, in tandem with Experiments I and II, to test the dual nature of OCP as a blocker and a trigger of phonological patterns.¹³ In summary, by studying both nonce words and real loanwords at the same time, this experiment intends to test the generality of the activity of Lyman's Law, extending on Experiments I and II reported above.

4.2. Method

4.2.1. Stimuli

The stimuli of Experiment III had four grammatical conditions: OCP-violating geminates, non-OCP-violating geminates, OCP-violating singletons, and non-OCP-violating singletons. Each of the grammatical conditions had nine test items. The stimulus items were all disyllabic, and all the target consonants were placed in word-internal position, as there are no word-initial geminates in Japanese. The stimuli used in this experiment were chosen with the following steps. First, real words containing OCP-violating geminates were chosen (as many of them as possible), because this condition has the least number of existing lexical items. This selection process resulted in nine items. Among those nine items, six of them had [d] followed by (epenthetic) [o], and the remaining three had [g] followed by (epenthetic) [u]. No stimuli with [b] were included, because there does not exist a lexical item containing an OCP-violating [bb] ([bb] is very rare in Japanese loanwords in the first place: Katayama, 1998; Shirai, 2002). Then the words for the other three grammatical conditions were selected with six items with [d] and three items with [g], as listed in Table 2. Short vowels were used before geminates and singleton [g]. Long vowels and diphthongs ([ai, oi]) had to be used before singleton [d], because disyllabic loanwords with an initial short vowel almost always have a geminate [dd], not a singleton [d] (one exception, [bado], is a truncated form of [badominton]).

In nonce words (in Table 3), on the other hand, there is no such restriction against a short vowel followed by a singleton [d], so short vowels were used in order to make the vowel length identical across the four conditions.

4.2.2. Task

Native speakers of Japanese rated the naturalness of devoicing in the four grammatical conditions described in Tables 2 and 3. For each question, the participants were presented with one stimulus word and asked to judge the naturalness of the form that undergoes devoicing of the target consonants (e.g. given [baddo], how natural would you find it to pronounce it as [batto]?). The *katakana* orthography was used for the stimuli, both for real loanwords and nonce words, following the standard Japanese orthographic convention (Labrune, 2012). As with the previous two experiments, this experiment used a 5-point scale: A. "very natural", B. "somewhat natural", C. "neither natural nor unnatural", D. "somewhat unnatural", and E. "very unnatural". (This scale was converted to a numerical one later for statistical analyses. The alphabetical scale was used due to a restriction on Sakai (see below).) The main session was blocked into two parts. The first block presented all the real loanword stimuli. After a break, the second block presented all the nonce word stimuli. The entire experiment was organized this way because making judgments about real loanwords was assumed to be easier for the participants. (See Kawahara, 2010 which addresses how this order may have affected the results.)

4.2.3. Procedure

Sakai, a Java-based online system hosted by Rutgers University, was used to run the online experiment (<https://sakai.rutgers.edu/portal>). The first page of the website presented a consent form and the instructions. After the participants expressed their consent to participate in the experiment and read the instructions, the main session started. In the main

¹³ This experiment was first reported as a part of a manuscript circulated earlier in 2010 (Kawahara, 2010), now substantially shortened and circulated as Kawahara (2012). This project intended to test the effect of experimental variables on the judgment of devoicing of several types of consonants in Japanese, extending on Kawahara (2011a,b). The intended focus of this experiment, as reported in this paper, is thus different from Kawahara (2010, 2012).

Table 2
The list of the real loanword stimuli.

OCP GEM		GEM		OCP SING		SING	
baddo	'bad'	heddo	'head'	bado	'badminton'	muudo	'mood'
beddo	'bed'	reddo	'red'	gaido	'guide'	waido	'wide'
daddo	'dad'	uddo	'wood'	zoido	common name	haido	'hide'
deddo	'dead'	kiddo	'kid'	boodo	'board'	roodo	'road'
guddo	'good'	maddo	'mad'	gaado	'guard'	riido	'lead'
goddo	'god'	roddo	'rod'	baado	'bird'	huudo	'food'
baggu	'bag'	eggu	'egg'	dagu	'Doug'	hagu	'hug'
biggu	'big'	reggu	'leg'	bagu	'bug'	magu	'mug'
doggu	'dog'	taggu	'tag'	d₃ogu	'jog'	ragu	'rag'

Table 3
The list of the nonce word stimuli.

