/p/-driven geminate devoicing in Japanese: Corpus and experimental evidence

Abstract

In Japanese loanwords, voiced geminates can be devoiced in the presence of another voiced obstruent (e.g. /**dogg**u/ → /**dokk**u/). This devoicing pattern has been studied extensively in the recent phonological literature, in terms of theoretical modeling as well as from the perspective of experimentation and corpus studies. Less well-known is the observation that /p/ may cause devoicing of geminates as well (e.g. /**p**irami**dd**o/ → /**p**irami**tt**o/), although to date no objective evidence has been offered to confirm this observation. The current study thus attempts to test this observation objectively, by way of a corpus study and two phonological judgment experiments. All the results generally support the idea that /p/ causes devoicing of geminates in loanwords. In addition to this descriptive discovery, throughout the paper we discuss intriguing task effects in phonological experimentation, by comparing the corpus data and the results of the two experiments. Although our aim is primarily descriptive, we offer some analytical possibilities for the /p/-driven devoicing of geminates toward the end of the paper.

1 Introduction

It is well known since Nishimura's (2003) discovery that in Japanese loanword phonology, voiced geminates optionally devoice when they co-occur with another voiced obstruent; e.g. /**dogg**u/ 'dog' can be pronounced as /**dokk**u/, but /e**gg**u/ 'egg' cannot be pronounced as */e**kk**u/ (see Kawahara 2015c for a review).[1] In other words, a restriction against two voiced obstruents—a constraint known as Lyman's Law or the Obligatory Contour Principle on [+voice] (OCP(voice)) in the native phonology (Ito & Mester, 1986, 2003; Vance, 2007)— causes devoicing of geminates. What makes this pattern even more interesting is the fact that OCP(voice) does not seem to devoice singletons (e.g. /**bag**u/ → */**bak**u/ 'bug').

---

[1]This paper uses phonemic transcription (Vance, 1987, 2008) rather than IPA transcription for the sake of typographical ease, as the phonetic details do not matter much in this paper.

This devoicing of geminates has been studied extensively within various theoretical frameworks (Coetzee & Kawahara, 2013; Coetzee & Pater, 2011; Crawford, 2009; Farris-Trimble, 2008; Ito & Mester, 2008; Hayes, 2009; Kawahara, 2006, 2008; McCarthy, 2008; Nishimura, 2003, 2006; Pater, 2009, to appear; Rice, 2006; Tesar, 2007; Tsujimura, 2014), and has been used to argue for several theoretical apparatuses, such as local conjunction (Nishimura, 2003, 2006), Harmonic Grammar (Farris-Trimble, 2008; Pater, 2009, to appear), and Max-Ent Grammar (Coetzee & Pater, 2011), among others. This OCP-driven devoicing pattern has also been studied experimentally (Kaneko & Iverson, 2009; Kawahara, 2011a,b, 2013), as well as from the perspective of corpus-based studies (Kawahara & Sano, 2013; Sano, 2013; Sano & Kawahara, 2013). It thus seems safe to say that this OCP-driven devoicing pattern has received substantial attention in the field in the last ten years or so, not exclusively among those who are interested in Japanese phonology *per se*, but also among those who work in the field of phonological theory in general.

Against this background, this paper points out a less well-known—but yet important—complication to this devoicing pattern. That is, it seems to be the case, at least according to our intuition, that geminates can devoice when they co-occur with /p/ as well; e.g., /kyuu**pitt**o/ 'cupid' and /**p**irami**tt**o/ 'pyramid'. If our intuition is correct, then it is not only the OCP(voice), but also the co-occurrence with /p/, that can cause devoicing of geminates. This /p/-driven devoicing would probably come as a surprise to many phonologists, because having /p/ and having a voiced geminate seem phonologically mutually irrelevant. At the same time, there is a sense in which /p/ is special in Japanese, in that singleton /p/s are allowed only in loanwords and onomatopoetic words but are banned in the native phonology (Ito & Mester, 1995, 1999, 2008). It may be the case that /p/ causes geminate devoicing because of this special property. At any rate, if /p/-driven geminate devoicing does indeed exist in the contemporary phonology of Japanese, it would also require significant revisions to the theoretical analyses of the OCP-driven geminate devoicing pattern cited above, because the co-occurrence of /p/ and voiced geminates should not violate the OCP(voice).

The pattern of /p/-driven devoicing, however, would probably be taken to be surprising by many practicing phonologists, and can be viewed with suspicion, because as far as we are aware, no other languages show a pattern of devoicing caused by /p/ at a distance. In order to check our intuition on this matter, we conducted a search using Jeff Mielkes P-Base (http://pbase.brohan.ca/query) to examine whether such an alternation exists in other languages. The search results did not find any example of /p/ causing devoicing. The P-Base contains 7318 patterns from 629 languages, indicating that /p/-driven devoicing is rare at best—and possibly hitherto unattested—in natural languages. Therefore, this apparently surprising pattern should probably not be used for phonological argumentation

when it is purely based on the authors' own intuition (Kawahara, 2015a; Labov, 1996; Ohala, 1986; Schütze, 1996). Therefore, this /p/-driven devoicing pattern requires careful empirical scrutiny.

To summarize, this paper aims to verify this /p/-driven devoicing of geminate using objective methods, because (i) this /p/-driven devoicing of geminates is a surprising non-local interaction between two phonological structures, and because (ii) if this /p/-driven devoicing is a real process, then the previous analyses of geminate devoicing need to be revised. To that end we report one corpus-based study and two judgment experiments to explore the reality of the /p/-driven devoicing. The judgment experiments build on the previous judgment experiments on OCP-driven devoicing of geminates (Kawahara, 2011a,b, 2013).

The rest of this paper is structured as follows. A corpus-based analysis is reported in Section 2. Experiment I used a yes/no format, which shows that /p/ does induce more "devoicing possible" responses than other consonants. Experiment II asked the participants which form—voiced or devoiced—they would actually use in a forced-choice format, which again supports the reality of /p/-driven devoicing. In addition, the comparison of these two experiments reveals an interesting task effect in phonological experimentation. Section 5 discusses some possible theoretical analyses. The final section is a conclusion.

