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

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 was believed to hold only in native words, not in loanwords, because there are many loanwords that violate this restriction (e.g. [**ga**a**d**o] 'guard' and [**b**a**g**u] 'bug': Itô and Mester 2003, 2008).

Building on Vance (1980), Tateishi (2003) and Nishimura (2003), however, this study shows that Lyman's Law is active even in loanwords, or nonce words in general. In Experiments I and II, native speakers of Japanese judged Rendaku less natural when it resulted in a violation of Lyman's Law. In Experiment III, native speakers of Japanese judged devoicing 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' behavior, as predicted by theories that posit that constraints are violable (Legendre et al., 1990a,b; Prince and Smolensky, 1993/2004).

1   Introduction

Perhaps one of the most well-known phonological alternations in Japanese is Rendaku, 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; McCawley 1968; Otsu 1980; Vance 1980, 1987 among many others).[1] Also well known is Lyman's Law (Lyman, 1894), one

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[1][h], which is arguably underlyingly /p/ (McCawley 1968: Rule 9, p124.), becomes [b].

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 applies to Rendaku; for example, Rendaku applies mainly to native words: e.g. Itô and Mester 1986, 1995; McCawley 1968.)

(1) Rendaku

    a. /nise+**t**anuki/ → [nise**d**anuki] 'fake raccoon'

    b. /nise+**k**arasu/ → [nise**g**arasu] 'fake crow'

    c. /nise+**s**akura/ → [nise**z**akura] 'fake cherry trees'

    d. /nise+**h**aʃira/ → [nise**b**aʃira] 'fake pillar'

(2) Lyman's Law blocks Rendaku

    a. /nise+**t**amago/ → [nise**t**ama**g**o], *[nise**d**ama**g**o] 'fake egg'

    b. /nise+**k**agi/ → [nise**k**a**g**i], *[nise**g**a**g**i] 'fake key'

    c. /nise+**s**awagi/ → [nise**s**awa**g**i], *[nise**z**awa**g**i] 'fake fuss'

    d. /nise+**h**anabi/ → [nise**h**ana**b**i], *[nise**b**ana**b**i] 'fake firework'

Lyman's Law has been formalized as a general phonotactic restriction, the OCP(voice), which prohibits two voiced obstruents within the same morpheme (Itô and Mester, 1986) (the rest of this paper refers to the 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 ([ɸu**d**a] 'amulet', [**b**uta] 'pig', *[**bud**a]: 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. [**b**a**g**u] 'bug', [**b**o**b**u] 'Bob', and see (7) below for more examples).

Reflecting this observation, Itô and Mester (2003, 2008) propose that a faithfulness constraint that protects 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 foreign words[3]: "[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.

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, or nonce words in general. One note is

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[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.

[3]They do note some of the evidence for the activity of the OCP in loanwords discussed just below.

in order here before proceeding. This paper assumes that loanwords and nonce words are treated alike by 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; McCawley 1968); neither native words nor Sino-Japanese words allow voiced geminates, while both loanwords and nonce words allow them (Itô and Mester, 1995, 1999).

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

Second, Tateishi (2003) pointed 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 for discussion of this pattern).[4]

(3)   *-s* pronounced as [zu]

    a.   [ʃuu-zu] 'shoes'

    b.   [suwaroo-zu] 'Swallows'

    c.   [ɸaitaa-zu] 'Fighters'

(4)   *-s* pronounced as [su]

    a.   [tai**g**aa-su] 'Tigers'

    b.   [ka**b**u-su] 'Cubs'

    c.   [rei**d**ii-su] 'Ladies'

    d.   [**d**a**b**uru-su] 'doubles'

Although there are a number of exceptions to these generalizations (e.g. [sokkusu] 'socks', [jankiisu] 'Yankees', [kaa**d**inaruzu] 'Cardinals' and [**b**uruzu] '(Chicago) Bulls') and this "devoicing" of [zu] is a suffix-specific phenomenon, 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) argues that the devoicing of OCP-violating geminates is grammatical in loanwords, as in (5), but the devoicing of non-OCP-violating

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[4]Post-nasal environments tend to encourage voicing in the pronunciation of this suffix, even at the cost of violating the OCP (e.g. [dora**g**on-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).