OCP GEM	GEM	OCP SING	SING
buddo	keddo	budo	hudo
boddo	koddo	dado	rado
doddo	ruddo	dodo	rudo
geddo	yuddo	dedo	rido
gaddo	taddo	gado	yudo
giddo	kuddo	gudo	wado
boggu	uggu	degu	hegu
gaggu	oggu	dogu	negu
goggu	naggu	gegu	mugu

session, each page presented one trial. Sakai randomized the order of the stimuli within each block. At the end of the experiment, the participants were asked if they were familiar with the devoicing phenomenon.

4.2.4. Participants

Thirty-three native speakers of Japanese, again university students in Japan, participated in this experiment; one participant reported that s/he was familiar with the OCP-induced devoicing phenomenon, so the data of this participant was excluded from the following analysis. Since this test was distributed to a university different from that for Experiments I and II, it is extremely unlikely that there is an overlap between the participants of Experiment III and those of Experiments I and II.

4.3. Results

Fig. 3 illustrates the average naturalness ratings of the four grammatical conditions, averaged over the thirty-two participants across all the relevant items in each condition. In the real loanword condition, the order of the naturalness rating was: OCP-violating geminates (4.23) > non-OCP-violating geminates (3.29) > OCP-violating singletons (2.69) > non-OCP-violating singletons (2.21).¹⁴ A linear mixed model shows that all factors were significant: OCP ($t = 5.29, p < .001$), geminacy ($t = 11.81, p < .001$), and the interaction ($t = 2.68, p < .01$).¹⁵ Since the interaction term was significant, the effect of OCP was assessed separately for the singleton pair (i.e. OCP-violating singletons vs. non-OCP-violating singletons) and the geminate pair (i.e. OCP-violating geminates vs. non-OCP-violating geminates). This post-hoc analysis revealed a significant effect of OCP on the singleton pair ($t = 5.59, p < .001$) and the geminate pair ($t = 10.39, p < .001$).

¹⁴ One remaining issue is a question of how this ordering between the four grammatical conditions is reflected in production patterns in actual utterances by native speakers of Japanese: do native speakers of Japanese devoice OCP-violating geminates most frequently, and non-OCP violating geminates next, and so on? An extensive production study is necessary to compare the current results with the actual production patterns. This issue is an important one, which is however beyond the scope of this paper. See Sano (2012) for an attempt to investigate the effect of Lyman's Law on devoicing using the Corpus of Spontaneous Japanese (Maekawa, 2004).

Another remaining question is why non-OCP violating geminates received higher scores than OCP-violating singletons, despite the fact that both structures are allowed in the loanword phonology of Japanese and prohibited in the native phonology of Japanese. Kawahara (2011a,b, 2012) offer various speculations about this issue, although admittedly none of these is substantially supported by empirical evidence.

¹⁵ Both of the main effects were also significant by non-parametric Wilcoxon tests, both at the $p < .001$ level.