2   A corpus-study based on the CSJ

We first analyzed the Corpus of Spontaneous Japanese (the CSJ) (NINJAL, 2008). This corpus is one of the largest corpora of spoken Japanese, containing about 7.5 million words, which is equipped with rich annotation systems. It also encodes underlying forms as well as actual pronounced forms, and this feature allows us to access the devoicing status of geminates (see Kawahara & Sano 2013; Maekawa 2004; Maekawa et al. 2000 for further details of the CSJ).

We first extracted all the words containing a voiced geminate, and classified them into three categories: (i) those that occur with /p/, (ii) those that occur with a voiced obstruent, and (iii) those that would fit neither of the structural descriptions (henceforth the "elsewhere" condition).[2] We then examined whether these geminates appear as voiced or devoiced in the corpus for each condition, based on the transcription provided by the CSJ. The results are shown in Table 1.

The bottom row shows that geminates rarely appear as devoiced when they do not

---

[2]We put double quotes around "elsewhere", in order to distinguish it from the Elsewhere Condition, one of the principles deployed in Lexical Phonology (Kiparsky, 1982)

Table 1: The results of the search of the CSJ: the second column shows the number of geminates appearing as voiced; the third column the number of geminates appearing as devoiced. The rightmost column shows the percentages of devoiced tokens.

	voiced	devoiced	total	percent devoiced
/p/ (e.g. /paddo/)	11	4	15	26.7%
[+voice, -son] (e.g. /beddo/)	163	313	476	65.8%
elsewhere (e.g. /heddo/)	689	28	717	3.9%

appear either with /p/ or a voiced obstruent. This result shows that context-free devoicing of geminates rarely occurs. The second row shows that geminates appear as voiceless 65.8% of the time when they appear with a voiced obstruent. The top row shows that although /p/ does not cause devoicing as much as a voiced obstruent, the devoicing percentage is higher than the third row, the "elsewhere" condition.

We fully admit that the N for the /p/-condition is small (the top row; N=15), and that we should not be conclusive about the productivity of /p/-driven devoicing based on these data alone. Nevertheless, Fisher's Exact tests show that /p/'s devoicing proportion is higher than the "elsewhere" condition ($p < .01$), although it is lower than the devoicing proportion by a voiced obstruent ($p < .01$). Again, we should not conclude based on this data that /p/ causes devoicing of geminates, because the relevant number of items is small. We thus followed up this corpus-based study with phonological judgment experiments.

3   Experiment I: A yes/no judgement task

Experiment I used a task in which the participants judged, for each given item, whether devoicing is possible or not in a yes/no format. This experiment followed the methodology of Kawahara (2013).

3.1   Method

3.1.1   Task

Within each trial, the participants were given one word containing a geminate. They were then asked if devoicing that geminate was possible or not. For example, they were asked: "given the word *kyuupiddo*, is it possible to pronounce it as /kyuupitto/?"

3.1.2 Stimuli

The stimuli consisted of a set of real words and another set of nonce words. Within each set, there were three conditions: (i) those that contain /p/, (ii) those that contain a voiced obstruent, and (iii) those that contain neither.[3] Seven items were included in all conditions; we could find only seven real words that fit the structural description of (i) (at the time of the experiment). The place of articulation was controlled across the three conditions; six items contained geminate /dd/ and one item contained geminate /gg/ for the real word stimuli; this unbalance was necessitated by the fact that there are not many words that contain /p...gg/. For the nonce word stimuli, for each condition, there were four items containing /dd/ and three items containing /gg/.

The experimental items for the real words and nonce words are provided in Table 2 and Table 3, respectively. The real words for the /p/-condition were largely based on those that were found in the CSJ.

Table 2: The real word stimuli.

/p...dd/		/b...dd/		/...dd/	
/kyuupiddo/	'cupid'	/baddo/	'bad'	/heddo/	'head'
/paddo/	'pad'	/beddo/	'bed'	/reddo/	'red'
/aipaddo/	'i-pad'	/deddo/	'dead'	/uddo/	'wood'
/aipoddo/	'i-pod'	/guddo/	'good'	/kiddo/	'kid'
/supureddo/	'spread'	/daddo/	'dad'	/maddo/	'mad'
/piramiddo/	'pyramid'	/goddo/	'god'	/roddo/	'rod'
/piggu/	'pig'	/biggu/	'big'	/eggu/	'egg'

Table 3: The nonce word stimuli.

/p...dd/	/b...dd/	/...dd/
/piddo/	/biddo/	/meddo/
/poddo/	/buddo/	/ruddo/
/puddo/	/boddo/	/yoddo/
/peddo/	/doddo/	/taddo/
/paggu/	/boggu/	/uggu/
/puggu/	/goggu/	/oggu/
/peggu/	/gaggu/	/noggu/

---

[3]One may wonder what would happen to words containing a geminate /pp/—not a singleton /p/—and a voiced geminate. Unfortunately, Japanese prohibits words with two geminates (Ito & Mester, 2003), which does not allow us to test such structures.

3.1.3 Procedure

The experiment was run online using Surveymonkey.[4] The participants were told that within each trial, they would be given one form, and another pronunciation, and would be asked if the latter form is a possible pronunciation of the first form. For the real word stimuli, the participants were told that all the stimuli would be existing loanwords. For the nonce word stimuli, they were told the stimuli were non-existing words in Japanese. All the stimuli were written in the *katakana* orthography, which is usually used for loanwords and nonce words. The real words and nonce words were separated into two different blocks, with a self-timed break in-between, and the block for the real word stimuli was presented first. Within each block, the order of the stimuli were randomized per participant by Surveymonkey.

In the instructions, the participants were asked to read the stimuli in their head, and use the auditory impression to respond to the questions.

3.1.4 Participants

The participants were recruited by word of mouth and through advertisement on a social networking service. Thirty-four native speakers of Japanese completed the online experiment.

