An Interaction of Mutually Bleeding Processes: Voicing of Intervocalic Plosives and Vowel Devoicing in Tohoku Japanese

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1 Introduction

Traditional phonology has paid considerable attention to the interactions of phonological processes. One pattern of the interaction is *mutual bleeding* (Baković 2011, Kiparsky 1971). Rules A and B are mutually bleeding if both these situations are present: (i) Rule A bleeds a later-ordered Rule B. (ii) If Rule B were ordered before A, B would bleed A.

Tohoku dialects are spoken in the northern part of Honshu (mainland), Japan, where intervocalic voiceless plosives /t, k/ undergo voicing. In addition, Eastern Japanese dialects, including Tohoku dialects, tend to devoice high vowels between voiceless consonants. These two processes, consonant voicing (Cvoi) and vowel devoicing (Vdev), are formulated in (1a) and (1b), respectively.

(1) a. C → [+voice] / V_V
b. V[+high] → [-voice] / C[-voice] _C[-voice]

These two processes have a mutual bleeding relationship in the sequence of C[-voice] V C[-voice] V. When voicing rule (1a) is first applied to the consonant, either side of the environment for (1b) is lost. In contrast, when (1b) is applied first, the conditional environment for (1a) is not satisfied. Therefore, the contradicting rules in (1) may result in variable realizations. For example, /kita/ may be realized as [kita] if neither is applied, [kida] if only (1a) is applied, [kḭta] if only (1b) is applied, and [kḭda] if both are applied.

Previous studies have attempted to clarify whether one rule takes over the other in certain situations, but these studies relied on aurally described data. Moreover, research on this issue was conducted a few decades ago, and the current situation may have changed because of language change. Therefore, this study addresses the issue based on acoustic measurements of new data. The following sections review previous key studies.

1.1 Consonant Voicing (Cvoi) in Tohoku Japanese

In Tohoku dialects, the voiceless plosives /t/ and /k/ are voiced intervocalically. Over the last few decades, research has demonstrated that Cvoi is diminishing among younger generations, but older adult speakers still maintain it (Saito 1990, Ohashi 2002). In addition, a recent study has shown that even speakers between the ages of 33 and 85 do not have a high Cvoi rate (33% maximum) (Noguchi et al. 2022).

1.2 Vowel Devoicing (Vdev) in Tohoku Japanese

In Tokyo Japanese, vowel devoicing frequently occurs in devoicing environments and is often claimed to be obligatory (Fujimoto 2015 and references therein).

Research on vowel devoicing in Tohoku Japanese is limited, but Byun (2012) reported regional and generational variations based on two large speech databases. According to her study, Tohoku speakers' devoicing rates change abruptly at a certain age. For example, speakers born between 1900 and 1940 in the Tohoku region showed a low devoicing rate (40–60%), whereas speakers born between 1950 and the 1990s showed a devoicing rate of over 80%.

1.3 Interaction of Consonant Voicing (Cvoi) and Vowel Devoicing (Vdev)

Previous studies on the interaction between Cvoi and Vdev were based on aurally described data (Saito 1990, Ohashi 2002). These studies state that Cvoi is preferred over Vdev when both the Cvoi and Vdev conditions are met and the vowel after the intervocalic plosive is [+high] (e.g., /kiku/ 'chrysanthemum'). In contrast, Vdev is preferred over Cvoi when the vowel after the intervocalic plosive is [-high] (e.g., /kita/ 'north'). For clarity, the basic descriptions in previous studies are summarized in Table 1, and we refer to three different patterns as Types A, B, and C, respectively.

Phonological context	Example	Realization	Type
Only the Cvoi condition is met.	/neko/ 'cat'	Cvoi	A
Both Cvoi and Vdev conditions are met, and the vowel after /t, k/ is [+high]. (C[-voi] V[+high] /t, k/ V[+high])	/kiku/ 'chrysanthemum'	Cvoi	B
Both conditions are met, and the vowel after /t, k/ is [-high]. (C[-voi] V[+high] /t, k/ V[-high])	/kita/ 'north'	Vdev	C

Table 1. Description of the interaction of Cvoi and Vdev in previous studies

Saito (1990) calculated the Cvoi rate in Types A, B, and C. For Type A and Type B words, the Cvoi rate was over 90% in the older age group. However, Type C words had a Vdev rate of approximately 100%. These results indicate that the three patterns in Table 1 occur categorically, especially in the older age group.

We will address the following limitations of previous studies: (1) We report our results based on acoustic analysis, not aural description. (2) To the best of our knowledge, research on this issue was conducted a few decades ago, and it may have changed in recent years due to language standardization. (3) Few studies have examined a sufficient number of words in several prefectures.