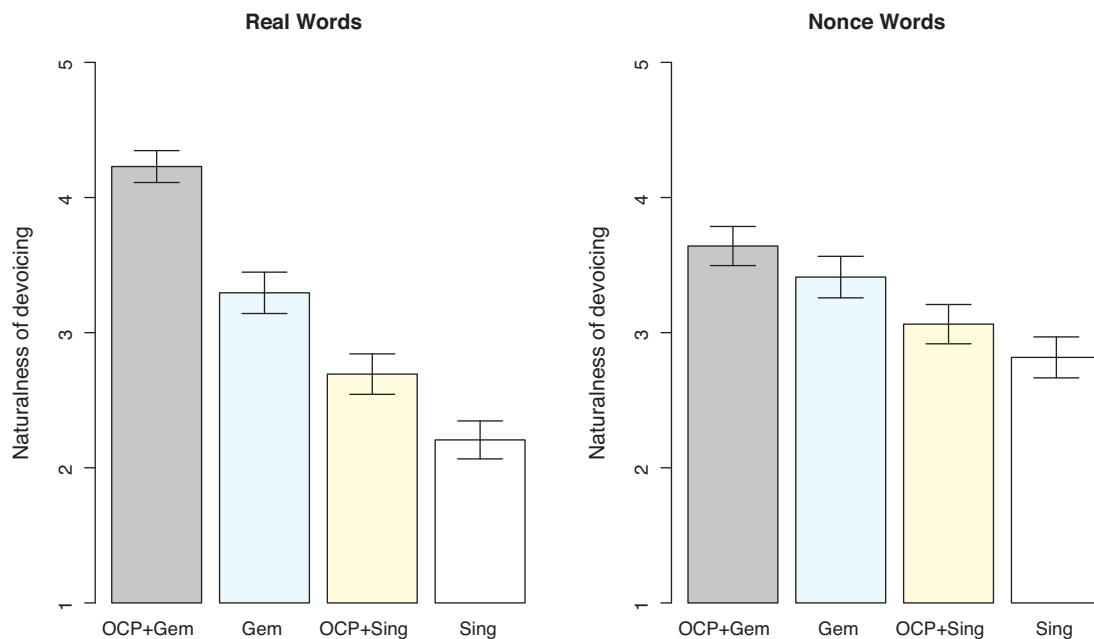


Fig. 3. The average naturalness ratings of devoicing in the four conditions both in real words and nonce words in Experiment III. The error bars represent 95% confidence intervals.

For nonce words, the order of the naturalness ratings was the same as the real word condition: OCP-violating geminates (3.64) > non-OCP-violating geminates (3.41) > OCP-violating singletons (3.06) > non-OCP-violating singletons (2.81). Statistically, OCP ($t = 2.56$, $p < .05$) and geminacy ($t = 6.44$, $p < .001$) were significant, but their interaction was not ($t = 0.06$, n.s.).¹⁶ The lack of interaction shows that the effect of OCP is (more or less) uniform between the singleton pair and the geminate pair.

4.4. Discussion

The results support the activity of the OCP as a trigger of a phonological alternation (Yip, 1988) in the sense that Japanese speakers find devoicing more natural when devoicing is caused by the OCP. The effect of the OCP is evident both for the singleton pair and the geminate pair, despite the fact that Nishimura (2003, 2006) argues that devoicing is possible in geminates, not in singletons. Moreover, the effect of the OCP is also observed in nonce words as well as in real loanwords, a finding that extends beyond Kawahara (2011a,b). In short, these results show, for both real loanwords and nonce words, and both for singleton pairs and geminate pairs, that the OCP makes devoicing more natural. This finding again supports the general thesis of this paper that Lyman's Law is active in real loanwords and nonce words in general.

The statistical significance of the interaction term between geminacy and OCP for real loanwords is due to the fact that the effect of the OCP on the naturalness ratings is more substantial in geminate pairs (4.23 – 3.29 = 0.94) than in singleton pairs (2.69 – 2.21 = 0.48). This significant interaction may indicate that there may be something special about the combination of OCP and geminacy (i.e. OCP-violating geminates), which is consistent with Nishimura's (2003, 2006) intuition that devoicing is possible only for geminates. We should bear in mind however that the data for the nonce word stimuli did not show a significant interaction effect.

We also observe less variability in naturalness ratings across the four grammatical conditions in nonce words than in real words. As observed in Fig. 3, the most natural devoicing (OCP-violating geminates) is judged to be less natural in nonce words than in real words, and the least natural devoicing (non-OCP-violating geminates) is judged to be more natural in nonce words than in real words. This lower variability across the conditions in nonce words may be responsible for the lack of a significant interaction between OCP and geminacy; since “the grammatical space” is reduced in

¹⁶ Both of the main effects were significant by Wilcoxon tests (OCP: $p < .01$, Geminacy: $p < .001$).

nonce words, there may not be space left for OCP-violating geminates to have a rating that is high enough to yield a significant interaction between OCP and geminacy.