3.1.5 Statistics

Since the response was binary (devoicing possible or devoicing impossible), ANOVA was avoided, and instead logistic linear mixed effects model analyses were run (Baayen et al., 2008; Jaeger, 2008). Subjects and items were encoded as random factors. Both slopes and intercepts of random effects were included in the models to have the maximal random structure, following the recent suggestions by Barr (2013) and Barr et al. (2013). R was used to implement the statistical analysis (R Development Core Team, 1993–2015).

3.2 Results

Figure 1 shows the proportions of devoicing possible responses for each condition for real word stimuli, with error bars representing 95% binomial confidence intervals. It shows that the first two bars show higher devoicing proportions than the third bar (87.8%, 85.3% vs. 72.3%).

The first linear mixed model comparing all the three conditions shows that there is a statistically significant difference among the three conditions ($z = 2.52, p < .05$). Subsequent contrast analyses show that the difference between the first condition (the /p/-condition)

---

[4]Several experiments have shown that online experimentation is as reliable as experiments conducted in a laboratory setting (Reips, 2002; Sprouse, 2011; Yu & Lee, 2014).
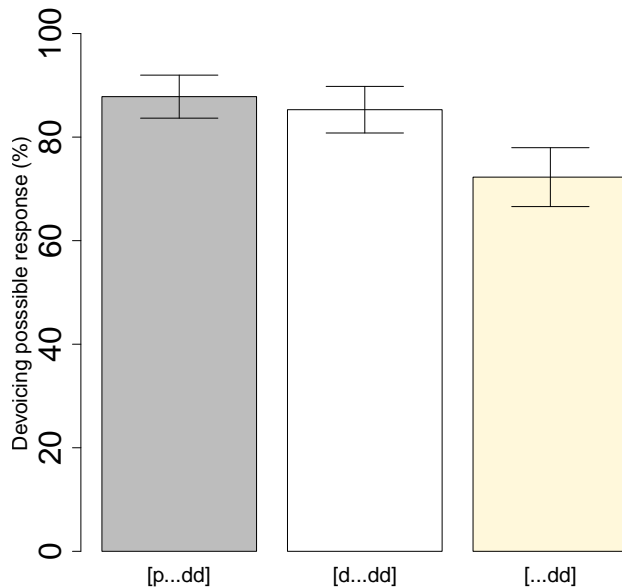
Figure 1: The proportions of devoicing possible responses for each condition: Real words.

and the third condition (the "elsewhere" condition) is significant ($z = 2.50, p < .05$). The difference between the first two conditions was not significant, however ($z = 0.05, n.s.$). This result supports that /p/ indeed causes devoicing of geminates in Japanese, which is also compatible with the patterns found in the corpus, shown in Table 1.

Despite the fact that the overall patterns are compatible with what is expected from the patterns in the corpus, as well as our own intuition, the devoicing possible responses are overall unexpectedly high. This issue is taken up on in the discussion section as well as in Experiment II.

Figure 2 shows the results of nonce words. Although the third condition shows slightly low devoicing possible responses compared to the first two (79.8%, 80.7% vs. 77.3%), the differences were very small; about 2.5%. In fact, a linear mixed model analysis comparing the three different conditions shows no statistically significant differences ($z = 0.03, n.s.$).

3.3   Discussion

The results of the real words show that naive native speakers of Japanese have an intuition that /p/ can cause devoicing at least more than the "elsewhere" condition, just like our own intuition (which could have been biased).

One immediate point to notice, however, is the overall differences between the results
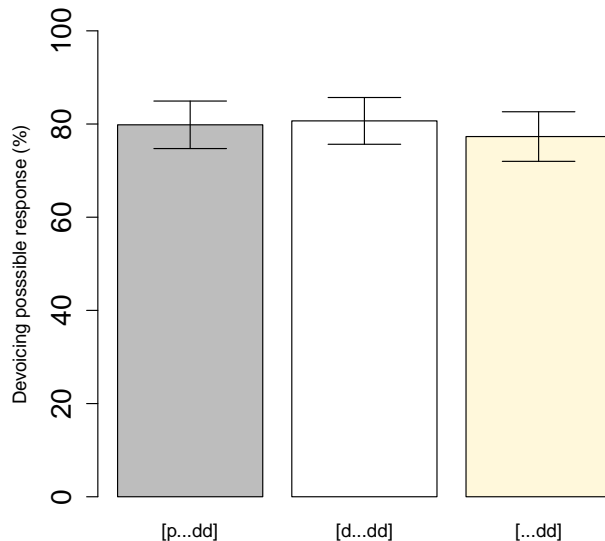
Figure 2: The proportions of devoicing possible responses for each condition: Nonce words.

of the experiment and the patterns in the corpus. For example, /p/-driven devoicing was judged to be possible 87.8% of the time in experiment, but in the corpus, actually 26.7% of geminates appear as devoiced. This discrepancy is more notable in the "elsewhere" condition; in the experiment 72.3% of them were considered to be devoicable, whereas in the actual corpus, only 3.9% of them appear as devoiced. Why is it that devoicing possible responses were so high in the experiment, across all the conditions?

This discrepancy may point to an important lesson about general methodology in phonological judgment experimentation. If the participants were asked whether some phonological pattern is *possible or not*, they may be inclined to be "more forgiving"—or more willing to accept a phonological change—than what they actually do in their actual speech behavior (cf. Labov 1996). This task effect may arise partly because speakers know that other speakers may do what they do not do themselves, possibly due to dialectal or speech style differences. The current participants may have thought that *some* speakers may devoice these geminates in the stimuli, even if they themselves would pronounce them as voiced.

In fact, this task effect of the possible vs. impossible judgment paradigm may not be new. Kawahara (2013) used the same methodology as Experiment I and asked about the devoicability of singletons and geminates in Japanese. The results were that geminates in the "elsewhere" condition were judged to be devoicable 62% of the time, again higher than the corpus data presented above. Singletons were judged to be devoicable 34% of the time

when there is another voiced obstruent, and 22% of the time when there is not. We do not have corpus data regarding how often singletons are devoiced in actual utterances, but these percentages seem unrealistically high (see the results of Experiment II). This issue of the task effect observed in Experiment I will be addressed in Experiment II by directly asking the participants what they would actually do.