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), devoicing is ungrammatical for singleton consonants, even when they violate the OCP, as in (7).

(5)   Optional grammatical devoicing of OCP-violating geminates

    a.   /**b**a**dd**o/ → [**b**atto] 'bad'

    b.   /**b**a**gg**u/ → [**b**akku] 'bag'

    c.   /**d**o**gg**u/ → [**d**okku] 'dog'

(6)   Ungrammatical devoicing of non-OCP-violating geminates

    a.   /suno**bb**u/ → *[sunoppu] 'snob'

    b.   /re**dd**o/ → *[retto] 'red'

    c.   /e**gg**u/ → *[ekku] 'egg'

(7)   Ungrammatical devoicing of OCP-violating singletons

    a.   /**gi**b**u/ → *[**gi**pu] 'give'

    b.   /**b**agu/ → *[**b**aku] 'bug'

    c.   /**d**agu/ → *[**d**aku] '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 the OCP may nevertheless be active in loanwords and nonce words.

Given these pieces of evidence, 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) to test whether the OCP is active or not in loanwords and nonce words, using a phonological judgment paradigm. This experimental methodology has been shown to reveal subtle aspects of native speakers' phonological knowledge (see e.g. Daland et al. 2011; Greenberg and Jenkins 1964; Hayes 2000; Anonymous 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 words, or nonce words in general.

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 stimuli and by gathering 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) contention that Lyman's Law is active in loanwords. Taken as a package, 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: 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 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.[5] 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 (as shown in Table 1 below, Vance 1980 had 4 items for particular conditions), by way of a naturalness judgment paradigm. The current experiment also gathered many more participants using 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 much larger set of 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 stimuli were trisyllabic nonce words only with light 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], and Rendaku applies mainly to native words. 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).[6]

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

[6]For *tamuma*, Vance (1980) actually used *tanuma*, but *tanuma* was avoided because it is an existing family name.

Table 1: The list of the stimuli in Experiment I.

no-OCP violation	local OCP-violation	non-local OCP-violation
tamuma*	ta**g**uta*	tatsu**g**a*
tatsuka*	to**z**umi	tena**g**o
taruna	te**g**ura	tomi**b**a
ki**m**ane*	ki**d**ake*	kita**g**e*
kikake*	ko**b**ono	kori**g**a
katoni	ka**b**omo	kama**g**i
se**m**aro*	se**b**ato*	seka**b**o*
sekato*	se**g**eha	soyo**g**a
sutane	so**z**umo	suka**z**a
ho**n**ara*	ho**b**asa*	hoka**d**a*
hotaka*	ha**b**oke	heka**z**u
hinumi	ho**g**ore	hemi**g**a

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. These instructions were provided because if the participants considered the stimuli as foreign 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.

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 session 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 *tamuma*, how natural would you find it to pronounce it as [nise+damuma] (as opposed to [nise+tamuma])?". 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 (*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 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 linguistic 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 were excluded from the following analysis.

2.2.5 Statistics

A general linear mixed model (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

Figure 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 ($t = 1.48, n.s.$).[7]

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 in loanwords or nonce words.

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[7]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.
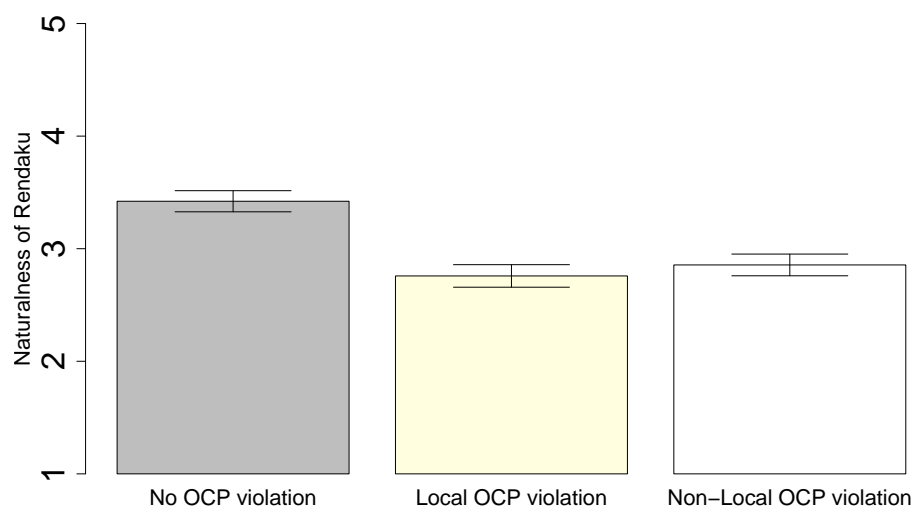
Figure 1: The average naturalness ratings in Experiment I. The error bars represent 95% confidence intervals.