To statistically assess the reduction of variability in rating in the nonce word condition, the standard deviations across all tokens were calculated for each speaker separately for real words and nonce words. These standard deviations were statistically compared between the real words and nonce words using a Wilcoxon test. The average standard deviations are 1.30 for the real words and 1.03 for the nonce words, and the difference is significant ($p < .001$). Although there is this important difference between real words and nonce words, for the present purpose, what is most important is that OCP nevertheless had an impact on both the singleton pairs and the geminate pairs, both in the real word condition and the nonce word condition.

5. General discussion and conclusion

To summarize the overall results, the three experiments as a package show that Lyman's Law, or the OCP, is active in nonce words and loanwords, despite the fact that there are many loanwords that violate this phonotactic restriction. Furthermore, OCP is active both as a trigger (Yip, 1988) and as a blocker (McCarthy, 1986) of phonological patterns. The results support the findings that Lyman's Law is active even in the loanword phonology (and nonce word phonology) of Japanese (Nishimura, 2003, 2006; Tateishi, 2003; Vance, 1980).

Although the main purpose of this study was to challenge the claim that Lyman's Law is not active in loanwords, there are a few more general implications. First, it is well known that OCP functions both as a trigger and a blocker of phonological patterns, but to the best of my knowledge, the current study offers the first experimental demonstration for this dual nature of phonological constraints.

Second, this study adds to the body of literature suggesting that a restriction with many lexical exceptions can still impact native speakers' behavior, as predicted by theories such as Optimality Theory (McCarthy and Prince, 1993; Prince and Smolensky, 1993/2004) and Harmonic Grammar (Legendre et al., 1990a,b; Pater, 2009; Potts et al., 2010) which posit that constraints are violable, or that constraints are not simply "turned off" (see also e.g. Albright and Hayes, 2003; Coetzee, 2008; Frisch and Zawaydeh, 2001; Hayes and Londe, 2006; Kawahara and Kao, 2012; Pierrehumbert, 2001; Zuraw, 2000, 2010 for studies showing the productivity of patterns with lexical exceptions). In these theoretical frameworks in which constraints are violable, dominated constraints or constraints with low weights still affect speakers' linguistic behavior. Although this finding itself is not new, this study replicates the previous studies cited above. Furthermore, this study adds to this growing body of literature in two senses. It comes from a new language, namely, Japanese, and a new phonological restriction, namely, an OCP constraint on a voicing contrast.

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References

- Albright, A., Hayes, B., 2003. Rules vs. analogy in English past tenses: a computational/experimental study. *Cognition* 90, 119–161.
- Baayen, H.R., 2008. *Analyzing Linguistic Data: A Practical Introduction to Statistics Using R*. Cambridge University Press, Cambridge.
- Baayen, H.R., 2009. *Language R: R Package*.
- Baayen, H.R., Davidson, D., Bates, D.M., 2008. Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language* 59, 390–412.

