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

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"the second part of a compound word takes the nigori; that is if beginning with ch, f, h, k, s, sh, or t, those consonants are changed into the corresponding sonant ones ... the general rule does not apply ... when b, d, g, j, p, or z already occurs anywhere in the second part of the compound" (Lyman 1894: 2)

Abstract

In Japanese loanwords, voiced geminates can be devoiced in the presence of another voiced obstruent (e.g. /**dogg**u/ → /**dokk**u/ 'dog'). 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/ 'pyramid'), 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. The results generally support the idea that /p/ can cause devoicing of geminates in Japanese loanwords; in other words, /p/ may trigger Lyman's Law in causing devoicing of geminates. 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 judgment experiments. Although our aim is primarily descriptive, we offer some analytical possibilities for the /p/-driven devoicing of geminates at 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 /**do**kku/, but /e**gg**u/ 'egg' cannot be pronounced as */e**kk**u/ (see Kawahara 2015c for a recent review).[1] In other words, a restriction against two voiced obstruents in the native phonology—a constraint known as Lyman's Law or the Obligatory Contour Principle on [+voice] (the OCP(voice)) (Ito & Mester, 1986, 2003; Vance, 2007)—causes devoicing of geminates. What makes this pattern even more interesting is the fact that the OCP(voice) does not seem to devoice singletons (e.g. /**b**a**g**u/ → */**b**a**k**u/ 'bug'). In short, only when two conditions are met—having a voiced geminate and having a OCP(voice) violation—do we observe devoicing.

This OCP-driven devoicing of geminates has been studied extensively within various theoretical frameworks (Coetzee & Kawahara, 2013; Coetzee & Pater, 2011; Crawford, 2009; Farris-Trimble, 2008; Hayes, 2009; Ito & Mester, 2008; 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; Hayes, 2009), and MaxEnt Grammar (Coetzee & Pater, 2011; Hayes, 2009). 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 of geminates 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—yet important— complication to this devoicing pattern. That is, it seems to be the case, at least according to our intuition, that geminates can be devoiced when they co-occur with /p/ as well; e.g., /kyuu**pidd**o/ → /kyuu**pitt**o/ 'cupid' and /**p**irami**dd**o/ → /**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.[2] This /p/-driven devoicing would probably come as a surprise to many phonologists, because having /p/ and having a voiced geminate seem

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

[2]As quoted as the epithet of this paper, Lyman (1894) includes /p/ as a potential trigger of Lyman's Law in the context of the blockage of rendaku. Lyman in fact cites /ama+gappa/ 'rain cape' as an *exception* to Lymans Law, indicating that he believed that /p/ should block rendaku by way of Lyman's Law. In this sense, our finding—/p/ can trigger Lyman's Law-like effect—was already anticipated in the work of Lyman's (1894) original work. Thanks to an anonymous reviewer for bringing this observation to our attention.

phonologically mutually irrelevant. At the same time, there is a sense in which /p/ is special in the phonology of Japanese, in that singleton /p/s are allowed only in loanwords and mimetic words but are banned in the non-mimetic 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). (We will discuss several analytical possibilities of /p/-driven devoicing in Section 5.)

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 Mielke's (2008) P-Base (http://pbase.brohan.ca/query) to examine whether such an alternation exists in other languages. The search did not find any example of devoicing that was caused by /p/ at a distance. The P-Base contains 7318 phonological patterns from 629 languages, indicating that /p/-driven devoicing is rare at best—and possibly hitherto unattested—in natural languages. This apparently atypical pattern should not probably be used for phonological argumentation when it is based solely on the authors' own intuition (see Kawahara 2015a; Labov 1996; Ohala 1986; Schütze 1996 for related discussion). This /p/-driven devoicing pattern thus 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, or at least extended. 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 phonological 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, reported in Section 3, used a yes/no format, which shows that /p/ does induce more "devoicing possible" responses than other consonants. Experiment II, reported in Section 4, 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 of

the /p/-driven devoicing in Japanese. 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, and it includes a rich annotation system. 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 an underlyingly voiced geminate, and classified them into three categories: (i) those that also contain /p/, (ii) those that also contain a voiced obstruent, and (iii) those that would fit neither of these structural descriptions (henceforth the "elsewhere" condition).[3] 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.

