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A corpus-based study of geminate devoicing in Japanese: linguistic factors

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ABSTRACT

Ever since Nishimura (2003, 2006) pointed out that voiced geminates can optionally devoice in Japanese when they co-occur with another voiced obstruent (e.g. /baddo/ → [batto] 'bad'), the pattern has been analyzed within a number of theoretical frameworks and studied in several experimental studies. However, there are only a few studies on actual production data. Moreover, most of the previous studies have generally assumed that this pattern is a linguistically monolithic phenomenon—all OCP-violating geminates would have equal probability of devoicing. By studying the Corpus of Spontaneous Japanese (Kokuritsu-Kokugo-Kenkyuujo, 2008), we show that many linguistic factors affect the probability of the devoicing of voiced geminates: in addition to OCP (voice), we find effects of the location of the trigger with respect to the target, the number of triggers, place of articulation, and lexical usage frequency. All of these observed patterns accord well with phonetic considerations and/or cross-linguistic tendencies. We conclude that geminate devoicing in Japanese phonology is not a linguistically monolithic phenomenon, because the probability of devoicing is affected by several linguistic factors. We suggest that future analyses of this phenomenon should take into account the factors that are identified in this project.

1. Introduction

In the native phonology of Japanese, voiced obstruent geminates are not allowed; however, recent borrowings from English and other languages result in voiced obstruent geminates due to a word-final gemination process (Irwin, 2011; Itô and Mester, 1995, 1999; Kubozono et al., 2008; Vance, 1987).[1] Nishimura (2003, 2006) pointed out that such voiced geminates can optionally devoice when they occur with another voiced obstruent in Japanese loanwords, as in (1). Ever since then, the pattern has been analyzed within a number of theoretical frameworks and studied in several experimental studies. Furthermore, Nishimura (2003, 2006) claims that this devoicing is caused by a well-known restriction in native Japanese phonology that does not allow two voiced obstruents within the same morpheme (also known as Lyman's Law, or OCP (voice),[2] henceforth the OCP), as shown by the (purportedly) ungrammatical devoicing in (2).

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[1] Emphatic gemination can create voiced obstruent geminates in native words, as in /sugoi/ → [suggoi] 'super' and /hidoi/ → [hiddoi] 'awful'. This emphatic gemination process is generally non-structure-preserving in that it creates kinds of geminates that are not allowed to make lexical contrasts (Kawahara, 2001; Vance, 1987).

[2] OCP (voice) in Japanese only targets voicing in obstruents, not in sonorants. The formulation of Lyman's Law as the OCP effect on a [(+)voice] feature is originally due to Itô and Mester (1986). Their analysis is further developed in their subsequent work (Itô and Mester, 1996, 1998, 2003; Mester and Itô, 1989). See also Vance (2007) on the discussion of Lyman's original article (Lyman, 1894) on this restriction, and Ihara et al. (2009), Kawahara (2012), and Vance (1980) for the evidence for the synchronic psychological reality of Lyman's Law from the perspective of Rendaku, a process of voicing of the initial consonant of the second member in compounding. See also Vance (in press) for a comprehensive recent overview of related issues.

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(1) OCP-violating geminates can optionally devoice
  a. be**dd**o → be**tt**o 'bed'
  b. ba**gg**u → ba**kk**u 'bag'
  c. bi**gg**u → bi**kk**u 'big'

(2) Non-OCP-violating geminates do not devoice
  a. suno**bb**u → *suno**pp**u 'snob'
  b. he**dd**o → *he**tt**o 'head'
  c. re**gg**u → *re**kk**u 'leg'

Several researchers have analyzed this devoicing pattern using various theoretical mechanisms, including local conjunction (McCarthy, 2008; Nishimura, 2003, 2006), phonetically-based phonology (Kawahara, 2006, 2008; Steriade, 2004), the theory of markedness and contrast (Rice, 2006), Harmonic Phonology (Farris-Trimble, 2008; Pater, 2009, in press), Noisy Harmonic Phonology (Coetzee and Kawahara, 2013; Coetzee and Pater, 2011), and Maximum Entropy Grammar (Coetzee and Pater, 2011). In this sense, this pattern has contributed much to many recent debates in phonological theory (see Kawahara, 2011a for a more extensive review).