- Bach, E., Harms, R., 1972. How do languages get crazy rules? In: Stockwell, R., Macaulay, R. (Eds.), *Linguistic Change and Generative Theory*. Indiana University Press, Bloomington, pp. 1–21.
- Bates, D., Maechler, M., Bolker, B., 2011. lme4: Linear Mixed-Effects Models Using Eigen and R Packages. R Package.
- Berent, I., Shimron, J., 1997. The representation of Hebrew words: evidence from the Obligatory Contour Principle. *Cognition* 64, 39–72.
- Berko, J., 1958. The child's learning of English morphology. *Word* 14, 150–177.
- Coetzee, A.W., 2008. Grammaticality and ungrammaticality in phonology. *Language* 84 (2), 218–257.
- Coetzee, A.W., Pater, J., 2011. The place of variation in phonological theory. In: Goldsmith, J.A., Riggle, J., Yu, A. (Eds.), *The Handbook of Phonological Theory*, 2nd ed. Blackwell-Wiley, Oxford, pp. 401–431.
- Crawford, J.C., 2009. *Adaptation and Transmission in Japanese Loanword Phonology*. Doctoral dissertation, Cornell University.
- Daland, R., Hayes, B., White, J., Garellek, M., Davis, A., Norrmann, I., 2011. Explaining sonority projection effects. *Phonology* 28 (2), 197–234.
- Farris-Trimble, A., 2008. *Cumulative Faithfulness Effects in Phonology*. Doctoral dissertation, Indiana University.
- Frisch, S., Zawaydeh, B.A., 2001. The psychological reality of OCP-Place in Arabic. *Language* 77, 91–106.
- Fukazawa, H., Kitahara, M., 2005. Ranking paradoxes in consonant voicing in Japanese. In: Van de Weijer, J., Nanjo, K., Nishihara, T. (Eds.), *Voicing in Japanese*. Mouton de Gruyter, Berlin/New York, pp. 105–122.
- Fukazawa, H., Kitahara, M., Ota, M., 2002. Acquisition of phonological sub-lexica in Japanese: an OT account. In: Otsu, Y. (Ed.), *Proceedings of the Tokyo Conference on Psycholinguistics*. Hitsuji Shobo, Tokyo, pp. 97–114.
- Greenberg, J., Jenkins, J., 1964. Studies in the psychological correlates of the sound system of American English. *Word* 20, 157–177.
- Haraguchi, S., 2001. On Rendaku. *Onin Kenkyuu [Phonological Studies]* 4, 9–32.
- Haraguchi, S., 2006. A Theory of Voicing. Ms. Meikai University (available at: <http://www.let.leidenuniv.nl/ulcl/faculty/vdweijer/jvoice/haraguchi.pdf>).
- Hayashi, E., Iverson, G., 1998. The non-assimilatory nature of postnasal voicing in Japanese. *Journal of Humanities and Social Sciences* 38, 27–44.
- Hayes, B., 2000. Gradient well-formedness in Optimality Theory. In: Dekkers, J., Van der Leeuw, F., Van de Weijer, J. (Eds.), *Optimality Theory: Phonology, Syntax, and Acquisition*. Oxford University Press, Oxford, pp. 88–120.
- Hayes, B., 2009. Embedding grammar in a quantitative framework: case studies from phonology and metrics. A handout for a minicourse at Brown University (available at: <http://www.linguistics.ucla.edu/people/hayes/brownminicourse/>).
- Hayes, B., Londe, Z., 2006. Stochastic phonological knowledge: the case of Hungarian vowel harmony. *Phonology* 23, 59–104.
- Hayes, B., Stivers, T., 1995. Postnasal Voicing. Ms. University of California, Los Angeles (available at: <http://www.linguistics.ucla.edu/people/hayes/phonet/ncphonet.pdf>).
- Ihara, M., Tamaoka, K., Lim, H., 2011. Rendaku and markedness: Phonetic and phonological effects. Talk presented at Tokyo Circle of Phonologists (TCP), July 24.
