Testing the OCP-labial effect on Japanese rendaku

Abstract

Japanese rendaku is a morphophonological phenomenon in which a morpheme-initial voiceless obstruent becomes voiced when it is the non-initial member of a compound. There are a number of factors that inhibit rendaku. A well-known factor is a voiced obstruent: Rendaku does not apply if the second member of compounds contains a voiced obstruent (i.e. Lyman's Law, or OCP (-son, voice)). This paper focuses on another factor to block rendaku. Although /h/ usually becomes labial [b] when rendaku applies (e.g., *hako* 'box' + *hune* 'ship' → *hako**b**une* 'ark'), the rendaku application of /h/ is blocked if the following consonant is labial [m] (e.g., *suna* 'sand' + *hama* 'beach' → *suna**h**ama* 'sand beach'/**suna**b**ama*). One hypothesis about this rendaku blocking is that, if /h/ became labial [b], it would beget a sequence of homorganic consonants [**b**…m], which would violate a putative OCP-labial effect. The current paper is the first report of an experiment that examined whether this restriction applies productively to nonce words that contain labial consonants. The results show that 1) the OCP-labial effect can be generalized in rendaku; 2) it works locally rather than non-locally; and 3) the applicability of rendaku is gradient: The more similar two consonants are, the more strongly they are disfavored. To account for this gradient effect, I argue that the process involves two OCP-labial constraints: OCP (labial) and OCP (labial, -continuant).

Keywords: Japanese; rendaku; OCP-labial effect

1. Introduction

In Japanese, one of the most intriguing consonants is the voiceless glottal fricative /h/, in that it shows several allophones and alternations with other consonant(s). For allophones (1a), /h/ is realized as a voiceless bilabial fricative [ɸ] before /u/, as a voiceless palatal fricative [ç] before /i/, and as [h] before /a, e, o/ (e.g., Labrune 2012; Tsujimura 2014). Gemination of /h/ occurs in loans and some compounds, as exemplified in (1b) (Labrune 2012; see also Kawagoe 2015). For alternations, /h/ turns into [p], [pp], or [b].[1] In Sino-Japanese as in (1c), in which bracketed *i* and *u* are underlyingly absent, /h/ turns into [p] when preceded by a nasal or moraic obstruent (Labrune 2012). The preceding consonant shows assimilation with the following [p], then resulting in [mp] or [pp], respectively. In native words, as in the first three examples in (1d), /h/ is geminated to [pp] to create emphatic forms (Labrune 2012).[2] In the last example in (1d), /h/ alternates with [p], with which the preceding consonant /k/ assimilates, with the underlying *u* not realized. In native words, the Japanese /h/ changes to [b] in post-nasal voicing, as in (1e) (e.g., Ito et al. 1995, 2001; Ito & Mester 1999; Rice 1997, 2005), or in rendaku, which will be explained below. The current paper explores the blocking phenomenon of rendaku in which /h/ does not become [b] in a certain environment.

(1) Allophones and alternations of the Japanese /h/

a. Allophones

/huku/	‘clothes’	→	[**ɸ**ɯkɯ]	/h/ → [ɸ]/_u
/hito/	‘person’	→	[**ç**ito]	/h/ → [ç]_i
/hana/	‘flower’	→	[hana]	/h/ → [h]/_a
/heso/	‘navel’	→	[heso]	/h/ → [h]/_e
/hosi/	‘star’	→	[hoʃi]	/h/ → [h]/_ o

[1] The current paper assumes that the *h* is /h/ in underlying forms. However, there is also the view that *h* is posited as /p/ in underlying forms (e.g., Ito & Mester 1999, 2015; McCawley 1968; Nasu 2015): the underlying /p/ is debuccalized to [h], since the singleton /p/ is not allowed to occur in the onset position in native and Sino-Japanese words (e.g., **pune* ‘ship’ → *hune* [ɸɯne]) (e.g., Ito & Mester 1995, 1999, 2008).

[2] While the prefix /su-/ in the second example in (1d) is not always followed by consonant geminates (e.g., *su* ‘bare’ + *te* ‘hand’ → [sɯde] ‘bare hand’/ *[sɯ**tt**e]), the prefix /ma-/ sometimes requires the following consonant to be geminated unless followed by consonants that are disallowed from geminating, such as glides (e.g., /ma-/ + /kuro/ ‘black’ → [ma**kk**ɯro]; /ma-/ + /siro/ ‘white’ → [ma**ʃʃ**iro]; /ma-/ + /aka/ ‘red’ → [ma**kk**a]; /ma-/ + /naka/ ‘middle’ → [ma**nn**aka]; /ma-/ + /maru/ ‘round’ → [ma**mm**arɯ]; cf. /ma-/ + /jonaka/ ‘night’ → [majonaka]/*[ma**jj**onaka]) (see e.g., Poser 1984:78; Shibatani 1990:104 for the prefix /ma-/).

b. Gemination

Loans

Mach	→	[ma**hh**a]
Gogh	→	[go**hh**o]

Compounds

juu	十 ‘ten’	+	hari	針 ‘needle’	→	juhhari ‘ten stitches’
[ʤɯː]			[hari]			[ʤɯ**hh**ari]
zet(u)	絶	+	huchoo	不調 ‘bad condition’	→	zehhuchoo ‘bad condition’
[zeʦ(ɯ)]			[ɸɯʧoː]			[ze**ɸɸ**ɯʧoː]

c. /h/ → [p] in Sino-Japanese words

sen	先	+	hai	輩	→	senpai ‘boss’
[seɴ]			[hai]			[se**mp**ai]
en	鉛	+	hitu	筆	→	enpitu ‘pencil’
[eɴ]			[çiʦɯ]			[e**mp**iʦɯ]
san	三 ‘three’	+	hun	分 ‘minute’	→	sanpun ‘three minutes’
[saɴ]			[ɸɯɴ]			[sa**mp**ɯɴ]
san	三 ‘three’	+	hen	編 ‘volume’	→	sanpen ‘three volumes’
[saɴ]			[heɴ]			[sa**mp**eɴ]
san	散	+	ho	歩	→	sanpo ‘walking’
[saɴ]			[ho]			[sa**mp**o]
sit(u)	失	+	hai	敗	→	sippai ‘failure’
[ʃiʦ(ɯ)]			[hai]			[ʃi**pp**ai]
zet(u)	絶	+	hin	品	→	zeppin ‘a superb piece of work’
[zeʦ(ɯ)]			[çiɴ]			[ze**pp**iɴ]
rok(u)	六 ‘six’	+	hun	分 ‘minute’	→	roppun ‘six minutes’
[rok(ɯ)]			[ɸɯɴ]			[ro**pp**ɯɴ]
it(i)	一 ‘one’	+	hen	片	→	ippen ‘a piece’
[iʧ(i)]			[heɴ]			[i**pp**eɴ]
it(i)	一 ‘one’	+	hon	本	→	ippon ‘a …; one …’
[iʧ(i)]			[hoɴ]			[i**pp**oɴ]

d. /h/ → [pp] in native words

suki	‘empty’	+	hara	‘stomach’	→	sukippara ‘empty stomach’
[sɯki]			[hara]			[sɯki**pp**ara]
su-	‘bare’ (prefix)	+	hadaka	‘naked’	→	suppadaka ‘naked’
[sɯ]			[hadaka]			[sɯ**pp**adaka]
ma-	‘truly’ (prefix)	+	hiruma	‘daytime’	→	mappiruma ‘daytime’
[ma]			[çirɯma]			[ma**pp**irɯma]
hik(u)	‘pull’	+	har(u)	‘stretch’	→	hipparu ‘pull’
[çik(ɯ)]			[har(ɯ)]			[çi**pp**arɯ]

e. /h/ → [b] in post-nasal voicing

hun	‘to step on’	+	har(u)	‘stretch’	→	hunbaru ‘stand firm’
[ɸɯɴ]			[har(ɯ)]			[ɸɯm**b**arɯ]