Furthermore, Kawahara (2011a,b, 2012, 2013) has studied the devoicing pattern in several naturalness judgment experiments. The results generally support the intuition-based data in (1)–(2) in that naive native Japanese speakers find the devoicing of OCP-violating geminates more natural than the devoicing of non-OCP-violating geminates. However, all of these studies also found that Japanese speakers do not find devoicing of non-OCP-violating geminates, as in (2), to be entirely unnatural, contrary to the intuition reported by Nishimura (2003, 2006) and Kawahara (2006).

Our first aim of this study is thus to examine the role of the OCP in the geminate devoicing pattern in actual production data, using a large-scale speech corpus (our companion paper, Sano and Kawahara (2013), offers a similar attempt, but the current paper goes a few steps further in this respect; see below). Although this pattern has been studied from a variety of theoretical and experimental perspectives, actual production patterns have been generally understudied. Nishimura (2003, 2006), in the appendices to his papers, reports some analyses of the devoicing pattern using the older versions of the Corpus of Spontaneous Japanese (the CSJ, see below), and shows the effect of the OCP on devoicing. The first aim of this study is to replicate this result with an updated version of the CSJ.[3] In addition, we go one step further and examine how other linguistic factors related to OCP, such as the number of triggers and the location of the trigger with respect to the target, affect the probability of devoicing.

The second question addressed in this study is whether the devoicing of geminates is a linguistically monolithic phenomenon—that is, whether all OCP-violating geminates are equally likely to devoice, regardless of other factors that may possibly affect devoicing. Most previous theoretical studies have assumed that the geminate devoicing pattern is a monolithic phonological phenomenon, i.e., it is as simple as "geminates optionally devoice when they violate the OCP." However, Kawahara (2011a) found that various linguistic factors affect the naturalness judgments of the devoicing of geminates, as judged by a number of naive native speakers of Japanese. Moreover, our companion paper (Sano and Kawahara, 2013), through an extensive corpus study of the CSJ, found that various linguistic-external factors, such as gender, age, and education level, affect the devoicability of geminates in actual production.[4] These studies (Kawahara, 2011a; Sano and Kawahara, 2013) raise the possibility that geminate devoicing in Japanese loanwords is not a monolithic phenomenon, because various factors affect the probability—or naturalness—of devoicing. This study thus aims to test the hypothesis that the devoicing of voiced geminates in Japanese is affected by several linguistic factors, using the production data provided by the CSJ.

In summary, the current study uses the CSJ to test how various linguistic factors affect the devoicability of geminates in Japanese. We in particular examine those factors that are known to affect devoicing and the effects of OCP cross-linguistically.[5] To provide a preview of our results, we will observe that many linguistic factors do indeed affect the devoicing probability of voiced geminates: the OCP, the number of triggers, the distance between the trigger and the geminate, place of articulation, and lexical usage frequency. Furthermore, all of these observed patterns accord well with cross-linguistic tendencies and/or phonetic considerations. We conclude that geminate devoicing in Japanese phonology is not a linguistically monolithic phenomenon, being affected by several linguistic factors, and that future theoretical analyses of this phenomenon should take into account the factors that are identified in this project.

2. Method

To investigate how the OCP and other linguistic factors affect the probability of devoicing, we searched through the Corpus of Spontaneous Japanese, version 2 (the CSJ; Kokuritsu-Kokugo-Kenkyuujo, 2008; Maekawa, 2003, 2004; Maekawa et al.,

[3] Nishimura (2003) used the monitor—trial—version, and Nishimura (2006) used the first version (p.c. Kohei Nishimura, Aug. 2012). For the updated information of the 2nd version, which the current study has used, see http://www.ninjal.ac.jp/csj/data/previous/2nd/02revision/.

[4] We report the effects of linguistic factors and those of extra-linguistic factors separately in a different paper (Sano and Kawahara, 2013) for the sake of exposition. In doing so, we also follow the claim that linguistic factors and extra-linguistic factors do not interact (Labov, 1982; Sankoff and Labov, 1979; Weiner and Labov, 1983).

[5] See Sano (2013) for an examination of many other factors as well as the diachronic development of this devoicing pattern.