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	% 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%

The bottom row shows that geminates rarely appear as devoiced (only 3.9%), when they do not appear either with /p/ or a voiced obstruent. This result shows that context-free devoicing of geminates rarely occurs in the CSJ (Kawahara & Sano, 2013; Sano & Kawahara, 2013).[4] 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

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[3]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)

[4]An anonymous reviewer asked for the breakdown of the "elsewhere" condition, which is as follows: /r/=11 tokens; /h/=6 tokens; /t/=5 tokens; /m/=2 tokens; /d/=1 token; /s/=1 token. It seems that /r/ stands out in this list; studying the interaction of /r/ and voiced geminates may be worth a future study.

devoicing as much as a voiced obstruent, the devoicing percentage is higher than the third row, the "elsewhere" condition.

We acknowledge 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 ($p < .01$). We reiterate that 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 judgment 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 Experiment I 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 a 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.[5] Seven items were included in each condition; 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

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[5]One may wonder what would happen to morphemes containing a geminate /pp/—not a singleton /p/—and a voiced geminate. Unfortunately, Japanese seems to prohibit a morpheme containing two geminates (Ito & Mester, 2003), and hence does not allow us to test such structures. There are words that contain a geminate /pp/ and another geminate across a morpheme boundary; e.g., /hi**pp**u-ho**pp**u/ 'hip-hop', /pi**kk**u-a**pp**u/ 'pick out', and /to**pp**u-ba**tt**aa/ 'lead-off hitter'. However, this experiment used only monomorphemic words as stimuli.

/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/

3.1.3   Procedure

The experiment was run online using Surveymonkey.[6] 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 that 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

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[6]Several studies have shown that online experimentation is as reliable as experiments conducted in a laboratory setting (Reips, 2002; Sprouse, 2011; Yu & Lee, 2014).

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 was randomized per participant by Surveymonkey.

In the instructions, the participants were asked to subvocalize the stimuli, 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 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 percentages of devoicing possible responses for each condition for real word stimuli, with error bars representing 95% binomial confidence intervals. The first two bars show higher devoicing percentages than the third bar (87.8%, 85.3% vs. 72.3%).
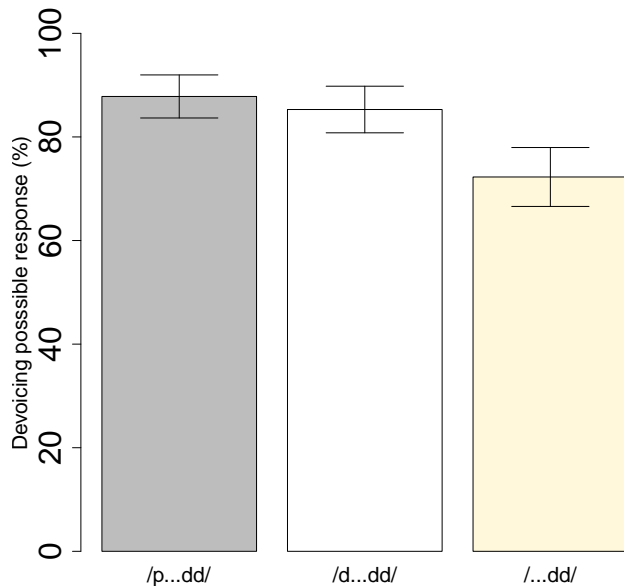
Figure 1: The percentages of devoicing possible responses for each condition: Real words.

The first linear mixed model comparing all 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) and the third condition (the "elsewhere" condition) is significant ($z = 2.50, p < .05$). As expected from the previous experiments (Kawahara, 2011a,b, 2013), the difference between the voiced obstruent condition (the second bar) and the "elsewhere" condition (the third bar) is also significant ($z = 2.70, p < .01$). The difference between the first two conditions is not significant, however ($z = 0.05, n.s.$). The overall results, especially the difference between the first condition and the third condition, support the claim that /p/ does in fact cause 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 in the discussion section as well as in Experiment II.