The results of nonce words, albeit being null results, may be informative as well. Although we should not make a conclusion based on null results, one possible explanation is that the /p/-driven devoicing is "phonologically too outlandish" that it may not be internalized as a productive process in the minds of Japanese speakers, and hence is not extended to nonce words (see Becker et al. 2011 and Hayes et al. 2009 for related discussion). This possibility is discussed in further depth in the general discussion section.

An alternative explanation for the results of the nonce word stimuli is possible. It is independently observed that, for some reason, differences between different grammatical conditions in phonological judgment experiments become smaller when the participants make a judgment about nonce words than when they make judgements about real words (Kawahara, 2010, 2013). Furthermore, responses become closer to a chance level for nonce words than for real words (Kawahara, 2010, 2013). These general characteristics of nonce words in phonological experimentation may have diminished the potential differences between the three conditions in the current experiment.

4   Experiment II: A forced-choice judgment task

In Experiment I, the participant judged devoicing of geminates to be possible much more frequently than what is observed in the corpus as well as our intuition-based expectations. As discussed above, this result may be due to a task effect by which the participants were more accommodating about a possible phonological process when asked if the process is possible or not. In order to address this possibility, Experiment II asked the participants to choose a form that they would actually use.

4.1   Method

4.1.1   Task

As with Experiment I, within each trial, the participants were given one word containing a geminate, but this time presented with two forms, one "faithful" rendition and the other "devoiced rendition". For example, they were asked: "given the word *kyuupiddo*, which pronunciation would you actually use, /kyuupiddo/ or /kyuupitto/?" This task can be con-

sidered as a "head-to-head" or "forced-choice" task in which the participants are presented with two forms, and are asked to choose one form that sounds more grammatical (see Daland et al. 2011, Kawahara & Sano 2014 and Kawahara 2015b for the use of this paradigm in phonological experimentation; see also Sprouse & Almeida 2012 and others for the use of this test in experimental syntax).

In this paradigm, the participants may have been biased toward choosing the faithful form, because it is also given as a base form, and also because they may think that devoicing a geminate is "prescriptively not correct". However, the results showed that there were enough non-faithful, devoiced responses, as we will see below.

4.1.2 Stimuli

The current methodology cannot be used for nonce words, because the participants would not know how they actually pronounce words that do not exist. This restriction, however, allowed us to include more conditions than in Experiment I. Therefore, Experiment II included five conditions: (i) geminates appearing with /p/ (e.g. /paddo/), (ii) geminates appearing with another voiced obstruent (e.g. /baddo/), (iii) geminates without either /p/ or a voiced obstruent (e.g. /heddo/—the "elsewhere" condition above), (iv) voiced singletons appearing with another voiced singleton (e.g. /baado/), and (v) voiced singletons without another voiced singleton (e.g. /haado/). This experiment included singleton conditions, because devoicability of singletons has never been tested in this task format.

The experimental items for the real words and nonce words are provided in Table 4.[5] The stimuli for the first three conditions were almost identical to that of Experiment I, except that those words with /gg/ were replaced with those with /dd/. By mistake, /gaado/ was included twice in the fourth condition, and the responses for the first occurrence of /gaado/ were excluded from the analysis.

4.1.3 Procedure and statistics

The procedure and the statistical analyses were identical to those of Experiment I.

4.1.4 Participants

Fifty native speakers of Japanese completed the online experiment. Since the participants were invited partly through a social network service, there may be some overlap of the participants between the two experiments. However, since the two experiments were conducted more than a year apart, we expected little or no influences.

---

[5]Singleton consonants tend to be preceded by a long vowel or a diphthong because gemination is very common after a short vowel in the phase of loanword adaptation (Katayama, 1998; Kubozono et al., 2008).

Table 4: The stimuli for Experiment II.

/p...dd/		/b...dd/		/...dd/	
/kyuupiddo/	'cupid'	/baddo/	'bad'	/heddo/	'head'
/paddo/	'pad'	/beddo/	'bed'	/reddo/	'red'
/aipaddo/	'i-pad'	/deddo/	'dead'	/uddo/	'wood'
/aipoddo/	'i-pod'	/guddo/	'good'	/kiddo/	'kid'
/supureddo/	'spread'	/daddo/	'dad'	/maddo/	'mad'
/piramiddo/	'pyramid'	/goddo/	'god'	/roddo/	'rod'
/tetorapoddo/	'tetrapod'	/budda/	'Buddha'	/middo/	'mid'

		/d...d/		/....d/	
		/baraado/	'ballad'	/haado/	'hard'
		/baado/	'bird'	/raado/	'lard'
		/bideo/	'video'	/kaado/	'card'
		/gaado/	'guard'	/koodo/	'cord'
		/boodo/	'board'	/roodo/	'road'
		/gaaden/	'garden'	/saido/	'side'
				/huudo/	'hood'

4.2 Results

Figure 3 shows the proportions of devoiced forms being selected, with error bars representing 95% binomial confidence intervals. We observe declining order of devoiced forms being selected from left to right (46.6%, 31.4%, 7.7%, 0.6%, 0%).

Setting aside the singleton consonants, which showed few or no devoiced responses, a linear mixed model comparing the first three conditions, all containing geminates, showed a significant effect ($z = 3.75, p < .001$). The difference between the first bar (the /p/-condition) and the third condition (the "elsewhere" condition) is significant ($z = 4.31, p < .001$); the difference between the first two conditions did not reach significance ($z = 1.83, n.s.$), although it is near significance ($p = .067$).