Japanese rendaku, called sequential voicing (Martin 1952), is a morphophonological phenomenon in which a morpheme-initial voiceless obstruent becomes voiced when it is the non-initial member of a compound (e.g., McCawley 1968; Ito & Mester 1986, 2003; Vance 1979, 1980, 1987, 2015, 2016; see also Vance & Irwin 2016 for a collection of recent papers on rendaku). It is well known that rendaku is blocked by Lyman’s Law if the second member of a compound already contains a voiced obstruent. In addition to Lyman’s Law, there are other factors that inhibit rendaku. One of them is that, although /h/ usually becomes labial [b] when rendaku applies, the rendaku application of /h/ is blocked if the following consonant is labial [m] (e.g., *suna* ‘sand’ + *hama* ‘beach’ → *suna**h**ama* ‘sand beach’/**suna**b**ama*; *kutu* ‘shoe’ + *himo* ‘lace’ → *kutu**h**imo* ‘shoelace’/**kutu**b**imo*) (Kawahara et al. 2006; Kawahara 2015a). One hypothesis about why rendaku is blocked in these forms is that an OCP-labial constraint is active in compound formation (*[**b**…m]) (see, e.g., Bye 2011; Goldsmith 1978; Leben 1973; McCarthy 1986; Odden 1986, 1988; Rose 2001; Suzuki 1998; Yip 1988 for OCP effects; see, e.g., Alderete & Frisch 2007; Bye 2011; Odden 1994; Selkirk 1993; Zuraw & Lu 2009 for OCP-labial effects). However, as will be seen in section 2, while we find many cases where rendaku is blocked when the resulting form will be [h…m], there are few words in which /h/ is followed by other labial consonants such as [ɸ, w]. Thus, we need to examine whether the rendaku blocking really comes from the OCP-labial effect or whether it is specific to words with [h…m].

The OCP-labial effect in Japanese has been examined by several studies through corpusbased and experimental approaches. As will be seen in section 2, Kawahara et al.'s (2006) dictionary-based survey showed that labial sequences are less likely to occur than we expect. Regarding experimental approaches, Kawahara and Sano (2014a, 2014b, 2016) examined identity avoidance of moras or consonants, including labial consonants, across the word boundary or within the second member of compounds. However, no study has tested in detail the OCP-labial effect on rendaku by examining all labial consonants.

The current paper is the first report of an experiment that examined whether the rendaku blocking applies productively to nonce words that contain labial consonants. The results show that 1) the OCP-labial effect can be generalized in rendaku; 2) it works locally rather than non-locally; and 3) the applicability of rendaku is gradient: [m] shows a stronger blocking effect on the applicability of rendaku than [ɸ] does. The last finding is observed in various languages: The more similar two consonants are, the more strongly they are disfavored (e.g., Berent & Shimron 2003; Berent et al. 2004; Buckley 1997; Frisch et al. 2004; Greenberg 1950; Pierrehumbert 1993). To account for this gradient effect, I argue that the process involves two OCP-labial constraints: OCP (labial) and OCP (labial, -continuant).

The organization of the current paper is as follows. Section 2 explicates the restriction on rendaku that this paper focuses on. Section 3 explains the experimental design and reports the results of the current experiment. Section 4 discusses the issue of the nature of the OCP-labial effect. Section 5 ends with concluding remarks.

2. OCP-labial effect in Japanese

2.1 OCP-labial effect on native words

In Japanese, there are five labial consonants [p, b, m, ɸ, w] (see section 3.4.2 for discussion of the place of articulation of /w/). While all of these can appear as a singleton consonant, there are some restrictions on geminate consonants [pp, bb, mm, ɸɸ, ww]. Of these labials, [p, m] can appear as geminated consonants in native words (e.g., [ka**pp**a] 'water spirit'; /simi + ri/ → [si**mm**iri] 'quiet, abject': see Mester & Ito 1989 for /ri/-suffixation) and loans (e.g., [ma**pp**ɯ] 'map'; [ka**mm**a] ~ [ko**mm**a] 'comma'). Gemination of voiced obstruents such as [b] is allowed to occur in loan words (e.g., [sɯno**bb**ɯ] 'snob'), but not in native words (Ito & Mester 1995, 1999). As for gemination of [ɸ], we find a few cases in Sino-Japanese compounds (e.g., [ze**ɸɸ**ɯʧoo] 'bad condition: Labrune 2012). Basically, geminated [w] never occurs in native, Sino-Japanese, and loan words. Note that the voiced obstruent [b] and glide [w] can be geminated when we create emphatic forms (e.g., [ʃoboi] 'useless' → [ʃo**bb**oi], cf. /ʃobo + ri/

→ [ʃombori]; [kawaii] 'cute' → [ka**ww**aii]) (see Kawahara 2015b: footnote 3 for voiced gemination in emphatic forms, Kawahara 2015c for a related discussion).

In the current paper, we assume that OCP-labial constraints are violated when singleton labial consonants are placed in each onset position within a word or across word boundaries. In other words, geminated labial consonants per se do not invite a violation of the OCP-labial constraints. In the remainder of section 2, we first look at whether the OCP-labial effect works in non-derived environments and then provide a survey of the OCP-labial effect on a derived environment, or rendaku. Kawahara et al. (2006), based on the large Japanese dictionary *Kōjien* (Shinmura 1998), investigated whether there are co-occurrence restrictions on the place of articulation in native words. The results showed that words with homorganic consonants are less likely to appear within a root than we may expect, and that labial sequences (N=86) are less likely to occur than labial-coronal (or coronal-labial) sequences (N=1,335) or labial-dorsal (or dorsal-labial) sequences (N=450).[3] Their study suggests that the OCP-labial effect seems to be active in native words, in the sense that words with labial sequences are less likely to occur. However, the restrictions are not absolute (Kawahara et al. 2006): in fact, we find native words with labial sequences (e.g., *mame* [mame] 'bean'; *mimi* [mimi] 'ear'; *momo* [momo] 'peach'; *humi* [ɸɯmi] 'letter, trample'). It is therefore safe to assume that, though there are fewer native words with identical place of articulation than we can expect, we need to admit that labial sequences per se are tolerated in non-derived environments (see section 4 for discussion).

2.2 OCP-labial effect on Japanese rendaku

We will examine the OCP-labial phenomenon in a derived environment, or rendaku, which is a morphophonological phenomenon in which a morpheme-initial voiceless obstruent /t, k, s, h/ becomes voiced [d, g, z, b], respectively, when it is the non-initial member of a compound. Illustrative examples are given in (2).

[3] For detailed analyses, see http://user.keio.ac.jp/~kawahara/yamato.htm.

(2) Typical examples of Japanese rendaku

aka	'red'	+	tama	'ball'	→	akadama 'red ball'
[aka]			[tama]			[aka**d**ama]
oo	'big'	+	tako	'octopus'	→	oodako 'big octopus'
[oː]			[tako]			[oː**d**ako]
umi	'sea'	+	kame	'turtle'	→	umigame 'sea turtle'
[ɯmi]			[kame]			[ɯmi**g**ame]
hi	'sun'	+	kasa	'umbrella'	→	higasa 'parasol'
[çi]			[kasa]			[çi**g**asa]
oo	'big'	+	same	'shark'	→	oozame 'big shark'
[oː]			[same]			[oː**z**ame]
oo	'big'	+	sake	'alcohol'	→	oozake 'heavy drinking'
[oː]			[sake]			[oː**z**ake]
hako	'box'	+	hune	'ship'	→	hakobune 'ark'
[hako]			[ɸɯne]			[hako**b**ɯne]
hude	'pencil'	+	hako	'box'	→	hudebako 'pencil case'
[ɸɯde]			[hako]			[ɸɯde**b**ako]

It is well known that rendaku is blocked by Lyman's Law if the second member of a compound already contains a voiced obstruent, as illustrated in (3). The initial consonant /t, k, s, h/ of the second example does not undergo rendaku because the second member of the compound already contains a voiced obstruent [b, d, g].