2000; Sano and Hibiya, 2012—for the evaluation of the CSJ's reliability as a spoken corpus, see Maekawa, 2003 in particular). This is one of the largest and most reliable corpora in spoken Japanese, based on 662 h of speech with 7.5 million words, produced by a total of 1417 speakers. This corpus is large in size and comes with a rich annotation system. Another characteristic of this database is that it provides both underlying forms and surface forms (coded in the forms of *hatsuon-kei*). Using this feature, we retrieved a set of words with voiced geminates, and studied how the words are actually pronounced using the phonetic transcription provided by the CSJ.[6]

We first extracted words with underlying voiced obstruent geminates ($N = 1666$). As the focus of this study was on devoicing, we excluded tokens in which the voiced geminates went through changes other than devoicing, such as degemination. This process resulted in 1617 tokens (97%).[7] Among those tokens, 472 of them showed devoicing (29%). We then tested how the OCP and various other linguistic factors affected the probability of devoicing. Any token containing another voiced obstruent within 6 preceding or following moras was taken to violate the OCP.[8] To calculate the probability of devoicing for each condition, we calculated the proportion of relevant tokens which showed devoicing (=devoiced tokens/total relevant tokens).

3. Results and discussion

3.1. The general role of OCP

Fig. 1 shows the probability of devoicing in the OCP-violating condition (e.g. *beddo* 'bed') and the non-OCP-violating condition (e.g. *shureddaa* 'shredder'). It demonstrates that devoicing is more likely for OCP-violating geminates (438/1099 = 40%) than for non-OCP-violating geminates (26/518 = 5%) ($\chi^2(1) = 207.1$, $p < .001$).[9] These data support the intuition by Nishimura (2003, 2006) and Kawahara (2006) that the OCP is a crucial factor in inducing devoicing, and also replicate the earlier corpus studies reported in the appendices of Nishimura (2003, 2006) which used older versions of the CSJ. However, we also note that devoicing is not entirely impossible for non-OCP-violating geminates (it happens about 5% of the time), which may be the basis of the judgment patterns found in Kawahara (2011a,b, 2012, 2013).

3.2. The distance effect

Having established that the OCP plays a crucial role in triggering devoicing in the previous section, Fig. 2 examines the distance effect; i.e., the distance between the trigger and the potential undergoer of devoicing. In some cases, the trigger and the undergoer are in adjacent moras, as in *beddo* 'bed'[10]; on the other hand, they can be separated by intervening moras, as in *neebaahuddo* 'neighborhood'. The distance effect is interesting to examine, because it is known cross-linguistically that dissimilatory force is stronger between closer segments (Frisch, 2004; Frisch et al., 2004; Ihara et al., 2009; Itô and Mester, 2003; Kawahara et al., 2006; Odden, 1994; Pulleyblank, 2002; Suzuki, 1998; Vance, 1980; Tanaka, 2007).

Against this background, Fig. 2—together with Table 1—lays out the probabilities of devoicing for each number of intervening moras. We observe a general trend in which the closer the trigger is to the target, the more likely devoicing is to occur ($\chi^2(5) = 191.1$, $p < .001$). The effect of the OCP is strongest when the trigger is in the adjacent mora, and disappears when the trigger is more than 5 moras away.

This observation accords well with the cross-linguistic observation that the OCP functions more strongly between closer segments (Frisch, 2004; Frisch et al., 2004; Ihara et al., 2009; Itô and Mester, 2003; Kawahara et al., 2006; Odden, 1994; Pulleyblank, 2002; Suzuki, 1998; Vance, 1980; Tanaka, 2007). For example, in Arabic consonant co-occurrence restrictions, constraints against a pair of homorganic consonants are stronger between syllable-adjacent consonants than non-syllable-adjacent consonants (Frisch, 2004; Frisch et al., 2004).[11] This result shows that the Japanese OCP (voice) constraint shares the same characteristic as the OCP effects found in other languages.

[6] As made explicit in some previous work (Kawahara, 2006, 2008, 2011b; Kaneko and Iverson, 2009), devoicing occurs in loanword phonology, rather than in the process of loanword adaptation (the latter process referring to borrowing of words into Japanese from other languages). Therefore, we assume that the underlying forms are those forms that are already borrowed into Japanese, not those of source language; e.g. for 'dog', it is [doggu] rather than [dɔg].

[7] Devoicing accounted for 92% of the repair strategies that happened to voiced geminates; the next most frequent repair strategy was degemination (7%); other strategies happened very rarely. See Sano (2013) for details.

[8] We will observe in Fig. 2 that most of the OCP-induced devoicing was caused by a local trigger at the moraic level, but we included non-local triggers as well in this study to see how the distance between the trigger and the target affects devoicability. See Fig. 2, which shows that the OCP's effects virtually disappear with more than 5 intervening moras.