4.3 Discussion

First of all, the experimental results show that /p/ does cause devoicing of geminates, as much as—possibly more than—a voiced obstruent does. This result supports our initial intuition that words of the form /p...dd/ may be pronounced as /p...tt/ with fifty naive native speakers of Japanese. Although the same results were obtained in Experiment I for real words, the differences between the /p/ condition and the "elsewhere" condition were more pronounced in the current study.
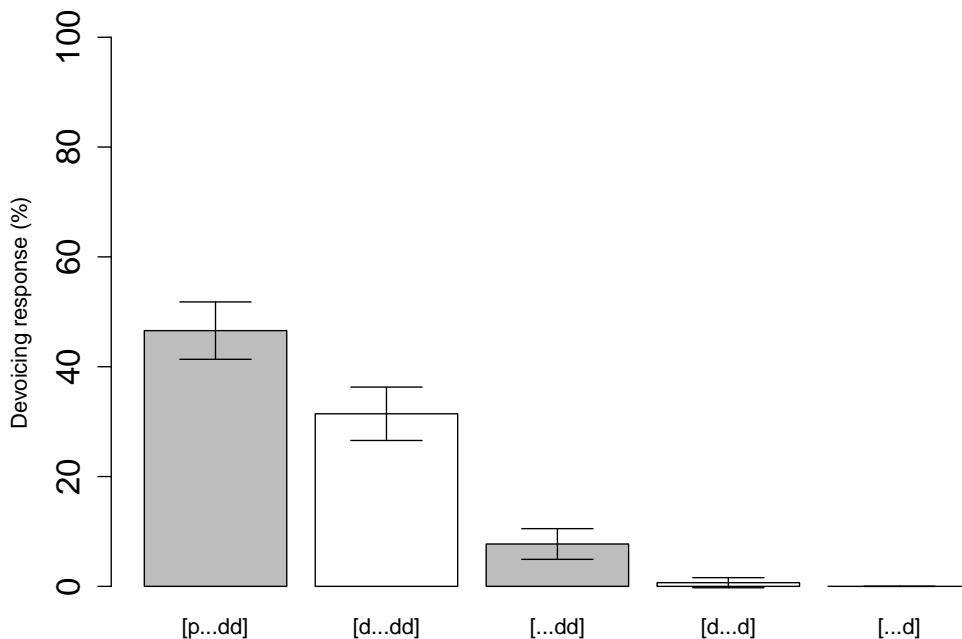
Figure 3: The proportions of devoicing responses for each condition.

Compared to Experiment I, the current experimental paradigm yielded values that are closer to those that are found in the corpus studies, at least for the /p/ condition and the "elsewhere" condition. Recall also that the participants did not choose devoiced singletons in Experiment II, while Kawahara (2013) found that in a possible vs. impossible format, singletons were judged to be devoicable about 20-30% of the time. Which experiment better reflects the true production of voiced singletons by Japanese speakers needs to be checked against actual production patterns, although we are inclined to say, admittedly based on our own intuition, that the current paradigm yielded results that are closer to what Japanese speakers actually do.

This task effect is perhaps not too surprising because the current experiment asked the participants about what they would actually do. This result again highlights the importance of probing task effects in phonological experimentation. It may be the case that this type of methodology is better than the possible vs. impossible format deployed in Experiment I and Kawahara (2013), especially when we are interested in what the speakers actually do. However, this paradigm has a drawback of not being able to use nonce word stimuli.

Another point to be noted about this experimental paradigm is that this experiment was

unexpectedly successful in that it elicited enough "non-faithful" responses. Given that the devoicing process is optional, there was a concern that the participants may not choose the devoiced options at all.[6] Recall that the participants were presented with a word A, and they were asked if they would pronounce it as A (faithful) or A' (non-faithful).[7] It would not be surprising if all the participants would have chosen A throughout, especially if they think they should be "prescriptively correct". The experimental results show that the head-to-head methodology is possible when probing an optional process, because participants do choose unfaithful options. This methodology can and perhaps should be applied to other optional phonological processes, such as t/d-deletion in English (Coetzee & Pater, 2011; Coetzee & Kawahara, 2013; Guy, 1991).[8]

5   Possible analyses

The corpus-based study as well as the judgement experiments have shown that /p/ does cause devoicing of geminates in Japanese loanwords. Although the focus of this paper is descriptive (i.e. to attempt to find objective evidence for /p/-driven devoicing), we briefly entertain possible ways of modeling this pattern theoretically. Overall, modeling the interaction between /p/ and voiced geminates is challenging, because /p/ and voiced geminates do not have anything in common, at least superficially. At least none of the theoretical analyses that are developed for devoicing of geminates due to another voiced obstruent predicts this /p/-driven devoicing (Coetzee & Kawahara, 2013; Coetzee & Pater, 2011; Farris-Trimble, 2008; Kawahara, 2006; Nishimura, 2003; Pater, 2009; Rice, 2006). This is because essentially all the analyses assume or posit that the cause of devoicing is OCP(voice), but /p/ should not induce a violation of OCP(voice).[9]

5.1   Prohibition against two rare structures?

One possible analysis is to build on the observation that both singleton /p/'s and voiced geminates are allowed only in loanwords (Ito & Mester, 1995, 1999, 2008). In this sense, /p/

---

[6]If the target phenomenon is a morphophonological process involving morpheme concatenation, then this paradigm is equivalent to a well-known wug-test in a forced choice format (Berko, 1958).

[7]A comparable question in English would be: "given a word like *west*, would you usually pronounce it as /west/ or /wes/?"

[8]Anonymous (p.c.) pointed out that "[f]rom a sociolinguistic perspective, the finding that participants are willing to acknowledge devoicing indicates that this is not a stigmatized variant associated with non-standard speech, in contrast to the other processes suggested, such as t/d deletion in English".

[9]Or should it? We could potentially postulate that /p/ and /b/ are both [+voice], and distinguish them in terms of [spread glottis], for example. As far as we know, there is no independent evidence that /p/ is [+voice] in Japanese, however. The fundamental problem here is that /p, b, d, g/ do not form a natural class for other phonological patterns in Japanese.

and voiced geminates share the property of being unfamiliar or non-frequent in the entire lexicon of Japanese. Fukazawa et al. (2015) show based on the lexical search of Amano & Kondo (1999) that /p/ and voiced geminates are the two most infrequent sounds in the whole Japanese lexicon. They argue that there may be a sort of OCP constraint, independent of OCP(voice), which prohibits the occurrence of two unfamiliar segments within a word; i.e. OCP(unfamiliar). This theory predicts that there should be other languages which prohibit a word that contains two sounds that are infrequent or two sounds that are found only in loanwords. This prediction is yet to be explored in other languages.