(3) Lyman's Law

hitori	'alone'	+	tabi	'travel'	→	hitoritabi 'travelling alone'
[çitori]			[tabi]			[çitoritabi]
						*hitoridabi [çitori**d**a**b**i]
ie	'house'	+	kagi	'key'	→	iekagi 'house key'
[ie]			[kagi]			[iekagi]
						*ie**g**agi [ie**g**a**g**i]
kuro	'black'	+	sabi	'rust'	→	kurosabi 'black rust'
[kɯro]			[sabi]			[kɯrosabi]
						*kurozabi [kɯro**z**a**b**i]

tori	‘bird’	+	hada	‘skin’	→	torihada ‘gooseflesh’
[tori]			[hada]			[torihada]
						*toribada [tori**bad**a]

In addition to Lyman’s Law, there are other factors that block rendaku (see Irwin 2012 for other factors that dampen rendaku). As already seen in (2), /h/ usually becomes labial [b] when rendaku applies, but the rendaku application of /h/ is inhibited if the following consonant is labial [m], as in (4) (Kawahara et al. 2006; Kawahara 2015a). Note that labial [m] per se is not the potential segment that blocks rendaku, as can be seen in examples (2). Hypothesizing that the blocking on rendaku in (4) may be attributed to the OCP-labial effect, the current paper examines whether it can be generalized in rendaku, and whether it works locally, non-locally, or both.

(4) Rendaku blocking in /h…m/

suna	‘sand’	+	hama	‘beach’	→	sunahama ‘sand beach’
[sɯna]			[hama]			[sɯnahama]
						*sunabama [sɯna**bam**a]
mai	‘dancing’	+	hime	‘princess’	→	maihime ‘dancing girl’
[mai]			[çime]			[maiçime]
						*maibime [mai**bim**e]
kutu	‘shoe’	+	himo	‘lace’	→	kutuhimo ‘shoe lace’
[kɯʦɯ]			[çimo]			[kɯʦɯçimo]
						*kutubimo [kɯʦɯ**bim**o]
ma	‘genuine’	+	hamo	‘pike conger’	→	mahamo ‘genuine pike conger’
[ma]			[hamo]			[mahamo]
						*mabamo [ma**bam**o]

Though we saw in (4) that rendaku is blocked when /h/ is followed by [m], we take a close look below at whether rendaku is also blocked by other labial consonants. Based on the rendaku database (Irwin et al. 2017), I examined whether real native words with /h…C_2(…C)/ (i.e. local condition) and /h…C…C_3/ (i.e. non-local condition), where C_2 and C_3 is any of [m, ɸ, w], undergo rendaku. Of the five labial consonants [p, b, m, ɸ, w], [p] and [b] are excluded from analysis, since the singleton [p] rarely appears in Japanese native words (e.g., Ito & Mester 1995, 1999, 2008; Nasu 2015) and voiced [b] blocks rendaku by Lyman’s Law. For comparison, I also examined whether initial-/h/ words that do not contain labial consonants undergo rendaku.

	Examples	No. of lexical items	No. of compounds	No. of rendaku	Rate(%)
h…(φV)	hae 'fly'	17	387	308	79.59
h…kV…	hako 'box'	15	298	267	98.6
h…tV…	hato 'pigeon'	17	303	242	79.87
h…sV…	hasira 'pillar'	13	373	328	87.94
h…nV…	hane 'feather'	16	429	322	75.06
h…jV…	hayasi 'wood'	14	87	71	81.61
h…rV…	hari 'needle'	20	699	503	71.96
h…N…	han 'volume'	3	35	30	85.71
ALL		115	2611	2071	82.54

Table 1: Survey of real native words with /h…C/, where C is a non-labial consonant

Table 1 shows the rate of rendaku application of words with /h…C/, where C is a non-labial consonant.[4] The results indicate that the average rate is beyond 70% in each sequence: it is 82.54%. The full results of /h…C_2(…C)/ and /h…C…C_3/, where C_2 and C_3 are any of [m, ɸ, w], are presented in Tables 2 and 3, respectively. We found 21 lexical items of /h…C_2(…C)/ and 15 lexical items of /h…C…C_3/ in the database, and all examples are 365 compounds of /h…C_2(…C)/ and 262 compounds of /h…C…C_3/ in total, respectively.[5] The results show that while the overall rate of rendaku is beyond 70% in the non-local condition, as exemplified in (5), it is under 50% in the local condition (i.e. local vs. non-local: 74.43% vs. 47.46%). Comparing Table 1 with Tables 2 and 3, it follows that while the words in the non-local condition usually undergo rendaku, the rate of rendaku drops when [h] is *immediately* followed by labials (i.e. in the local condition). Looking at some examples in the local condition, the

[4] The rate of rendaku of words with [h…h] is excluded from Table 1, since it is extremely low, due to the fact that there are only two lexical items (e.g., *haha* 'mother'; *hoho* 'cheek'). We found only one out of seven compounds that undergo rendaku.

[5] This survey indicates that there are fewer native words with [h…m], [h…ɸ], or [h…w]. Considering the historical change wherein the word-initial *[p] was replaced with *[ɸ] and then with [h] (e.g., Sato 1977; cf. Hamano 2000), one may wonder if the number of native words with [ɸ…ɸ], [p…m], or [p…w] is also few. No native words with these sequences can be found in contemporary Japanese.

words *hama* ‘beach’, *hime* ‘princess’, and *himo* ‘string’ rarely undergo rendaku (*hama*: 1 out of 25 examples; *hime*: 2 out of 62 examples; *himo*: none out of 53 examples), as they are said to be immune to rendaku (e.g., Martin 1987; Rosen 2003; Vance 1987). One exception is the word *humi* ‘letter; trample’, which does undergo rendaku (Vance & Asai 2016) (i.e., *humi* ‘letter’: 121 out of 124 examples; *humi* ‘trample’: 8 out of 16 examples) (e.g., *koi* ‘love’ + *humi* ‘letter’ → *koi**b**umi* ‘love letter’; *asi* ‘foot’ + *humi* ‘trample’ → *asi**b**umi* ‘halt’)[6], which is why the current experiment excludes words that begin with *hu* from a set of stimuli (see footnote 8 in section 3).

[6] One reason that the word *humi* does undergo rendaku is that its surface form [ɸɯmi] already violates the OCP-labial constraint (Kawahara et al. 2006). Thus, if rendaku applies, the word does not invite a violation of the OCP-labial constraint (i.e., [ɸɯmi] → [bɯmi]).

	words	glossary	No. of compounds	No. of rendaku	Rate(%)
h…m(...C)	hama	‘beach’	25	1	4
	hamari	‘fitting’	1	1	100
	hamaru	‘fit’	1	0	0
	hami	‘pit viper’	2	1	50
	hami	‘eating’	9	7	77.78
	hamu	‘fit’	1	0	0
	hamu	‘eat’	6	3	50
	hamuki	‘flattery’	1	0	0
	hame	‘fitting’ (嵌)	2	2	100
	hame	‘fitting’ (嵌め)	4	3	75
	hame	‘panel’	10	5	50
	hameru	‘fit’	1	0	0
	hima	‘time to spare’	2	0	0
	hime	‘princess’	62	2	3.26
	himo	‘string’	53	0	0
	humi	‘letter’	124	121	97.58
	humi	‘trample’	16	8	50
	humoto	‘bottom’	1	0	0
	home	‘praise’	8	5	62.5
h…ɸ(…C)	huhuki	‘butterbur’	1	0	0
h…w(…C)	hiwa	‘cardueline finch’	5	0	0
		ALL	335	159	47.46

Table 2: Survey of real native words with /h…C_2(…C)/ (C_2 = [m, ɸ, w])

	words	glossary	No. of compounds	No. of rendaku	Rate(%)
h…C…m	hakama	‘hakama’	118	113	95.76
	hasami	‘scissors’	62	33	53.23
	hasamu	‘sandwich’	8	3	37.5
	harami	‘becoming pregnant’	5	5	100
	hitomi	‘eye’	2	0	0
	hirame	‘flounder’	5	1	20
	hirome	‘wideness’	4	1	25
	hiromeru	‘spread’	3	0	0
	hukumi	‘implication’	4	1	25
	hukumu	‘contain’	2	0	0
	hukumeru	‘include’	3	0	0
	husuma	‘husuma’	21	21	100
	hutomu	‘get stout’	1	1	100
	hurumai	‘behavior’	20	16	80
h…C…ɸ	-	-	0	0	0
h…C…w	haniwa	‘clay figure’	4	0	0
		ALL	262	195	74.43