[9] This result is also reported in our companion paper (Sano and Kawahara, 2013).

[10] We assume, following the majority of the literature, that the basic prosodic unit in Japanese is a (C) V mora. In Japanese, vowels and any coda consonants (coda nasals or coda part of geminates) count as one mora, and onsets count as being in the same mora as their nucleus. For example, *beddo* is divided into *be-d-do* in terms of moras in Japanese. See Kubozono (1999), Labrune (2012a,b), Poser (1990), Vance (1987, 2008) and many references cited therein for extensive discussion on the status of mora as a basic prosodic unit in Japanese prosodic phonology.

[11] This observation also accords well with another observation about the OCP-driven blockage of Rendaku in Japanese. The OCP blocks a morphophonemic alternation which voices the initial consonant of compounds (Rendaku) (Itô and Mester, 1986, 2003; Kawahara, 2012; Kubozono, 2005; Vance, 2007), and in some nonce-word experiments, this blockage effect was found to be stronger when the blocker is closer to the potential undergoer of Rendaku (Ihara et al., 2009; Vance, 1980) (though see Kawahara, 2012 who did not find this distance effect in naturalness judgment experiments with contemporary speakers).

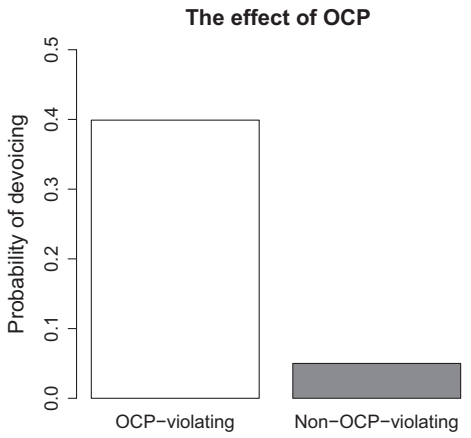

Fig. 1. The effect of OCP on devoicing.

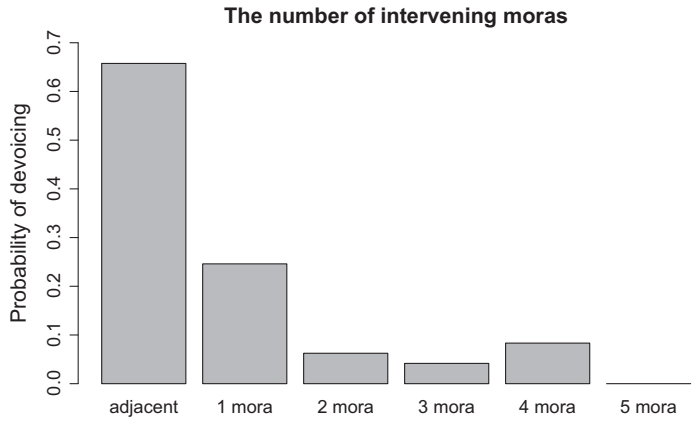

Fig. 2. The number of intervening moras and the probability of devoicing. The more moras that intervene between the trigger and the target, the less likely devoicing is to occur.

Table 1
The number of intervening moras and the probability of devoicing (actual numbers).

	Total	Devoiced	%
Adjacent	476	313	65.8
1 mora	126	31	24.6
2 moras	112	7	.6
3 moras	24	1	.4
4 moras	12	1	.8
5 moras	4	0	0

3.3. Number of triggers

Next we examine the effect of the numbers of triggers; in some case, there is only one trigger for OCP-induced devoicing, as in *beddo* 'bed', but there can be two (e.g. *debaggu* 'debug') or three (e.g. *bagudaddo* 'Bagdad'). Kawahara (2011a), in his naturalness experiment, found that the number of triggers do indeed impact the naturalness of devoicing; see also Tesar (2007) for related discussion on the effect of multiple triggers from a theoretical perspective.

Fig. 3 shows the effect of the number of triggers on the devoicability of OCP-violating geminates. It shows that the more voiced obstruents there are, the more likely it is that devoicing occurs: one trigger (353/754 = 46.8%), two triggers (56/102 = 54.9%), and three triggers (23/29 = 79%) ($\chi^2(2) = 13.7$, $p < .01$). This result is compatible with the naturalness judgement patterns obtained in Kawahara (2011a). This case instantiates a pattern in which dissimilation is coerced more strongly with more trigger consonants.