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, and it may be that this trend continued and that the locality effect has diminished by 2011 (when the current experiment was conducted).

3 Experiment II: Naturalness of Rendaku 2

3.1 Introduction

The previous experiment shows that Japanese speakers find Rendaku 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 experiment protocol encouraged the speakers to consider the stimuli as (old) native Yamato words. 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.
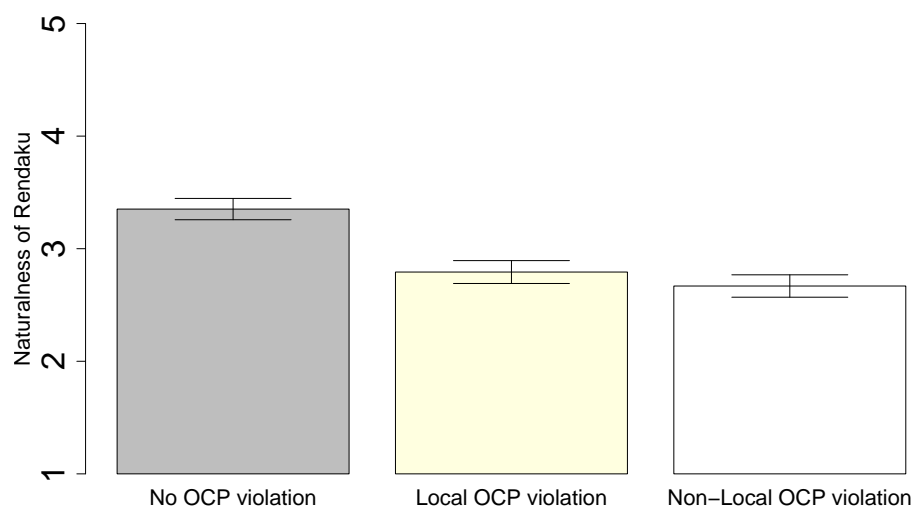
Figure 2: The average naturalness ratings in Experiment II. The error bars represent 95% confidence intervals.

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 orthography convention). A total of 48 native speakers completed the experiment, but three of them reported that they were familiar with Lyman's Law. There was no overlap between the remaining 45 speakers and those who participated in Experiment I.

3.3 Results

Figure 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 (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 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 ($t = -1.87, n.s.$). [8]

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[8]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.

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 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 as 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 listeners 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 shows 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 listeners consider the stimuli as nonce words. More generally, as a methodological point, it shows that it is possible to use nonce words to test aspects of Rendaku, although in actual production, Rendaku is mainly limited to native words. In turn it shows that nonce word experiments may reveal interesting aspects of Rendaku (see also Ihara et al. 2009, 2011 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) argues that the OCP can trigger devoicing of geminates in real loanwords, as shown in (5). 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.[9] 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 Anonymous (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

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[9]This experiment was reported as a part of a manuscript circulated earlier in (2010) (Anonymous, 2011c), which itself was an extension of Anonymous (2011a,b).