Table 3: Survey of real native words with /h…C…C_3/ (C_3 = [m, ɸ, w])

(5) Examples of rendaku application in /h…C…m/

siro	‘white’	+	hakama	‘hakama’	→	sirobakama
[ʃiro]			[hakama]			‘white hakama’
						[ʃiro**b**akama]
sentaku	‘washing’	+	hasami	‘scissors’	→	sentakubasami
[seɴtakɯ]			[hasami]			‘clothes pins’
						[seɴtakɯ**b**asami]
kiri	‘fog’	+	husuma	‘husuma’	→	kiribusuma
[kiri]			[ɸɯsɯma]			‘thick fog like a husuma’
						[kiri**bɯ**sɯma]
ooban	‘rice with a bowl	+	hurumai	‘behavior’	→	oobanburumai
[oːbaɴ]			[ɸɯrɯmai]			‘big treat’
						[oːbaɴ**bɯ**rɯmai]

To summarize, the survey presented above shows that rendaku is more likely to be blocked in the local condition, where [h] is immediately followed by [m] (e.g., /h…m…/ as in *hama* 'beach', *hime* 'princess', and *himo* 'string') (exceptions: *humi* 'letter; trample'), whereas it is likely to apply in the non-local condition (e.g., /h…C…m/ as in *hakama* 'hakama' and *hasami* 'scissors'). We also found few examples in which [h] is followed by [ɸ, w], and thus, it is still unclear that the rendaku blocking really comes from the OCP-labial effect. These results allow us to establish two hypotheses about the rendaku blocking. First, the OCP-labial effect can be found only in the local condition in nonce-word experiments. Second, it shows up only when the labial consonant is [m], rather than [ɸ, w]. As will be seen in the next section, the current experiment demonstrates that the first hypothesis is correct, but also shows that the second hypothesis is not; in fact, we obtained results showing that the OCP-labial effect on rendaku works in a gradient way, when /h/ is followed by [m, ɸ], but not by [w].

3. Experiment

3.1 Stimuli

To test whether the OCP-labial effect works in rendaku, the current experiment provides native speakers of Japanese with nonce words, and then asks whether it is natural for them to undergo rendaku. As shown in Tables 4 and 5, the current experiment prepared two conditions to test locality: each target segment was located on the second-initial mora (Table 4) and on the third-initial mora (Table 5). For each condition, we had five groups of nonce words: (a) /b-C/ was used as a control group that did not contain any labial consonants, while (b) /b-b/, (c) /b-m/, (d) /b-ɸ/, and (e) /b-w/ contained a labial consonant, the last four sequences of which can violate the OCP-labial constraint if rendaku applies.[7] The group (b) also violates Lyman's Law since it contains two voiced obstruents. In each group, the first vowel (V_1) was any of [a, i, o][8], and we thus used 30 trimoraic nonce words (2 conditions*5 groups*3vowels each).[9] For

[7] We have excluded singleton [p] from the set of stimuli, since it rarely appears in Japanese native words (e.g., Ito & Mester 1995, 1999, 2008; Nasu 2015), and have also excluded a long vowel because it does not appear in native monomorphemic words.
[8] As already explained in section 2, words that begin with /hu/ are excluded from a set of stimuli since they do undergo rendaku.
[9] Following a number of previous wug-tests on rendaku (e.g., Kawahara 2012; Kawahara & Sano 2014a, 2014b, 2016), the current experiment used only trimoraic words with a light (CV-moraic) syllable.

V_2 and V_3, we used [a] in (a, b, c, e), but [ɯ] in (d), as the bilabial fricative [ɸ] is an allophone of /h/ after /u/ (e.g., Labrune 2012; Tsujimura 2014).

		N_1		N_2			Compounds	
a.	b-t	nise	+	hatara	[hatara]	→	nisebatara	[nise**b**atara]
		nise	+	hitara	[hitara]	→	nisebitara	[nise**b**itara]
		nise	+	hotara	[hotara]	→	nisebotara	[nise**b**otara]
b.	b-b	nise	+	habara	[habara]	→	nisebabara	[nise**b**a**b**ara]
		nise	+	hibara	[hibara]	→	nisebibara	[nise**b**i**b**ara]
		nise	+	hobara	[hobara]	→	nisebobara	[nise**b**o**b**ara]
c.	b-m	nise	+	hamara	[hamara]	→	nisebatara	[nise**b**a**m**ara]
		nise	+	himara	[himara]	→	nisebimara	[nise**b**i**m**ara]
		nise	+	homara	[homara]	→	nisebomara	[nise**b**o**m**ara]
d.	b-ɸ	nise	+	hahura	[haɸɯra]	→	nisebahura	[nise**b**a**ɸ**ɯra]
		nise	+	hihura	[hiɸɯra]	→	nisebihura	[nise**b**i**ɸ**ɯra]
		nise	+	hohura	[hoɸɯra]	→	nisebohura	[nise**b**o**ɸ**ɯra]
e.	b-w	nise	+	hawara	[hawara]	→	nisebawara	[nise**b**a**w**ara]
		nise	+	hiwara	[hiwara]	→	nisebiwara	[nise**b**i**w**ara]
		nise	+	howara	[howara]	→	nisebowara	[nise**b**o**w**ara]

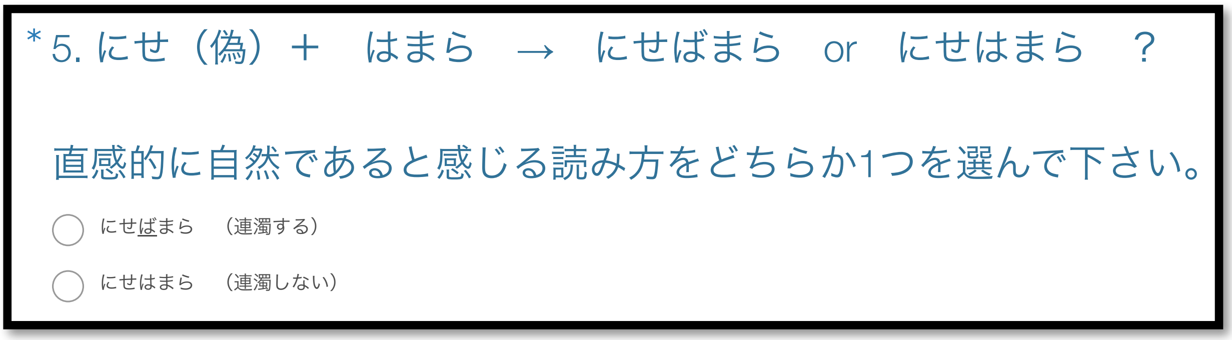
Table 4: Stimuli in the local condition (/h$V_1C_2V_2$ra/)

		N_1		N_2			Compounds	
a.	b-C-r	nise	+	hasara	[hasara]	→	nisebasara	[nise**b**asara]
		nise	+	hisara	[hisara]	→	nisebisara	[nise**b**isara]
		nise	+	hosara	[hosara]	→	nisebosara	[nise**b**osara]
b.	b-C-b	nise	+	hasaba	[hasaba]	→	nisebasaba	[nise**b**asa**b**a]
		nise	+	hisaba	[hisaba]	→	nisebisaba	[nise**b**isa**b**a]
		nise	+	hosaba	[hosaba]	→	nisebosaba	[nise**b**osa**b**a]
c.	b-C-m	nise	+	hasama	[hasama]	→	nisebasama	[nise**b**asa**m**a]
		nise	+	hisama	[hisama]	→	nisebisama	[nise**b**isa**m**a]
		nise	+	hosama	[hosama]	→	nisebosama	[nise**b**osa**m**a]
d.	b-C-ɸ	nise	+	hasahu	[hasaɸɯ]	→	nisebasahu	[nise**b**asa**ɸ**ɯ]
		nise	+	hisahu	[hisaɸɯ]	→	nisebisahu	[nise**b**isa**ɸ**ɯ]
		nise	+	hosahu	[hosaɸɯ]	→	nisebosahu	[nise**b**osa**ɸ**ɯ]
e.	b-C-w	nise	+	hasawa	[hasawa]	→	nisebasawa	[nise**b**asa**w**a]
		nise	+	hisawa	[hisawa]	→	nisebisawa	[nise**b**isa**w**a]
		nise	+	hosawa	[hosawa]	→	nisebosawa	[nise**b**osa**w**a]

Table 5: Stimuli in the non-local condition (/hV_1saC_3V_3/)

3.2 Participants and procedure

The current experiment was conducted online using SurveyMonkey. Participants were 76 naïve native speakers of Japanese, all of whom were undergraduate students in a Japanese university. None of them had majored in linguistics. In the instruction session, they were informed about the concept of rendaku, and given a couple of actual examples. For the test, they were told that the target nonce words were used in Old Japanese, in order for them to assume they are underlying forms. They were then asked to choose which of the forms seemed more natural than the other if each target word was combined with the word *nise*, meaning fake. Each question comprised original words and those that undergo for each nonce word rendaku (e.g., *nise**h**amara*; *nise**b**amara*). The nonce words and compounds were written in *hiragana*, a Japanese orthography, which is usually used to represent native words. A page of the test session is shown in Figure 1. The order of 30 questions was randomized and different for each participant.