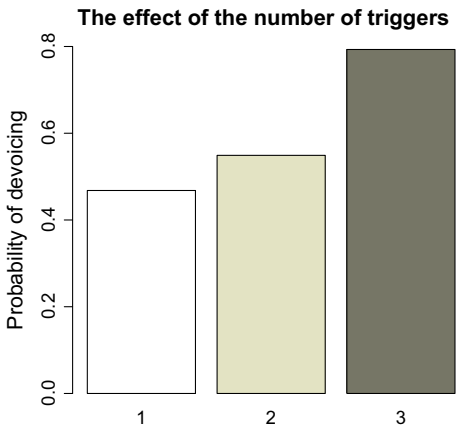

Fig. 3. The effect of the number of triggers. The more triggers exist, the more likely that geminates devoice.

This case shows that more triggers can make a variable process more likely to apply. A question arises whether there can be a categorical pattern of dissimilation which occurs only when there are more than one trigger. There are patterns of vowel harmony that are triggered only when there is more than one trigger: e.g. Classical Manchu (Dresher, 2010; Walker, 2001; Zhang, 1996) and Oroqen (Walker, 2001). The current result shows that the same pattern may hold in dissimilation—dissimilative force is stronger with multiple triggers (Kawahara, 2011a). However, Itô and Mester (2003) argue that there should not be dissimilative pattern which is triggered only by multiple triggers. Given the current results, it thus remains to be seen whether there can be a dissimilation pattern which can be triggered only by multiple triggers.

3.4. The effect of place of articulation

We now look at factors not related to the OCP, starting with the effect of place of articulation of the voiced geminates. Place of articulation is interesting to examine, because cross-linguistically it is known that backer places of articulation suffer from more articulatory difficulty in maintaining voicing for aerodynamic reasons (Hayes, 1999; Hayes and Steriade, 2004; Jaeger, 1978; Kawahara, 2006; Kingston, 2007; Ohala, 1983; Ohala and Riordan, 1979; Westbury, 1979; Westbury and Keating, 1986).

Fig. 4 shows the probabilities of devoicing according to place of articulation: [bb], [dd], and [gg]. We observe that as place of articulation goes further back in the mouth, the more likely the geminate to be devoiced: [bb] (1/18 = 5.6%), [dd] (319/1100 = 29%), [gg] (115/230 = 50%) ($\chi^2(2) = 44.3$, $p < .001$). We do acknowledge that the number of tokens for [bb] is rather small, but nevertheless we maintain that this effect of place articulation is compatible with what we expect from the aerodynamics of voiced stops, as we discuss below.[12]

This effect of place of articulation is compatible with a well-known aerodynamic consideration. Intraoral air pressure goes up with stop closure, but this rise in pressure makes it hard to maintain the transglottal air pressure drop that is necessary to produce voicing. The further back the place of articulation, the worse the problem, because the intraoral cavity behind the closure is smaller and more difficult to expand. As a result, the further back the place of articulation, the harder it is to maintain voicing (see Hayes, 1999; Hayes and Steriade, 2004; Jaeger, 1978; Kawahara, 2006; Kingston, 2007; Ohala, 1983; Ohala and Riordan, 1979; Westbury, 1979; Westbury and Keating, 1986). Therefore, the devoicability hierarchy follows the order that is predicted from an aerodynamic point of view.

3.5. The effect of lexical frequency

Finally, Fig. 5 plots the effect of lexical usage frequency on the *x*-axis against the probability of devoicing on the *y*-axis for OCP-violating geminates. The figure shows a trend for a positive correlation between the two factors. Statistically, the Pearson correlation coefficient *r* between the log-transformed lexical frequency and devoicing probability is 0.49. This result matches well with what Kawahara (2011a,b) found, although, unfortunately, the correlation coefficient did not reach significance due to small N, because there are not many words containing OCP-violating geminates (type-wise). There is one outlier whose frequency is relatively high (90) and the devoicing probability is relatively low (0.01) (*neebaahuddo* 'neighborhood'). If we exclude this item as an outlier, the *r* Pearson coefficient becomes as high as 0.69 and is statistically significant ($p < .01$).