5.2   Local conjunction?

A related possibility is to posit a locally conjoined constraint (Smolensky 1993 *et seq.*), in the spirit of Nishimura (2003), like {*/p/&*VoiceObsGem}$_{stem}$. However, this constraint seems nothing more than a restatement of the observation, and predicts that, cross-linguistically, two irrelevant markedness constraints can be conjoined with a domain as large as a stem. Allowing this sort of local conjunction would probably result in too much theoretical power (Kawahara, 2006; McCarthy, 2003; Pater, 2009, to appear), although Blust (2012) recently argues that this sort of powerful local conjunction is necessary after all. The prediction of this approach is that any segment can be a trigger of geminate devoicing, as long as there exists a markedness constraint against that segment. This prediction needs to be tested in further detail, although we are suspicious of this prediction at this point.

Anonymous (p.c.) pointed out an interesting follow-up of this hypothesis. Although /p/ is voiceless, /p/ is the 'worst' of the voiceless stops for aerodynamic reasons—cession of vocal fold vibration is hardest for /p/ because it has the largest intraoral space (Hayes, 1999; Ohala, 1983). In fact, Maddieson (2013) documents a number of languages that lack /p/, just like the native phonology of Japanese (Ito & Mester, 1995, 1999, 2008). Thus, both /p/ and voiced geminates are in some sense 'laryngeally marked', and /p/-driven geminate devoicing could be understood as a pattern that avoids the presence of too many laryngeally marked things in the same word. To put it another way, even though /p/ and voiced geminates do not have the same value of the feature [voice], they are both marked with respect to that feature. To formalize the idea, we can formulate a constraint like OCP(LaryngealyMarked).

5.3   An orthography-based explanation?

A more radical alternative analysis is possible based on the Japanese orthography: voiced obstruents and /p/ are shown with diacritic marks on the upper right corner, the former with *dakuten* and the latter with *han-dakuten*, as illustrated by some examples in Figure 4.

ハ = /ha/

パ = /pa/

バ = /ba/

Figure 4: The Japanese orthography symbols for /ha/, /pa/, and /ba/. Those for /pa/ and /ba/ are shown with a diacritic mark on the upper right corner.

Therefore both /p/'s and voiced obstruents are written with an orthographic diacritic; in this sense, /p/ and voiced obstruents form a natural class. It may be the case then that OCP(voice) is actually OCP(diacritic), which accounts for both /p/-driven devoicing and OCP-driven devoicing at the same time. This analysis is radical in the sense that it shifts the burden of explanation from sounds to letters—a move that should be cautiously taken from the viewpoint of phonological theory (though see Ito et al. 1996 for a similar example of an orthography-based explanation of a phonological observation). This theory makes a specific prediction, namely in terms of the behavior of pre-literature children. To the extent that Lyman's Law or OCP(voice) is a matter of orthography, so as to target the configuration /p...dd/, then preliterate Japanese-speaking children should not show the evidence for Lyman's Law, or at least /p/-driven devoicing. In fact, Fukuda & Fukuda (1994) do find evidence to this effect—under-learning of Lyman's Law. A more targeted longitudinal experiment is called for to fully defend this prediction, however, especially to examine whether pre-literate children fail to show /p/-driven devoicing.[10]

5.4   It is not phonological after all?

A final possible explanation is to say that /p/-driven devoicing occurs in existing loanwords, but this pattern is too "outlandish" as a phonological pattern so that it is not phonologized in the minds of the contemporary Japanese speakers (cf. Becker et al. 2011). This idea would capitalize on the null results of the nonce words in Experiment I. Although this analysis is not impossible, it does not explain why the existing words show evidence for /p/-driven devoicing. This devoicing pattern of geminates emerged spontaneously in the loanword phonology, because Japanese did not used to have voiced geminates in the native phonology. This theory thus fails to explain why /p/-driven devoicing emerged in the first place. This

---

[10]This theory makes another specific prediction about rendaku and its blockage by Lyman's Law. To the extent that Lyman's Law is a prohibition against two diacritics, then /p/ should block rendaku as well. Rendaku generally applies only to native words, but singleton /p/s do not appear in native words. There are words, however, that undergo rendaku despite the presence of geminate /pp/; e.g. /ama+**zupp**ai/ 'sweat and sour'.

theory also has a danger of relying on null results.

5.5 Summary

Since there are no knock-out arguments for one over the other, we remain neutral about the best explanation of the /p/-devoicing pattern in this paper. We reiterate that the value of this paper mostly lies in its new descriptive discovery, in addition to the new findings about task effects in phonological experimentation.

We will close this section by raising one final question, which may bear on the theoretical analyses: are /p/-driven devoicing and OCP-driven devoicing the same phonological pattern or are they different? The corpus study shows that OCP-driven devoicing is more common; neither conditions in Experiment I revealed differences between the two; Experiment II shows that /p/-driven devoicing tends to be more common, although the difference did not reach statistical significance. At this point, the evidence seems so mixed that this issue needs to be resolved in a future study.

6 Conclusion

The main goal of this paper was to objectively examine, beyond our own intuition, whether /p/ causes devoicing of geminates in Japanese loanword phonology. A corpus study as well as two judgment experiments show that /p/ does cause devoicing, at least in existing words. This new descriptive discovery poses a challenge to the theoretical analysis of geminate devoicing patterns in Japanese phonology in general.

In addition to this new descriptive discovery, we found non-trivial task effects in phonological experimentation. Experiment I shows that when the participants were asked if a phonological process is possible or not, they may be more inclined to say yes, perhaps more than they actually do. Experiment II shows that it is possible to ask what they do in their phonological behavior of an optional phonological process.