*5. にせ（偽）＋　はまら　→　にせばまら　or　にせはまら　？

直感的に自然であると感じる読み方をどちらか1つを選んで下さい。

○ にせばまら　（連濁する）

○ にせはまら　（連濁しない）

(Translation in English)

* 5 . nise (偽)　+　hamara　→　nisebamara　or　nisehamara ?

Choose one which sounds natural, based on your intuitive judgment.

○ nisebamara　(rendaku)

○ nisehamara　(no rendaku)

Figure 1: Screenshot of the test session

3.3 Results

For analysis, we compare the applicability of rendaku between each group in each condition. If the ratio of rendaku application is significantly lower in the experimental groups (i.e. /b-b/; /b-m/; /b-ɸ/; /b-w/) than in the control group (i.e. /b-C/), we will conclude that the OCP-labial effect is at work. As seen below, we obtained results showing that the OCP-labial effect works in the local condition but not in the non-local condition. We also found that [w] did not participate in the effect even in the local condition.

The ratio of rendaku application for each condition was shown in Figures 2 and 3, where error bars represented 95% confidence intervals. As shown in Figure 2, in the local condition, the ratio of the rendaku application is as follows: [b-t] = 0.711; [b-b] = 0.189; [b-m] = 0.39; [b-ɸ] (represented as b-f) = 0.592; [b-w] = 0.697. For statistical analysis, we implemented a generalized mixed-effects logistic regression (e.g., Kawahara & Sano 2014a, 2014b, 2016) using the *glmer()* function of the *language R* and *lme4* packages (Baayen 2008: Baayen et al. 2008) of R (R Development Core Team 2013), as we should consider that each participant shows different responses to each item. Participants and items were coded as random effects (Baayen et al. 2008). The results show that there were significant differences between [b-t] and [b-b] (0.711 vs. 0.189; z = -11.034, p < .001), between [b-t] and [b-m] (0.711 vs. 0.39; z = -7.206, p < .001), and between [b-t] and [b-ɸ] (0.711 vs. 0.592; z = -2.854, p < .01), which suggests that the OCP-labial effect can be generalized in the local condition and also that Lyman's Law (*[b-b]) is active. We also found significant differences between [b-b] and [b-m] (0.189 vs. 0.39; z = 659.9, p < .001) and between [b-m] and [b-ɸ] (0.39 vs. 0.592; z = -4.739, p < .001), from which it follows that the OCP-labial effect on rendaku works gradiently. In other words, the more similar the two consonants are, the more unlikely the application of rendaku is to apply (see section 3.4.1 for discussion). However, there was no significant difference between [b-t] and [b-w] (0.711 vs. 0.697; z = -0.332, *n.s*). The reason that [w] did not participate in the OCP-labial effect will be discussed in section 3.4.2.

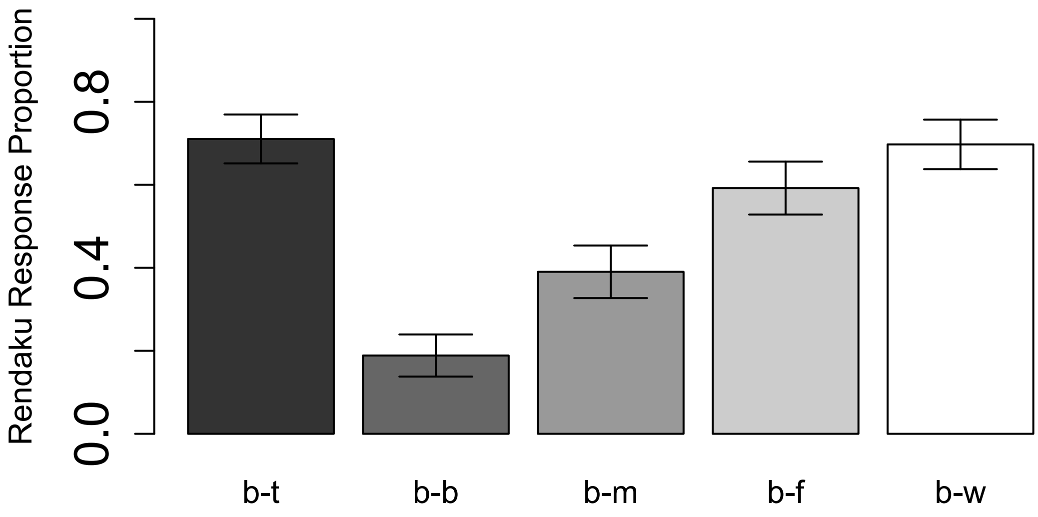


Figure 2: Results of rendaku applicability (local condition)

As shown in Figure 3, the ratio of the rendaku application in the non-local condition is as follows: [b-C-r] = 0.715; [b-C-b] = 0.39; [b-C-m] = 0.671; [b-C-ɸ] (represented as b-C-f) = 0.719; [b-C-w] = 0.588. Statistically, there were no significant differences between [b-C-r] and [b-C-m] (0.715 vs. 0.671; z = -0.737, *n.s*) and between [b-C-r] and [b-C-ɸ] (0.715 vs. 0.719; z = -0.006, *n.s*), which suggests that the OCP-labial effect does not show up when a non-labial consonant intervenes between the two labial consonants. In other words, the OCP-labial constraints on rendaku do not exhibit a long-distance effect. We also found a significant difference between [b-C-r] and [b-C-b] (0.715 vs. 0.39; $z = -4.722$, $p < .001$), which we believe comes not from the OCP-labial effect but from Lyman's Law effect. The result that Lyman's Law exhibits a long-distance effect is consistent with the results of some previous experiments (Ihara et al. 2009; Kawahara 2012; Kawahara & Sano 2014b; Vance 1980). While we expected that the OCP-labial effect does not work for a long distance in [b-C-m] and [b-C-ɸ] conditions, we also obtained an unexpected result that there was a slightly significant difference between [b-C-r] and [b-C-w] (0.715 vs. 0.588; $z = -2.001$, $p < .05$), although the *p* value is near 0.5 ($p = 0.045$). This issue will be left for discussion in section 3.4.2.