[12] This figure sets aside [zz] for two reasons. First, we should not treat voiced stops on par with voiced fricatives, because they involve different—though related—types of aerodynamic problems (Ohala, 1983; Lindblom and Maddieson, 1988). Second, in Japanese [zz] variably alternates with [ddz], and the variation pattern is governed by some complicating phonetic factors (Maekawa, 2010). Therefore, it does not seem safe to directly compare voiced stops and voiced fricative. See Sano (2013) for some discussion on the behavior of [zz].

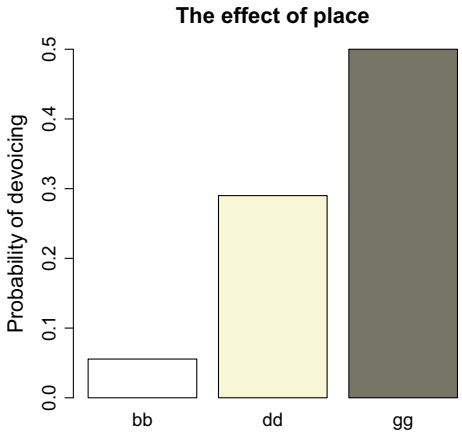

Fig. 4. The effect of place of articulation on devoicing. The backer the place of articulation, the more likely that geminates are devoiced.

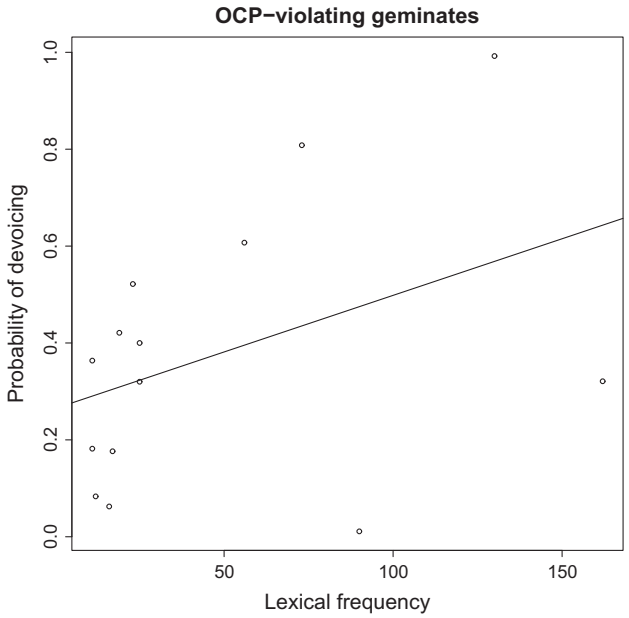

Fig. 5. The effect of lexical frequency. There is a trend toward a positive correlation relationship between lexical usage frequencies and devoicability probability.

We acknowledge, however, that the number of items under discussion is rather small, and this correlation should thus be interpreted with caution. However, we would like to point out that the correlation between lexical usage frequency and devoicing probability is compatible with Kawahara's (2011a) claim that the lexical usage frequency and devoicability stand in positive correlation, at least in naturalness judgment patterns. The result also accords well with the general, cross-linguistic observation that items with higher lexical frequency undergo phonological processes with higher probability (see Bybee, 2001, 2002; Coetzee, 2009; Coetzee and Kawahara, 2013; Goeman, 1999; Lacoste, 2008; Phillips, 2006, among others); for example, the English t/d-deletion rule is more likely to apply to more frequent items (see Coetzee and Kawahara, 2013 and references cited therein).

The claim that lexical usage frequency and probability of devoicing positively correlate can and should be validated with more solid statistical data, once Japanese speakers start using many more borrowings that contain OCP-violating geminates.

4. Conclusion

In conclusion, by studying the Corpus of Spontaneous Japanese, we have found that several linguistic factors affect the devoicing probability of voiced geminates: the OCP, the location of the trigger with respect to the geminate, the number

of triggers, place of articulation, and lexical usage frequency (the last of which may be a trend). These patterns are all in accord with phonetic considerations and/or cross-linguistic tendencies.

Overall the current results show that the devoicing of geminates in Japanese loanword phonology is not a monolithic phenomenon, as assumed in the previous theoretical analyses (except for Kawahara, 2011a). Our companion paper (Sano and Kawahara, 2013) shows that external factors, such as age and gender too, affect the probabilities of devoicing. It is hoped that further theoretical analyses of the devoicing pattern will incorporate several factors, both internal and external, in their analyses.

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