words. Second, unlike Anonymous (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 Anonymous 2011a). Third, this study controls for syllable structures and syllable length unlike the previous two studies. Finally, the focus here is to, in tandem with Experiments I and II, test the dual nature of OCP as a blocker and a trigger of phonological patterns. 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 consisted of four grammatical conditions: OCP-violating geminates, non-OCP-violating geminates, OCP-violating singletons, and non-OCP-violating singletons. The experiment had 9 items per each condition. The stimuli were all disyllabic, and all the target consonants were word-internal. The stimuli were chosen in the following way. First, real words containing OCP-violating geminates—the most rare case—were chosen (as many of them as possible), which resulted in 9 items. Among 9 items, 6 items contained [d] followed by epenthetic [o], and 3 items contained [g] followed by epenthetic [u]. No stimuli with [b] were used, because [bb] is very rare in Japanese loanwords (Katayama, 1998) and therefore no disyllabic words with OCP-violating [bb] were found. Then the words for the other three 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]) were used before singleton [d], because disyllabic loanwords with an initial short vowel almost always have a geminate [dd], not a singleton [d] ([bado] is a truncated form of [badominton]). In nonce words, there is no restriction against a short vowel followed by a singleton [d], so short vowels were used in order to make the vowel length comparable across the four conditions.

4.2.2 Task

Native speakers of Japanese rated the naturalness of devoicing in the four grammatical conditions. 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. 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". The main session was blocked into

Table 2: The list of the real loanword stimuli.

OCP GEM		GEM		OCP SING		SING	
ba**dd**o	'bad'	he**dd**o	'head'	**b**a**d**o	'badminton'	muu**d**o	'mood'
be**dd**o	'bed'	re**dd**o	'red'	**g**ai**d**o	'guide'	wa**id**o	'wide'
da**dd**o	'dad'	u**dd**o	'wood'	**z**oi**d**o	common name	hai**d**o	'hide'
de**dd**o	'dead'	ki**dd**o	'kid'	**b**oo**d**o	'board'	roo**d**o	'road'
gu**dd**o	'good'	ma**dd**o	'mad'	**g**aa**d**o	'guard'	rii**d**o	'lead'
go**dd**o	'god'	ro**dd**o	'rod'	**b**aa**d**o	'bird'	huu**d**o	'food'
ba**gg**u	'bag'	e**gg**u	'egg'	**d**a**g**u	'Doug'	ha**g**u	'hug'
bi**gg**u	'big'	re**gg**u	'leg'	**b**a**g**u	'bug'	ma**g**u	'mug'
do**gg**u	'dog'	ta**gg**u	'tag'	**j**o**g**u	'jog'	ra**g**u	'rag'

Table 3: The list of the nonce words stimuli.

OCP GEM	GEM	OCP SING	SING
bu**dd**o	ke**dd**o	**b**u**d**o	hu**d**o
bo**dd**o	ko**dd**o	**d**a**d**o	ra**d**o
do**dd**o	ru**dd**o	**d**o**d**o	ru**d**o
ge**dd**o	yu**dd**o	**d**e**d**o	ri**d**o
ga**dd**o	ta**dd**o	**g**a**d**o	yu**d**o
gi**dd**o	ku**dd**o	**g**u**d**o	wa**d**o
bo**gg**u	u**gg**u	**d**e**g**u	he**g**u
ga**gg**u	o**gg**u	**d**o**g**u	ne**g**u
go**gg**u	na**gg**u	**g**e**g**u	mu**g**u

two parts. The first block presented the real loanword stimuli. After a break sign, the second block presented 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 Anonymous 2011c which addresses how this order may have affected the results.)

4.2.3 Procedure

Sakai was used to run the online experiment. The first page of the website presented a consent form and the instructions. After the instructions, each page presented one trial. Sakai randomized the order of the stimuli. At the end of the experiment, the participants were asked if they were familiar with the devoicing phenomenon.

4.2.4 Participants

Thirty-two native speakers of Japanese, again university students in Japan, participated in this experiment; none reported that they were familiar with the OCP-induced devoicing phenomenon.

4.3 Results

Figure 3 illustrates average naturalness ratings. In real loanwords, 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).[10] 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 ($t = 2.68, p < .01$). Since the interaction term was significant, the effect of OCP was assessed separately for the singleton pair and the geminate pair. This post-hoc analysis revealed a significant effect of OCP on the singleton pair ($t = 5.59, p < .001$) and the geminate pair ($t = 10.39, p < .001$)

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 ($t = 0.06, n.s.$). The lack of interaction shows that the effect of OCP is uniform between the singleton pair and the geminate pair.