Figure 2 shows the results for nonce words. Although the third condition shows slightly lower devoicing possible responses compared to the first two (79.8%, 80.7% vs. 77.3%), the differences are very small: about 2.5% and 3.4%. In fact, a linear mixed model analysis comparing the three different conditions shows no statistically significant differences ($z =$
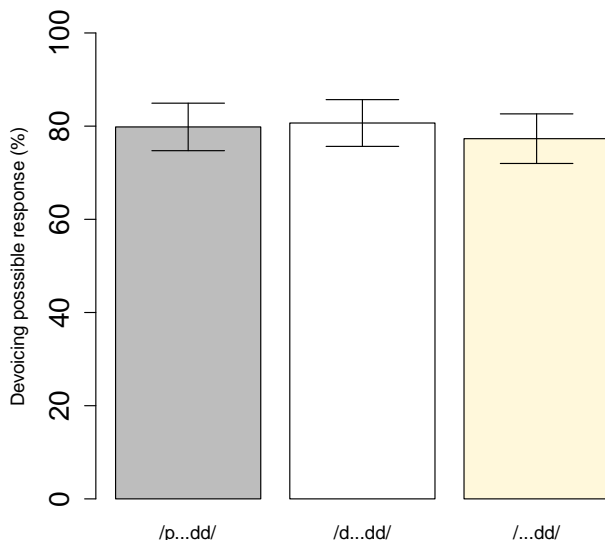
$0.03, n.s.$).

Figure 2: The percentages of devoicing possible responses for each condition: Nonce words.

3.3 Discussion of Experiment I

The results for 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 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 this experiment, but in the corpus, only 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 are 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 they are 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 might 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 in 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 in Table 1 (=3.9%). Singletons were judged to be devoicable 34% of the time when there was another voiced obstruent, and 22% of the time when there was not. We do not have corpus data regarding how often singletons are devoiced in actual utterances, but these percentages seem unrealistically high (see also the results of Experiment II below). 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, although null results, may potentially be informative as well. Although we should not draw a conclusion based on null results, one possible explanation is that the /p/-driven devoicing is "phonologically too outlandish" to 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, Hayes et al. 2009, and Hayes & White to appear for recent discussion). This possibility is discussed in further depth in the general discussion section.

An alternative explanation of the results of the nonce word stimuli is possible. It is independently observed that, for some reason, differences between grammatical conditions in phonological judgment experiments become smaller when the participants make judgments about nonce words than when they make judgments about real words (Kawahara, 2010, 2013). Furthermore, responses become closer to 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 participants judged devoicing of geminates to be possible much more frequently than what is observed in the corpus. 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 whether 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 an underlyingly voiced geminate, but this time presented with two forms, one a "faithful" rendition and the other a "devoiced rendition". For example, they were asked, "Given the word *kyuupiddo*, which pronunciation would you actually use, /kyuupiddo/ or /kyuupitto/?" This task can be considered 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 2015b,Kawahara & Sano 2014 and Perkins 2014 for the use of this paradigm in phonological experimentation; see also Sprouse & Almeida 2012 and others for the use of this test format in experimental syntax).[7]

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 ample 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/—equivalent to the "elsewhere" condition in Experiment I), (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 real-word and nonce-word experimental items are provided in Table 4.[8] The stimuli for the first three conditions were almost identical to those of Experiment I, except that words with /gg/ were replaced by words 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.

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[7]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).

[8]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'	

4.1.3 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 Experiment I and Experiment II. However, since the two experiments were conducted more than a year apart, we expected little or no influence.

4.2 Results

Figure 3 shows the percentages of devoiced forms being selected, with error bars representing 95% binomial confidence intervals. We observe a decline in the percentage 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 difference ($z = 3.75, p < .001$). The difference between the first bar (the /p/-condition) and the third bar (the "elsewhere" condition) was significant ($z = 4.31, p < .001$); the difference between the second bar (the voiced obstruent condition) and the third bar was
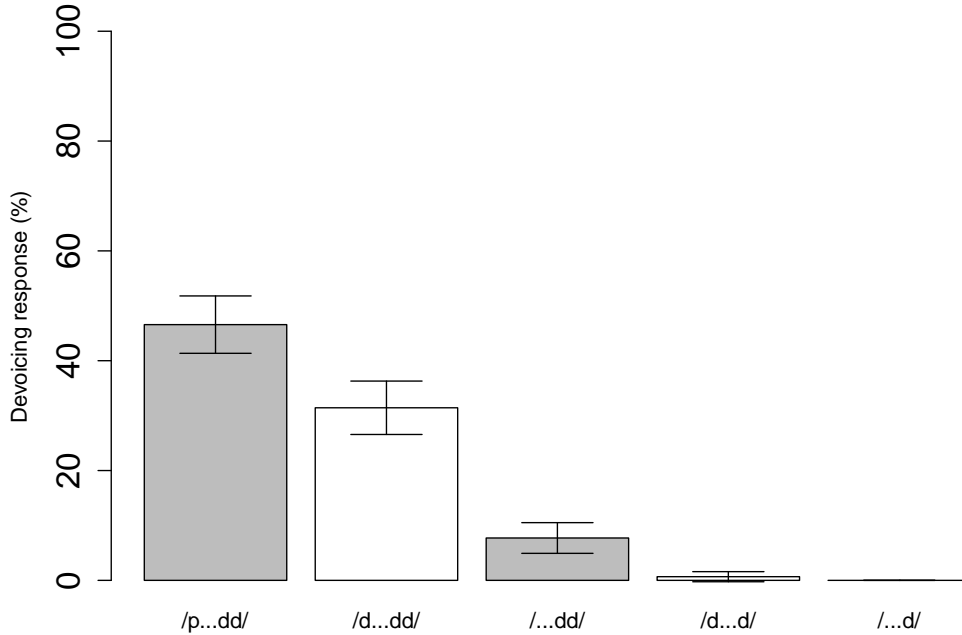
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Figure 3: The percentages of devoicing responses for each condition.