All in all, it seems safe to conclude that /p/, just like voiced obstruents, causes devoicing of geminates in Japanese. We look forward to seeing future theoretical analyses developed to account for these devoicing patterns.

References

Amano, Shigeaki & Tadahisa Kondo (1999) Nihongo-no goitokusei [Psylex: Lexical Properties of Japanese]. Tokyo: Sanseido.

Baayen, Harald R., Doug.J. Davidson, & Douglas. M. Bates (2008) Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language* **59**: 390–412.

Barr, Dale J. (2013) Random effects structure for testing interactions in linear mixed-effects models. *Frontiers in Psychology* **4**: 328.

Barr, Dale J., Roger Levy, Christoph Scheepers, & Harry J. Tily (2013) Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language* **68**: 255–278.

Becker, Michael, Nihan Ketrez, & Andrew Nevins (2011) The surfeit of the stimulus: Grammatical biases filter lexical statistics in Turkish voicing deneutralization. *Language* **88**(2): 231–268.

Berko, Jean (1958) The child's learning of English morphology. *Word* **14**: 150–177.

Blust, Robert (2012) One mark per word? Some patterns of dissimilation in Austronesian and Australian languages. *Phonology* **29**(3): 355–381.

Coetzee, Andries W. & Shigeto Kawahara (2013) Frequency biases in phonological variation. *Natural Language and Linguistic Theory* **30**(1): 47–89.

Coetzee, Andries W. & Joe Pater (2011) The place of variation in phonological theory. In *The Handbook of Phonological Theory, 2nd Edition*, John A. Goldsmith, Jason Riggle, & Alan Yu, eds., Oxford: Blackwell-Wiley, 401–431.

Crawford, J. Clifford (2009) *Adaptation and transmission in Japanese loanword phonology*. Doctoral dissertation, Cornell University.

Daland, Robert, Bruce Hayes, James White, Marc Garellek, Andrea Davis, & Ingrid Norrmann (2011) Explaining sonority projection effects. *Phonology* **28**(2): 197–234.

Farris-Trimble, Ashley (2008) *Cumulative faithfulness effects in phonology*. Doctoral dissertation, Indiana University.

Fukazawa, Haruka, Shigeto Kawahara, Mafuyu Kitahara, & Shin-ichiro Sano (2015) Two is too much: [p]-driven geminate devoicing in Japanese. *On-in Kenkyu [Phonological Studies]* **18**: 3–10.

Fukuda, Suzy & Shinji Fukuda (1994) To voice or not to voice: The operation of rendaku in the Japanese developmentally language-impaired. *McGill Working Papers in Linguistics* **10**: 178–193.

Guy, Gregory (1991) Explanation in variable phonology: An exponential model of morphological constraints. *Language Variation and Change* **3**: 1–22.

Hayes, Bruce (1999) Phonetically-driven phonology: The role of Optimality Theory and inductive grounding. In *Functionalism and Formalism in Linguistics, vol. 1: General Papers*, Michael Darnell, Edith Moravscik, Michael Noonan, Frederick Newmeyer, & Kathleen Wheatly, eds., Amsterdam: John Benjamins, 243–285.

Hayes, Bruce (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, Bruce, Kie Zuraw, Péter Siptár, & Zsuzsa Londe (2009) Natural and unnatural constraints in Hungarian vowel harmony. *Language* **85**(4): 822–863.

Ito, Junko, Yoshihisa Kitagawa, & Armin Mester (1996) Prosodic faithfulness and correspondence: Evidence from a Japanese Argot. *Journal of East Asian Linguistics* **5**: 217–294.

Ito, Junko & Armin Mester (1986) The phonology of voicing in Japanese: Theoretical consequences for morphological accessibility. *Linguistic Inquiry* **17**: 49–73.

Ito, Junko & Armin Mester (1995) Japanese phonology. In *The Handbook of Phonological Theory*, John Goldsmith, ed., Oxford: Blackwell, 817–838.

Ito, Junko & Armin Mester (1999) The phonological lexicon. In *The Handbook of Japanese Linguistics*, Natsuko Tsujimura, ed., Oxford: Blackwell, 62–100.

Ito, Junko & Armin Mester (2003) *Japanese Morphophonemics*. Cambridge: MIT Press.

Ito, Junko & Armin Mester (2008) Lexical classes in phonology. In *The Oxford Handbook of Japanese Linguistics*, Shigeru Miyagawa & Mamoru Saito, eds., Oxford: Oxford University Press, 84–106.

Jaeger, Florian T. (2008) Categorical data analysis: Away from ANOVAs (transformation or not) and towards logit mixed models. *Journal of Memory and Language* **59**: 434–446.

Kaneko, Emiko & Gregory Iverson (2009) Phonetic and other factors in Japanese on-line adaptation of English final consonants. In *Studies in Language Sciences 8: Papers from the eighth annual conference of the Japanese Society for Language Science*, Shunji Inagaki & Makiko Hirakawa, eds., Tokyo: Kuroshio Publications, 179–195.

Katayama, Motoko (1998) *Optimality Theory and Japanese Loanword Phonology*. Doctoral dissertation, University of California, Santa Cruz.

Kawahara, Shigeto (2006) A faithfulness ranking projected from a perceptibility scale: The case of [+voice]

in Japanese. *Language* **82**(3): 536–574.

Kawahara, Shigeto (2008) Phonetic naturalness and unnaturalness in Japanese loanword phonology. *Journal of East Asian Linguistics* **17**(4): 317–330.

Kawahara, Shigeto (2010) Modes of phonological judgments. Ms. Rutgers University.

Kawahara, Shigeto (2011a) Aspects of Japanese loanword devoicing. *Journal of East Asian Linguistics* **20**(2): 169–194.

Kawahara, Shigeto (2011b) Japanese loanword devoicing revisited: A rating study. *Natural Language and Linguistic Theory* **29**(3): 705–723.

Kawahara, Shigeto (2013) Testing Japanese loanword devoicing: Addressing task effects. *Linguistics* **51**(6): 1271 – 1299.