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[10]One remaining issue is a question of how frequent devoicing happens in each type of consonant in actual production patterns. An extensive production study is necessary to compare the current results with the actual production patterns (and the intuitions of Nishimura 2003, for that matter), which is beyond the scope of this paper.
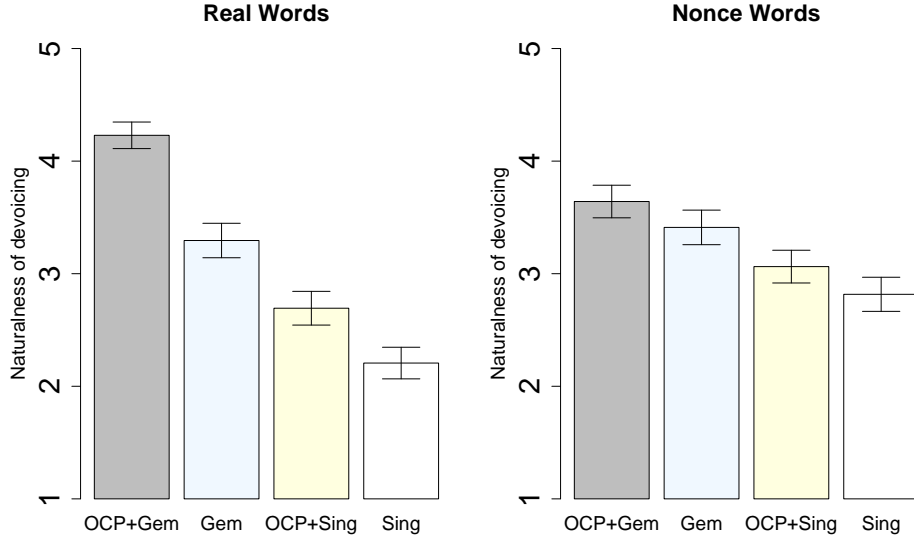
Figure 3: The average naturalness ratings of devoicing in Experiment III. The error bars represent 95% confidence intervals.

4.4 Discussion

The results support the activity of the OCP as a trigger of a phonological alternation (Yip, 1988) in a sense that Japanese speakers find devoicing more natural when devoicing is caused by the OCP. The effect of the OCP is tangible both for the singleton pair and the geminate pair, despite that Nishimura (2003) 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 Anonymous (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 significance of the interaction term for real loanwords is due to the fact that the effect of the OCP on the naturalness ratings is bigger in geminate pairs (4.23-3.29=0.94) than in singleton pairs (2.69-2.21=0.48). This significant interaction may thus indicate that there may be something special about OCP-violating geminates after all, which is consistent with Nishimura's intuitions that devoicing is possible only for geminates (although the significant interaction was not found for nonce words).

We also observe less variability in naturalness rating across the four grammatical conditions in nonce words than in real words. As observed in Figure 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. In other words, the grammatical space—the range within which acceptability ratings can vary—is generally reduced in nonce words. This reduction of the grammatical space in nonce words may be responsible for the lack of a significant interaction between OCP and geminacy in nonce words; there may not be a space left for OCP-violating geminates to have an acceptability rating that is high enough to yield a significant interaction between OCP and geminacy.

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

5   General discussion and conclusion

To summarize the 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; Tateishi, 2003; Vance, 1980).

Although the main purpose of this study was to show the activity of Lyman's Law in face of the claim that it 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 a restriction with many lexical exceptions can still impact native speakers' behavior, as predicted by theories such as Optimality Theory (Prince and Smolensky, 1993/2004) and Harmonic Grammar (Legendre et al., 1990a,b; Pater, 2009) which posit that constraints are violable, or that constraints are not simply "turned off" (e.g. Albright and Hayes 2003; Coetzee 2008; Frisch and Zawaydeh 2001; Hayes and Londe 2006; Kawahara and Kao 2012; Pierrehumbert 2001; Zuraw 2000). In these frameworks, 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 added 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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