also significant ($z = 4.85, p < .001$); 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 of Experiment II

The experimental results show that /p/ does cause devoicing of geminates, as much as—possibly more than—a voiced obstruent does. These responses from fifty naive native speakers of Japanese support our initial intuition that words of the form /p...dd/ may be pronounced as /p...tt/. 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.

Compared to Experiment I, the current experimental paradigm yielded values that are closer to those 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 the current experiment, 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 the drawback of not being able to use nonce word stimuli.

Another point to note about this experimental paradigm is that Experiment II was unexpectedly successful in that it elicited ample "non-faithful" responses. Given that the devoicing process is optional, there was a concern that the participants might not choose the devoiced options at all. 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).[9] 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).[10]

5 Possible analyses

The corpus-based study as well as the two judgment 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 appear to have a common feature (to the exclusion of /t/ and /k/), 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;

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

[10]An anonymous reviewer pointed out, however, 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". Thus, after all, we may expect a difference between the devoicing pattern explored in this paper and t/d-deletion in English.

Coetzee & Pater, 2011; Farris-Trimble, 2008; Kawahara, 2006; Nishimura, 2003, 2006; 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).[11]

5.1 Prohibition against two rare structures?

One possible analysis is to capitalize 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/ and voiced geminates share the property of being non-frequent or "unfamiliar" 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, 2006), like {*/p/&*VOICEOBSGEM}$_{morpheme}$. However, this constraint seems to be 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 morpheme. Allowing this sort of local conjunction would probably result in too much theoretical power (Kawahara, 2006; McCarthy, 2003; Padgett, 2002; Pater, 2009, to appear), although Blust (2012) argues that this sort of powerful local conjunction is necessary. 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 it at this point.

An anonymous reviewer pointed out an interesting follow-up of this hypothesis. Although /p/ is voiceless, /p/ is the 'worst' of the voiceless stops for aerodynamic reasons. Cessation of vocal fold vibration is hardest for /p/ because it has the largest intraoral space; it is most

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[11]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, or in other languages known to us. Neither does there seem to be a phonetic feature that would delineate these sounds from other sounds. The fact that /p, b, d, g/ pattern together may indicate that not all phonologically natural classes need to share a phonetic property (see Mielke 2008 and Ladd 2014 for recent discussion on this view).

difficult to raise the intraoral airpressure for /p/, so as to stop glottal vibration (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). Likewise, voiced obstruent geminates are marked because it is hard to maintain voicing during long obstruent closure (Hayes, 1999; Hayes & Steriade, 2004; Ohala, 1983). 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 elements 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 could 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/'s are written with diacritic marks on the upper right corner, the former with *dakuten* (two dots) and the latter with *han-dakuten* (a circle), 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-literate 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 for 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.

This theory makes another specific prediction about rendaku and its blockage by Lyman's Law. As pointed out by Mark Irwin (p.c.), 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/ 'sweet and sour' and /ama+**gapp**a/ 'rain cape' (the latter of which is mentioned in Lyman's (1894) work). The application of rendaku, despite the presence of a geminate /pp/, would be a problem for this orthographic explanation of Lyman's Law or OCP.

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 so outlandish as a phonological pattern 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 has never had voiced geminates in the non-mimetic native phonology. This theory thus fails to explain why /p/-driven devoicing emerged in the first place. This theory also has the drawback 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 general question: 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; Experiment I indicates no 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, even when they themselves would not actually apply the process. 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.

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