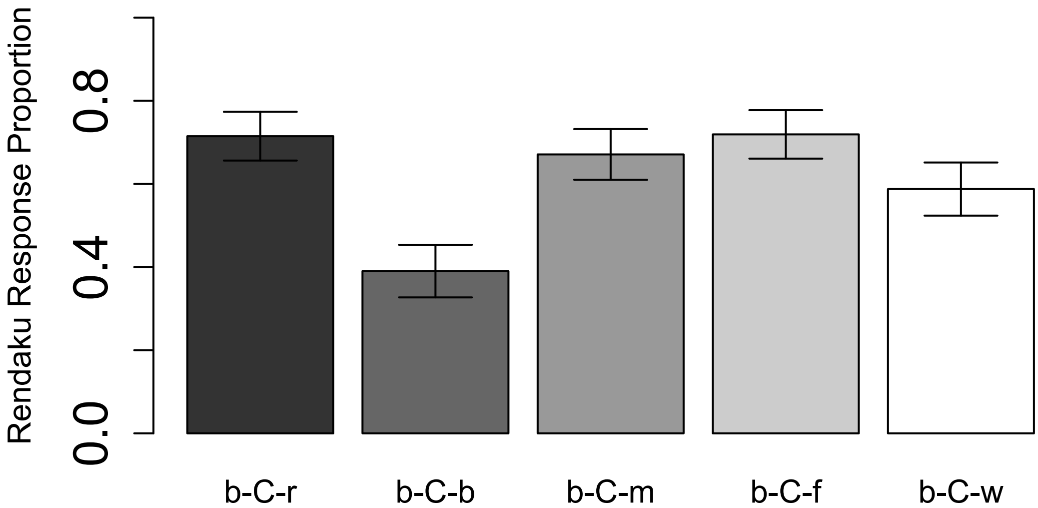


Figure 3: Results of rendaku applicability (non-local condition)

To summarize, the current experiment has shown that rendaku is more likely to be blocked when the resulting form will be [b-b], [b-m], and [b-ɸ], despite the fact that there are few real examples of native words with [h…ɸ]. Additionally, the applicability of rendaku is the lowest in [b-b], the highest in [b-ɸ], and intermediate in [b-m]. These results can lead us to conclude that 1) the OCP-labial effect can be generalized in Japanese rendaku; 2) that it works locally rather than non-locally; and 3) that the OCP-labial blocking effect is gradient.

3.4 Discussion

3.4.1 Locality and Gradiency of the OCP-labial effect

At the end of section 2, we established two hypotheses about rendaku blocking in nonce-word experiments. First, the OCP-labial effect on rendaku can be found only in the local condition, since the survey presented in section 2 showed that while rendaku is more likely to apply in the non-local condition (the average rate of rendaku = 74.43), it is less likely to apply in the local condition (47.46). Second, the OCP-labial effect shows up when the following consonant is [m], rather than other labial consonants such as [ɸ], since there are few native words with [h…ɸ]. The results of the current experiment have shown that the first hypothesis was correct but also that the second hypothesis was not. For the first hypothesis, in the local condition, rendaku was significantly less likely to apply in [b-b] (the average rate of rendaku = 0.189), [b-m] (0.39), and [b-ɸ] (0.592) than in [b-t] conditions (0.711) (see section 3.4.2 for [b-w]), but, in the non-local condition, [b-C-m] (0.671) and [b-C-ɸ] (0.719) were as likely to undergo rendaku as [b-C-r] (0.715), which suggests that the OCP-labial effect on rendaku works locally. For the second hypothesis, although we found no examples in which [h…ɸ] undergoes rendaku in the database, the current experiment showed that the OCP-labial effect is gradient in the local condition (the application rate of rendaku: [b-b] = 0.189; [b-m] = 0.39; [b-ɸ] = 0.592; cf. [b-t] = 0.711). This result is consistent with the studies on OCP effects that demonstrate that the more similar two consonants are, the more strongly they are disfavored (e.g., Berent & Shimron 2003; Berent et al. 2004; Buckley 1997; Frisch et al. 2004; Greenberg 1950; Pierrehumbert 1993). However, in the current case, how can we define similarity in terms of Place features and other featural aspects? There are three possibilities, to be discussed below.

The first possibility is voicing: the view that [b] is more similar to [m] than to [ɸ] could be explained by voicing, because [b] and [m] are voiced while [ɸ] is not. Why do the current results not involve a voicing feature? As already seen in (2) and (3), rendaku is blocked when the second member of compounds contains a voiced obstruent, rather than a (voiced) nasal such as [m]. In other words, Lyman's Law ignores sonorant voicing, as described as OCP (-son, voice) (e.g., Ito & Mester 2003). Furthermore, there are five sonorants [m, n, r, w, j] in Japanese, where there is no contrast of sonorants in voicing, which can lead us to infer that a voicing feature is inactive in, or is underspecified for, sonorants (Ito & Mester 1986) (see Kawahara & Zamma 2016 for an overview of rendaku in theoretical approach). Thus, we can rule out the possibility that voicing contributes to featural similarity in the current rendaku case.

The second possibility is continuancy and sonorancy. Padgett (1991, 1992) argues that such OCP subsidiary features, as well as Place features, are the key to accounting for consonant co-occurrence restrictions in Russian. For example, the root *sad-* 'sit' is well-formed because the value of [continuant] differs between [s] and [d], but the root *s'oz-* is ill-formed because the two consonants share [+continuant] (see also Coetzee and Pater (2008), who make a similar assumption in the analysis of Muna and Arabic). For continuancy, [b, m] have a negative value (i.e., [-continuant]) while [ɸ] has a positive one (i.e., [+continuant]). For sonorancy, [b, ɸ] have a negative value (i.e., [-sonorant]) while [m] has a positive one (i.e., [+sonorant]). A question that arises here is whether similarity in the current case can be accounted for by either subsidiary feature, or both. This question will be addressed below employing maximum entropy grammar (aka Maxent).

Maxent grammar is a probabilistic model used in a wide range of fields, including computational linguistics (e.g., Goldwater & Johnson 2003; Jäger 2007). Previous studies using this model in linguistics (e.g., Hayes & Wilson 2008; Hayes et al. 2009; Hayes et al. 2012; McPherson & Hayes 2016; Tanaka 2017; Zuraw & Hayes 2017; see also Kumagai & Kawahara 2017a and the reference cited therein) use data of frequency or experimental results to calculate probabilities of output forms, thus accounting for differences in free variation and gradiency of acceptability judgment. This paper uses the results of the rendaku applicability in the local condition, seen in Figure 2, to determine weights for relevant constraints.

Following the Optimality-theoretic (Prince & Smolensky 1993/2004) analysis of Japanese rendaku (e.g., Ito & Mester 2003), the current analysis assumes that it involves REALIZE MORPHEME (RM), IDENT (voice), and OCP (-son, voice): RM can be interpreted as requiring the initial consonant of the second member to become voiced; IDENT (voice) is violated if a voiced/voiceless consonant must have a correspondent with the same value between input and output; and OCP (-son, voice) is violated if the second element of compounds contains two and more voiced obstruents. We also assume three OCP-labial constraints that work locally: OCP (labial), OCP (labial, -continuant), and OCP (labial, -sonorant). OCP (labial) is violated if [b] is immediately followed by [m, ɸ] in the second element of compounds. OCP (labial, -continuant) is violated if [b] is immediately followed by [m] in the second element of compounds. OCP (labial, -sonorant) is violated if [b] is immediately followed by [b, ɸ] in the second element of compounds.

To examine whether OCP subsidiary features are involved in the blocking effect on rendaku, there are three possibilities of constraint violation profile, as shown in (6), where the asterisk * stands for a constraint violation. In (6a), the rendaku blocking in question is executed by OCP (labial, -continuant), rather than OCP (labial, -sonorant), as well as OCP (labial). In (6b), while OCP (labial, -sonorant) participates in blocking rendaku, OCP (labial, -continuant) does not. In (6c), both of the OCP subsidiary constraints are relevant.