- Ihara, M., Tamaoka, K., Murata, T., 2009. Lyman's Law effect in Japanese sequential voicing: questionnaire-based nonword experiments. In: The Linguistic Society of Korea (Ed.), *Current Issues in Unity and Diversity of Languages: Collection of the Papers Selected from the 18th International Congress of Linguists*. Dongam Publishing Co., Republic of Korea.
- Itô, J., Mester, A., 1986. The phonology of voicing in Japanese: theoretical consequences for morphological accessibility. *Linguistic Inquiry* 17, 49–73.
- Itô, J., Mester, A., 1995. Japanese phonology. In: Goldsmith, J. (Ed.), *The Handbook of Phonological Theory*. Blackwell, Oxford, pp. 817–838.
- Itô, J., Mester, A., 1999. The phonological lexicon. In: Tsujimura, N. (Ed.), *The Handbook of Japanese Linguistics*. Blackwell, Oxford, pp. 62–100.
- Itô, J., Mester, A., 2003. *Japanese Morphophonemics*. MIT Press, Cambridge.
- Itô, J., Mester, A., 2006. Indulgentia parentum filiorum pernicies: lexical allomorphy in Latin and Japanese. In: Bakovic, E., Itô, J., McCarthy, J.J. (Eds.), *Wondering at the Natural Fecundity of Things: Essays in Honor of Alan Prince*. Linguistics Research Center, University of California, Santa Cruz, pp. 201–211.
- Itô, J., Mester, A., 2008. Lexical classes in phonology. In: Miyagawa, S., Saito, M. (Eds.), *The Oxford Handbook of Japanese Linguistics*. Oxford University Press, Oxford, pp. 84–106.
- Kaneko, E., Iverson, G., 2009. Phonetic and other factors in Japanese on-line adaptation of English final consonants. In: Inagaki, S., Hirakawa, M. (Eds.), *Studies in Language Sciences 8: Papers from the Eighth Annual Conference of the Japanese Society for Language Science*. Kuroshio Publications, Tokyo, pp. 179–195.
- Katayama, M., 1998. *Optimality Theory and Japanese Loanword Phonology*. Doctoral dissertation, University of California, Santa Cruz.
- Kawahara, S., 2006. A faithfulness ranking projected from a perceptibility scale: the case of voicing in Japanese. *Language* 82 (3), 536–574.
- Kawahara, S., 2008. Phonetic naturalness and unnaturalness in Japanese loanword phonology. *Journal of East Asian Linguistics* 17 (4), 317–330.
- Kawahara, S., 2010. Modes of Phonological Judgments. Ms. Rutgers University (talk presented at the University of Pennsylvania, October 14, 2010).
- Kawahara, S., 2011a. Aspects of Japanese loanword devoicing. *Journal of East Asian Linguistics* 20 (2), 169–194.
- Kawahara, S., 2011b. Japanese loanword devoicing revisited: a rating study. *Natural Language and Linguistic Theory* 29 (3), 705–723.
- Kawahara, S., 2012. Testing Japanese Loanword Devoicing: Addressing Task Effects. Ms. Rutgers University.
- Kawahara, S., Kao, S., 2012. The productivity of a root-initial accenting suffix, [-zu]: judgment studies. *Natural Language and Linguistic Theory* 30 (3).
- Kubozono, H., 1996. Syllable and accent in Japanese: evidence from loanword accentuation. *The Bulletin (Phonetic Society of Japan)* 211, 71–82.
- Kubozono, H., 2005. Rendaku: its domain and linguistic conditions. In: van der Weijer, J., Nanjo, K., Nishihara, T. (Eds.), *Voicing in Japanese*. Mouton de Gruyter, Berlin/New York, pp. 5–24.
- Kubozono, H., 2006. Where does loanword prosody come from? A case study of Japanese loanword accent. *Lingua* 116, 1140–1170.
- Kubozono, H., 2008. Japanese accent. In: Miyagawa, S., Saito, M. (Eds.), *The Oxford Handbook of Japanese Linguistics*. Oxford University Press, Oxford, pp. 165–191.