Kawahara, Shigeto (2015a) Can we use rendaku for phonological argumentation? *Linguistic Vanguard* : 1–12.

Kawahara, Shigeto (2015b) Comparing a wug-test and a naturalness rating test: An exploration using rendaku. *Language Sciences* **48**: 42–47.

Kawahara, Shigeto (2015c) Geminate devoicing in Japanese loanwords: Theoretical and experimental investigations. *Language and Linguistic Compass* **9**(4): 168–182.

Kawahara, Shigeto & Shin-ichiro Sano (2014) Identity Avoidance and Lyman's Law. *Lingua* **150**: 71–77.

Kawahara, Shigeto & Shinichiro Sano (2013) A corpus-based study of geminate devoicing in Japanese: Linguistic factors. *Language Sciences* **40**: 300–307.

Kiparsky, Paul (1982) From cyclic phonology to lexical phonology. In *The Structure of Phonological Representations*, vol. 1, Harry van der Hulst & Norval Smith, eds., Dordrecht: Foris, 131–175.

Kubozono, Haruo, Junko Ito, & Armin Mester (2008) Consonant gemination in Japanese loanword phonology. In *Current Issues in Unity and Diversity of Languages. Collection of Papers Selected from the 18th International Congress of Linguists*, The Linguistic Society of Korea, ed., Republic of Korea: Dongam Publishing Co, 953–973.

Labov, William (1996) When intuitions fail. In *Proceedings of Chicago Linguistic Society 32: Papers from the parasession on theory and data in linguistics*, Lisa McNair, Kora Singer, Lise Dolbrin, & Michelle Aucon, eds., Chicago: Chicago Linguistics Society, 77–106.

Maddieson, Ian (2013) Voicing and gaps in plosive systems. In *The World Atlas of Language Structurse Online, Chapter 5*, Matthew Dryer & Martin Haspelmath, eds., Max Planck Institute for Evolutionary Anthropology.

Maekawa, Kikuo (2004) Nihongo hanashikotoba koopasu-no gaiyoo [An overview of the Corpus of Spontaneous Japanese]. *Nihongo Kagaku* **15**: 111–133.

Maekawa, Kikuo, Hanae Koiso, Sadaoki Furui, & Hitoshi Isahara (2000) Spontaneous speech corpus of Japanese. *Proceedings of the Second International Conference of Language Resources and Evaluation* : 947–952.

McCarthy, John J. (2003) Comparative markedness. *Theoretical Linguistics* **29**: 1–51.

McCarthy, John J. (2008) *Doing Optimality Theory*. Oxford: Blackwell-Wiley.

NINJAL (2008) Nihongo hanashikotoba koopasu [The Corpus of Spontaneous Japanese], Ver. 2. Database.

Nishimura, Kohei (2003) *Lyman's Law in loanwords*. MA thesis, Nagoya University.

Nishimura, Kohei (2006) Lyman's Law in loanwords. *On'in Kenkyu [Phonological Studies]* **9**: 83–90.

Ohala, John J. (1983) The origin of sound patterns in vocal tract constraints. In *The Production of Speech*, Peter MacNeilage, ed., New York: Springer-Verlag, 189–216.

Ohala, John J. (1986) Consumer's guide to evidence in phonology. *Phonology* **3**: 3–26.

Pater, Joe (2009) Weighted constraints in generative linguistics. *Cognitive Science* **33**: 999–1035.

Pater, Joe (to appear) Universal grammar with weighted constraints. In *Harmonic Grammar and Harmonic Serialism*, John J. McCarthy & Joe Pater, eds., London: Equinox.

R Development Core Team (1993–2015) *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria.

Reips, Ulf-Dietrich (2002) Standards for internet-based experimenting. *Experimental Psychology* **49**(4): 243–256.

Rice, Keren (2006) On the patterning of voiced stops in loanwords in Japanese. *Toronto Working Papers in Linguistics* **26**: 11–22.

Sano, Shin-ichiro (2013) Patterns in avoidance of marked segmental configurations in Japanese loanword

phonology. *Proceedings of GLOW in Asia* : 245–260.

Sano, Shinichiro & Shigeto Kawahara (2013) A corpus-based study of geminate devoicing in Japanese: The role of the OCP and external factors. *Gengo Kenkyu [Journal of the Linguistic Society of Japan]* **144**: 103–118.

Schütze, Carlson (1996) *The empirical base of linguistics: Grammaticality judgments and linguistic methodology.* Chicago: University of Chicago Press.

Smolensky, Paul (1993) *Optimality, markedness, and underspecification.* Paper presented at the Rutgers University Optimality Workshop, New Brunswick, NJ.

Sprouse, Jon (2011) A validation of Amazon Mechanical Turk for the collection of acceptability judgments in linguistic theory. *Behavior and Research Methods* **43**(1): 155–167.

Sprouse, Jon & Diogo Almeida (2012) Assessing the reliability of textbook data in syntax: Adger's Core Syntax. *Journal of Linguistics* **48**: 609–652.

Tesar, Bruce (2007) A comparison of lexicographic and linear numeric optimization using violation difference ratios. Ms. Rutgers University.

Tsujimura, Natsuko (2014) *An Introduction to Japanese Linguistics, 3rd Edition.* Oxford: Blackwell-Wiley.

Vance, Timothy (1987) *An Introduction to Japanese Phonology.* New York: SUNY Press.

Vance, Timothy (2007) Have we learned anything about *rendaku* that Lyman didn't already know? In *Current issues in the history and structure of Japanese*, Bjarke Frellesvig, Masayoshi Shibatani, & John Carles Smith, eds., Tokyo: Kurosio, 153–170.

Vance, Timothy (2008) *The Sounds of Japanese.* Cambridge: Cambridge University Press.

Yu, Alan & Hyunjung Lee (2014) The stability of perceptual compensation for coarticulation within and across individuals: A cross-validation study. *Journal of the Acoustical Society of America* **136**(1): 382–388.