(6) Constraint violation profile

a. Possibility #1

	RM	IDENT (voice)	OCP (-son, voi)	OCP (lab, -cont)	OCP (labial)
… h-ɸ	*				
… b-ɸ		*			* (b…ɸ)
… h-m	*				
… b-m		*		* (b…m)	* (b…m)
… h-b	*				
… b-b		*	* (b…b)	* (b…b)	* (b…b)

b. Possibility #2

	RM	IDENT (voice)	OCP (-son, voi)	OCP (labial)	OCP (lab, -son)
… h-ɸ	*				
… b-ɸ		*		* (b…ɸ)	* (b…ɸ)
… h-m	*				
… b-m		*		* (b…m)	
… h-b	*				
… b-b		*	* (b…b)	* (b…b)	* (b…b)

c. Possibility #3

	RM	IDENT (voice)	OCP (-son, voi)	OCP (lab, -cont)	OCP (labial)	OCP (lab, -son)
… h-ɸ	*					
… b-ɸ		*			* (b…ɸ)	* (b…ɸ)
… h-m	*					
… b-m		*		* (b…m)	* (b…m)	
… h-b	*					
… b-b		*	* (b…b)	* (b…b)	* (b…b)	* (b…b)

Following the previous studies in the framework of Maxent grammar (e.g., Hayes & Wilson 2008; Hayes et al. 2009; Hayes et al. 2012; McPherson & Hayes 2016; Kumagai & Kawahara 2017a; Tanaka 2017; Zuraw & Hayes 2017), we calculate weights for relevant constraints. First, like Harmonic Grammar (e.g., Pater 2009, 2016; Potts et al. 2010), for each candidate, harmonic score (H-score) is calculated in terms of the sum of C_i*w_i, where the candidate's violation of each constraint (C_i) is multiplied by the weight (w_i). Second, we calculate $e^{-(\text{H-score})}$, where e is the base of natural logarithms. Third, we sum $e^{-(\text{H-score})}$ of all candidates produced by GEN to the input. Finally, P(x), the predicted probability of candidate x, is its $e^{-(\text{H-score})}$ divided by the sum of $e^{-(\text{H-score})}$ of all candidates. With constraint violation profile and the results that we saw in Figure 2, we can leave the procedure to the Maxent software created by Hayes, Wilson, and George (2009).

Table 6 shows the results of the calculation for constraint weight. Table 7 compares the rendaku applicability obtained in the current experiment with predicted probabilities by the maxent analysis. Consistency between the two probabilities is desirable. From these results, we can rule out the second and third possibilities presented in (6b) and (6c), respectively. For the second constraint violation profile in (6b), in which OCP (labial, -continuant) does not participate, the predicted probabilities for [b-ɸ] (0.491) are inconsistent with the rendaku response proportion to [b-ɸ] (0.592) in Figure 2. Thus, the second constraint violation profile may not be valid.

Constraints	Possibility #1	Possibility #2	Possibility #3
REALIZE MORPHEME	5.45	5.45	5.45
IDENT (voice)	4.55	4.55	4.55
OCP (-son, voice)	1.0	1.4	0.82
OCP (labial, -continuant)	0.82	-	1.0
OCP (labial)	0.53	0.94	0.35
OCP (labial, -sonorant)	-	0	0.18

Table 6: Constraints and weights by the Maxent software

Candidates	Experimental Results	Possibility #1	Possibility #2	Possibility #3
h-t	0.289	0.289	0.289	0.289
b-t	0.711	0.711	0.711	0.711
h-ϕ	0.408	0.408	0.509	0.408
b-ϕ	0.592	0.592	0.491	0.592
h-m	0.61	0.61	0.509	0.61
b-m	0.39	0.39	0.491	0.39
h-b	0.801	0.809	0.81	0.809
b-b	0.189	0.191	0.19	0.191

Table 7: Frequency data and predicted probabilities

Seen in Table 7, there is no difference in predicted probabilities between the first and third possibilities, but, as seen in Table 6, a difference arises in cases where OCP-labial constraints are irrelevant: the difference between the two is the calculated weight for OCP (-son, voice) (Possibility #1: *w* = 1.0; Possibility #3: *w* = 0.82), which yields different consequences in selecting winners in cases where the second member of compounds contains a non-labial voiced obstruent (e.g., *tori* 'bird' + *hada* 'skin' → *torihada* 'gooseflesh'/ **tori**b**a**d**a*, which violates OCP (-son, voice), or Lyman's Law). In the case of the third possibility, the sum of weight for IDENT (*w* = 4.55) and OCP (-son, voice) (*w* = 0.82) does not reach the weight for RM (*w* = 5.45) (i.e. 4.55 + 0.82 = 5.37 < 5.45), which would predict that rendaku always applies even when OCP (-son, voice) (i.e. Lyman's Law) is violated, as shown in (7a) (*tori* 'bird' + *hada* 'skin' → **tori**b**a**d**a*). Meanwhile, in the case of the first possibility, the sum of weight for IDENT (*w* = 4.55) and OCP (-son, voice) (*w* = 1.0) is over the weight for RM (*w* = 5.45) (i.e. 4.55 + 1.0 = 5.55 > 5.45), which correctly predicts the rendaku blocking by Lyman's Law, as shown in (7b) (*tori* 'bird' + *hada* 'skin' → *torihada*). Thus, though this is not a positive motivation for ruling out the second possibility that sonorancy plays a role in the blocking rendaku, it can lead us to conclude that the analysis with OCP (labial, -sonorant) should be ruled out.

(7) Constraint violation profile

a. Possibility #3

	RM	IDENT (voice)	OCP (-son, voi)	
weight	5.45	4.55	0.82	H-score
… hada	-1			5.45
💀 … bada		-1	-1	5.37

b. Possibility #1

	RM	IDENT (voice)	OCP (-son, voi)	
weight	5.45	4.55	1.0	H-score
→ … hada	-1			5.45
… bada		-1	-1	5.57

To sum up, the first possibility of featural similarity in (6a) is more likely than the second and third ones in (6b) and (6c): featural similarity in the current case can be defined in terms of continuancy as well as Place features. Continuancy, rather than voicing or sonorancy, plays an essential role in accounting for the gradient OCP-labial effect on rendaku. There is a growing body of experiments demonstrating that phonological behavior shows a gradient aspect (e.g., Albright 2009; Berent & Simron 1997; Hayes 2000; Hayes & Londe 2006; Kawahara 2011a, 2011b, 2013a, 2013b; Kumagai & Kawahara 2017a; McPherson & Hayes 2016; Zuraw 2000). In the current case of rendaku, the gradient applicability of rendaku stems from an accumulation of markedness constraints: OCP (-son, voice), OCP (labial), and OCP (labial, -continuant), as schematized in (8). We saw in Figure 2 that, for the applicability of rendaku, the [b-b] pair is the lowest, and the [b-m] pair is lower than the [b-ɸ] pair ([b-b] = 0.189; [b-m] = 0.39; [b-ɸ] = 0.592). It follows that the more constraint a novel compound violates, the less likely it is to undergo rendaku.

(8) Accumulation of markedness constraints

	OCP (-son, voi)	OCP (lab, -cont)	OCP (labial)
… b-ɸ			* (b…ɸ)
… b-m		* (b…m)	* (b…m)
… b-b	* (b…b)	* (b…b)	* (b…b)

3.4.2 Issues of the Japanese *w*

The current experiments resulted in two unexpected results of the Japanese [w]. First, in the local condition, rendaku was as likely to apply in [b-w] (the average rate = 0.697) as in [b-t] (0.711). Second, in the non-local condition, there was a slightly significant difference between [b-C-r] (0.715) and [b-C-w] (0.588), although the difference between the two is subtle. As for these results, further discussion needs to be added below. In introductory textbooks or articles on Japanese phonetics and phonology, the place of articulation of the Japanese glide *w* is described as labial (e.g., Kubozono 2015; Shibatani 1990), as velar (e.g., Tsujimura 2014), or as labiovelar (e.g., Labrune 2012). However, there has been little evidence for place features of the Japanese *w* until recently. For this issue, Kumagai and Kawahara (2017b) suggest that the Japanese *w* is *phonologically* labial. They ran experiments on sound symbolism that explored Japanese diaper brand names for babies. The results suggested that [w] as well as other labial consonants conveys the image that labial consonants are associated with "diaper brand names for babies" in Japanese. They argue that Japanese speakers may have extracted the place feature [labial] from real examples of diaper names that contain [p, m], and applied to naming of diaper names in the task of their experiments in which they participated (i.e. feature-based generalization: Albright 2009, Finley & Badecker 2009). Contrary to this argument, the results of the current experiment on rendaku showed that [w] did not participate in the local OCP-labial effect, and thus this paper argues that it is *phonologically* non-labial. When the results of these two experiments are taken into consideration, there is room for discussion about the place feature of the Japanese *w*. Further evidence based on descriptive or experimental approaches is necessary for future research.