- Kurusu, K., 2007. Asymmetric voicing and relativized markedness. In: *Proceedings of Formal Approaches to Japanese Linguistics*, vol. 4. pp. 161–172.
- Labrone, I., 2012. *The Phonology of Japanese*. Oxford University Press, Oxford.
- Legendre, G., Miyata, Y., Smolensky, P., 1990a. Harmonic grammar – a formal multi-level connectionist theory of linguistic well-formedness: an application. In: *Proceedings of the Twelfth Annual Conference of the Cognitive Science Society*, Lawrence Erlbaum Associates, Mahwah, NJ, pp. 884–891.
- Legendre, G., Miyata, Y., Smolensky, P., 1990b. Harmonic grammar – a formal multi-level connectionist theory of linguistic well-formedness: theoretical foundations. In: *Proceedings of the Twelfth Annual Conference of the Cognitive Science Society*, Lawrence Erlbaum Associates, Mahwah, NJ, pp. 388–395.
- Lyman, B.S., 1894. Change from surd to sonant in Japanese compounds. *Oriental Studies of the Oriental Club of Philadelphia* 1–17.
- Maekawa, K., 2004. Nihongo hanashikotoba koopasu-no gaiyoo [An overview of the Corpus of Spontaneous Japanese]. *Nihongo Kagaku* 15, 111–133.
- McCarthy, J.J., 1986. OCP effects: gemination and antigemination. *Linguistic Inquiry* 17, 207–263.
- McCarthy, J.J., 2008. *Doing Optimality Theory*. Blackwell-Wiley, Oxford.
- McCarthy, J.J., Prince, A., 1993. *Prosodic Morphology I: Constraint Interaction and Satisfaction*. Ms. University of Massachusetts and Rutgers University.
- McCawley, J.D., 1968. *The Phonological Component of a Grammar of Japanese*. Mouton, The Hague.
- Mutsukawa, M., 2007. The realization of the English plural morpheme in Japanese and the accessibility to the morphological information. Talk presented at the 32nd Meeting of Kansai Linguistic Society.
- Nishimura, K., 2003. *Lyman's Law in Loanwords*. MA thesis, Nagoya University.
- Nishimura, K., 2006. Lyman's Law in loanwords. *Onin Kenkyuu [Phonological Studies]* 9, 83–90.
- Ohno, K., 2000. The lexical nature of Rendaku in Japanese. In: Nakayama, M., Quinn, C. (Eds.), *Japanese/Korean Linguistics 9*. CSLI Publications, Stanford, pp. 151–164.
- Oshita, T., 2010. *Chiumumei-wo arawasu keitaiso-no yuusei/musei-no ketteiyoo-ini tsuite-no koosatsu-onsetsu kouzou-to dakuon-ga ataeru eikyuu-ni tsuite [An analysis of factors determining the voicing value of a morpheme representing team names: the effects of syllable structure and voicing]*. MA thesis, Kobe University.
- Otsu, Y., 1980. Some aspects of Rendaku in Japanese and related problems. In: Farmer, A., Otsu, Y. (Eds.), *MIT Working Papers in Linguistics*, vol. 2. Department of Linguistics and Philosophy, MIT, Cambridge, MA, pp. 207–228.
- Pater, J., 1999. Austronesian nasal substitution and other NC effects. In: Kager, R., van der Hulst, H., Zonneveld, W. (Eds.), *The Prosody–Morphology Interface*. Cambridge University Press, Cambridge, pp. 310–343.
- Pater, J., 2001. Austronesian nasal substitution revisited: what's wrong with *NC (and what's not). In: Lombardi, L. (Ed.), *Segmental Phonology in Optimality Theory: Constraints and Representations*. Cambridge University Press, Cambridge, pp. 159–182.
- Pater, J., 2009. Weighted constraints in generative linguistics. *Cognitive Science* 33, 999–1035.
- Pertz, D.L., Bever, T.G., 1975. Sensitivity to phonological universals in children and adolescents. *Language* 51, 149–162.
- Pierrehumbert, J.B., 2001. Stochastic phonology. *GLOT* 5, 1–13.
- Potts, C., Pater, J., Jesney, K., Bhatt, R., Becker, M., 2010. Harmonic grammar with linear programming: from linear systems to linguistic typology. *Phonology* 27 (1), 1–41.
- Prince, A., Smolensky, P., 1993/2004. *Optimality Theory: Constraint Interaction in Generative Grammar*. Blackwell, Malden/Oxford [originally circulated in 1993 as Ms. University of Colorado and Rutgers University].
- Pycha, A., Shin, E., Shosted, R., 2006. Directionality of assimilation in consonant clusters: an experimental approach. *UC Berkeley Phonology Lab Annual Report* 152–166.
- R Development Core Team, 1993–2012. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria.
- Reips, U.-D., 2002. Standards for Internet-based experimenting. *Experimental Psychology* 49 (4), 243–256.
- Rice, K., 2006. On the patterning of voiced stops in loanwords in Japanese. *Toronto Working Papers in Linguistics* 26, 11–22.
- Sano, S.-I., 2012. *Patterns in Avoidance of Marked Segmental Configurations in Japanese Loanword Phonology*. Ms. International Christian University.
- Shademan, S., 2007. *Grammar and Analogy in Phonotactic Well-Formedness Judgments*. Doctoral dissertation, University of California, Los Angeles.
- Shibatani, M., 1990. *The Languages of Japan*. Cambridge University Press, Cambridge.
- Shinohara, S., 2000. Default accentuation and foot structure in Japanese: evidence from Japanese adaptations of French words. *Journal of East Asian Linguistics* 9, 55–96.
- Shirai, S., 2002. *Gemination in Loans from English to Japanese*. MA thesis, University of Washington.
- Sprouse, J., 2011. A validation of Amazon Mechanical Turk for the collection of acceptability judgments in linguistic theory. *Behavior and Research Methods* 43 (1), 155–167.
- Steriade, D., 2001/2008. The phonology of perceptibility effects: the P-map and its consequences for constraint organization. In: Hanson, K., Inkelas, S. (Eds.), *The Nature of the Word*. MIT Press, Cambridge [originally circulated in 2001 as Ms. UCLA], pp. 151–179.
- Steriade, D., 2004. Projecting non-lexical phonology from phonetic knowledge. Talk presented at *Symposium on Phonological Theory: Representations and Architectures* (the City University of New York, February 20–21, 2004).
- Tamaoka, K., Ihara, M., Murata, T., Lim, H., 2009. Effects of first-element phonological-length and etymological-type features on sequential voicing (Rendaku) of second elements. *Journal of Japanese Linguistics* 25, 17–38.
- Tanaka, S.-I., 2008. Adjacency in the typology of dissimilation: another case of Lyman's Law in Japanese loanwords. Talk presented at *PhonoFesta*.
- Tanaka, S.-I., 2010. The eurhythmics of segmental melody. *Onsei Kenkyuu [Journal of the Phonetic Society of Japan]* 13 (3), 44–52.
- Tateishi, K., 2002. Bunpou-no ichibutoshite-no goisou-no zehi [Lexical strata as a part of grammar]. *Onsei Kenkyuu [Journal of the Phonetic Society of Japan]* 6 (1), 34–43.