The current experiment also revealed that the applicability of rendaku was slightly reduced in the [b-C-w] condition ([b-C-r] = 0.715 vs. [b-C-w] = 0.588), although the p value is near 0.5 (p = 0.045). However, this result does not suggest that the OCP-labial effect works in a long distance. Recall that rendaku was as likely to apply in [b-C-m] (0.671) and [b-C-ɸ] (0.719) as in [b-C-r] (0.715). If the OCP-labial effect works even non-locally, we cannot provide an account for why the OCP-labial effect was not observed in [b-C-m] and [b-C-ɸ] conditions. Thus, even if the Japanese *w* is phonologically labial, the result that the applicability of rendaku dropped slightly in the [b-C-w] conditions is attributed not to OCP-labial effect. Then, is there a possibility that this result was caused by real words that Japanese speakers possess in the lexicon? The survey presented in section 2 showed that we found no examples in which both [h…C…ɸ] and [h…C…w] undergo rendaku, which means that the Japanese lexicon cannot offer any account for the discrepancy in rendaku applicability between [h…C…ɸ] and [h…C…w]. At the moment, there seems to be no other factor that could block rendaku in the [b-C-w] condition. Thus, the interim conclusion drawn by the current paper is that, since the p value is near 0.5 (p = 0.045) in the [b-C-w] condition, the result that the applicability of rendaku was slightly reduced could have been accidental. This should be examined in future research.

4. General discussion

The current experiment led us to admit that rendaku involves OCP-labial constraints. As seen in section 2, in native words in Japanese, labial sequences (N=86) are less likely to occur than labial-coronal (or coronal-labial) sequences (N=1,335) or labial-dorsal (or dorsal-labial) sequences (N=450) (Kawahara et al. 2006). Thus, the OCP-labial effect works in derived and non-derived environments in Japanese, and may be stronger than OCP-coronal and OCP-dorsal effects in Japanese. However, regarding the four segments' potential to undergo rendaku, /h/ is the only segment that changes its place feature when rendaku applies. Thus, there seems to be no clue to examine whether the OCP-coronal or OCP-dorsal effects work within a word of compounds. Apart from rendaku, an experimental study (Kumagai 2017) has been reported that examines the OCP-labial effect on nicknaming in Japanese, wherein /h/ alternates with [p]. For future research, we need to examine not only the OCP-labial effect but also the OCP-coronal or OCP-dorsal effects in other non-derived environments.

As also seen in section 2, OCP (-son, voice), or Lyman's Law, is a well-known constraint that prevents rendaku from being applied. However, there are two differences between OCP (-son, voice) and the OCP-labial constraints. First, while OCP (-son, voice) does work even on an underlying level, the OCP-labial constraints do not completely. Since OCP (-son, voice) prohibits voiced obstruents from occurring twice or more in a word, it can play a role in accounting for the fact that, in Japanese, there are few monomorphemic words with two voiced obstruents. For example, we have *huta* [ɸɯta] 'lid,' *huda* [ɸɯda] 'tag,' *buta* [bɯta] 'pig,' but not *buda* [bɯda] (Ito & Mester 1995:819, 2003:34-36), the last one of which contains two voiced obstruents. Instead, as seen in section 2, we find native words with consecutive labial consonants (e.g., *mame* 'bean'; *mimi* 'ear'; *momo* 'peach'; *humi* [ɸɯmi] 'letter, trample'), which means that the OCP-labial constraints do not completely work on an underlying level. Second, while OCP (-son, voice) works not only in the local, but also in the non-local conditions, the OCP-labial constraints work only in the local condition. OCP (-son, voice) blocks rendaku when a non-voiced obstruent is sandwiched by two voiced obstruents (e.g., *kuro* 'black' + *sabi* 'rust' → *kurosabi*/ **kuroza**bi*** 'black rust'; *oo* 'big' + *sawagi* 'fuss' → *oosawagi*/**oozawa**gi*** 'big fuss'). Meanwhile, as the current experiment demonstrated, the OCP-labial constraints seem not to be active when there is a non-labial consonant intervening between word-initial /h/ and the third labial consonant.

In light of the hallmarks of the OCP-labial constraints mentioned above, the OCP-labial constraints are similar to Identity Avoidance in Japanese, which bans sequential identical consonants or mora. There are a number of Japanese native words with sequential identical mora (e.g., *mimi* 'ear'; *momo* 'peach'; *nana* 'seven'; *sasa* 'bamboo'; *haha* 'mother'), but, in experimental settings, Identity Avoidance has been observed across morpheme boundaries in a number of morphophonological processes such as rendaku (Kawahara & Sano 2014a, 2016), name ordering (Kumagai & Kawahara 2017a), and compound truncation (Moon 2017) (see Irwin 2014 for a survey showing that Identity Avoidance in rendaku is not supported). These observations raise a question of how Japanese speakers can learn about Identity Avoidance and OCP-labial constraints (see Kawahara & Sano 2014b, 2016 for a related discussion). The features that Identity Avoidance and OCP-labial constraints possess in common are that, in creating novel combination, identical or featurally similar consonants are disallowed from occurring in succession. Presumably, they could work only in the word formation or (morpho)phonological processes that produce novel combinations, as (some) speakers are more "resistant to novel combination" than to lexicalized words or conventionalized phrases.[10] Apart from Japanese, there are cases where such OCP-related conditions are observed in

[10] Historically, voiced obstruents used to appear intervocalically as prenasalized stops (e.g., [^{m}b, ^{n}d, $^{\text{ŋ}}$g, ^{n}z]) (e.g., Frellesvig 2010:35; Yamane-Tanaka 2005; see also Labrune 2012). It would be interesting if the OCP-labial effect originally comes from the OCP-nasal effect (e.g., *[^{m}b…m]). However, this is less probable, as we do not find other OCP-place effects such as OCP-coronal or OCP-dorsal that would come from *[^{n}d…n] or *[$^{\text{ŋ}}$g…n]; these sequences indicate rendaku application (e.g., *hon* 'book' + *tana* 'shelf' → *hon-dana* 'book shelf'; *ke* 'hair' + *kani* 'crab' → *ke-gani* 'hair crab').

morphophonological processes that create novel compounds. For example, in name ordering in English, sequences with featurally similar consonants are less likely to be tolerated than those without it (e.g., *Jack Smith* […k-s…] is more likely to occur than *Josh Smith* […ʃ-s…], which has two sibilants [ʃ, s] across the word boundary) (Shih 2014). In Tagalog, in which adjective-noun word order is variable (e.g., *magandá* "beautiful" + *babáe* "woman" + -ng (LINK) → *magandá-ng babáe*/ *babáe-ng magandá* "beautiful woman"), when the nasal-initial linker *-ng* or *na* is inserted between an adjective and a noun, the word that follows it is more likely to begin with a non-nasal (e.g., the order like *manggá-ng diláw* "mango-LINK yellow" is more frequent than the order like *diláw* ***na m****anggá* "yellow-LINK mango") (Shih & Zuraw to appear). For future research, probing into OCP-related constraints in morphophonological processes that create novel compounds, in Japanese and other languages, is high on the agenda.

5. Concluding remarks

The current paper reported on the wug-test study that examined the OCP-labial effect on Japanese rendaku. The results showed that 1) it can be generalized in rendaku; 2) that it works only in the local condition; and 3) that the applicability of rendaku is gradient: The more similar two consonants are, the more strongly they are disfavored. To account for this, the current paper argued that rendaku involves not only OCP (labial) but also OCP (labial, -continuant).

Rendaku experiments have been extensively conducted to confirm the generalizability of rendaku rules and the psychological reality of constraints such as Lyman's Law and the Right-Branch Condition (e.g., Kawahara 2012; Kawahara & Sano 2014a, 2014b, 2016; Kozman 1998; Kumagai 2014; Ohno 2000; Vance 1979, 1980, 2014; see Kawahara 2016 for referential lists). Since there was no wug-test reported on the OCP-labial effect on rendaku, I believe that the current experiment can contribute to the discussion. However, the results leave a possibility that the OCP-labial effect can be generalized in other phonological or morphophonological processes. A recent experimental study (Kumagai 2017) suggests that the OCP-labial effect is found in a nicknaming process in Japanese. Following this study, whether it shows up beyond rendaku should be examined in future research.

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To be added.

Competing Interests

The author declares that he has no competing interests.

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