- Tateishi, K., 2003. Phonological patterns and lexical strata. In: *The Proceedings of International Congress of Linguistics XVII (CD-ROM)*. Matfyz Press, Prague.
- Tesar, B., 2007. A Comparison of Lexicographic and Linear Numeric Optimization Using Violation Difference Ratios. Ms. Rutgers University.
- Vance, T.J., 1980. The psychological status of a constraint on Japanese consonant alternation. *Linguistics* 18, 245–267.
- Vance, T.J., 1987. *An Introduction to Japanese Phonology*. SUNY Press, New York.
- Vance, T.J., 2007. Have we learned anything about Rendaku that Lyman didn't already know? In: Frellesvig, B., Shibatani, M., Smith, J.C. (Eds.), *Current Issues in the History and Structure of Japanese*. Kuroshio, Tokyo, pp. 153–170.
- Yip, M., 1988. The Obligatory Contour Principle and phonological rules: a loss of identity. *Linguistic Inquiry* 19, 65–100.
- Zuraw, K., 2000. *Patterned Exceptions in Phonology*. Doctoral dissertation, University of California, Los Angeles.
- Zuraw, K., 2010. A model of lexical variation and the grammar with application to Tagalog nasal substitution. *Natural Language and Linguistic Theory* 28 (2), 417–472.