2 Method

2.1 Participants

Speech data were initially collected for a large-scale project (Hashimoto 2019). A total of 23 Tohoku Japanese speakers (33–85 years old) participated in an elicited production task.

2.2 Recording and Material

The speech data were collected at six sites (Aomori, Akita, Ichinoseki, Morioka, Tsuruoka, and Aizu-Wakamatsu) in five prefectures in the Tohoku region with a SONY ECM-MS957 microphone on a SONY PCMD50 recorder (16bit, 44kHz). One author from the Tohoku region elicited target words using picture-naming tasks and riddle-like questions. Participants were instructed to name the objects displayed in the pictures or objects described by the researcher. Even when participants produced a word different than expected, the words were included in the analysis if they contained intervocalic /t/ or /k/.

2.3 Acoustic Analysis

The audio files were resampled to 16kHz for semi-automatic segmentation using Julius (Kawahara and Lee 2005). Trained phoneticians checked the annotations with Praat (Boersma and Weenink 2022) and fixed the results wherever necessary. Subsequently, the first author confirmed these changes.

Voice onset time (VOT) was measured by marking the onset of a release burst and the voicing onset based on the visible concentration of energy below the 1kHz range. As Abramson and Whalen (2017) proposed, if voicing continued from the end of the preceding segment, the closure duration where voicing persisted was measured as VOT. Tokens where VOT could not be measured, were excluded from the analysis. Many of these were cases where (1) the voice onset could not be determined because the vowel after the plosive was devoiced, or (2) the onset of a release could not be determined because the burst was not visible. We also examined vowel devoicing. Vowels without visible periodic cycles in the waveform were de-

termined to be devoiced. Four speaker tokens were excluded from the analysis because the number of tokens was approximately half the number for other speakers. Nineteen speakers were analyzed (11 males, eight females), of which 16 were born after 1940, and the number of tokens was 1445.

3 Results

3.1 Interaction of Cvoi and Vdev

We first checked whether consonant voicing occurred in words where only the condition for Cvoi was met, as some studies report that Cvoi is diminishing in the younger generation (Saito 1990, Ohashi 2002). Table 2 lists the number of occurrences of Cvoi and Vdev in tokens that fulfill only the Cvoi condition. For example, the /k/ in /neko/ 'cat' fulfills the Cvoi condition, as it is in an intervocalic position, but neither the vowel /e/ nor /o/ fulfills the Vdev condition.

Type A	Example	N	Ratio (%)
	/neko/		
No application	[neko]	720	86.7
Cvoi applied	[nego]	98	11.8
Vdev applied	[n̥eko]	12	1.4
Both applied	[n̥ego]	0	0
Total		830	

Table 2. Number of occurrences of Cvoi and Vdev in tokens fulfilling only the Cvoi condition.

Whereas neither Cvoi nor Vdev occurred in 86.7% of the tokens, Cvoi occurred to some extent (11.8%).

The left columns show the results for Type B words. In some cases, neither Cvoi nor Vdev occurred (11.3%), and in others, Cvoi occurred (7.8%); however, in many cases, only Vdev occurred (80.3%). Interestingly, there were some tokens in which both Cvoi and Vdev occurred, although the percentage was low (0.5%). Note that the high Vdev rate (80.3%) in Type B has not been observed in previous research.

Table 3 shows the number of occurrences of Cvoi and Vdev in tokens fulfilling both the Cvoi and Vdev conditions. The right columns show the results for Type C. In 2.0% of tokens, neither Cvoi nor Vdev occurred. Following previous studies, consonants were not voiced (0%), and vowels were devoiced in most cases (98.0%).

	Type B Vowel after /t, k/ is [+high]			Type C Vowel after /t, k/ is [-high]		
	Example	**N**	**Ratio**	**Exam-ple**	**N**	**Ratio**
	/kiku/			/kita/		
No applica-tion	[kiku]	69	11.3	[kita]	5	2.0
Cvoi applied	[kigu]	48	7.8	[kida]	0	0
Vdev applied	[kɻku]	243	80.3	[kɻta]	247	98.0
Both applied	[kɻgu]	3	0.5	[kɻda]	0	0
Total		363			252	

Table 3. Number of occurrences of Cvoi and Vdev in tokens fulfilling both Cvoi and Vdev conditions.

3.2 Geographical Variation

Figure 1 shows the distribution of Vdev rates against Cvoi rates for each prefecture in different colors. Each dot represents a speaker. The number in parentheses in the legend indicate the number of speakers in each prefecture. The Vdev and Cvoi rates were calculated in tokens fulfilling both the Cvoi and Vdev conditions (Types B and C). For example, in Akita and Fukushima, the Cvoi rate was almost zero, and the Vdev rate was over 80%, whereas both Cvoi and Vdev occurred in Iwate and Yamagata.

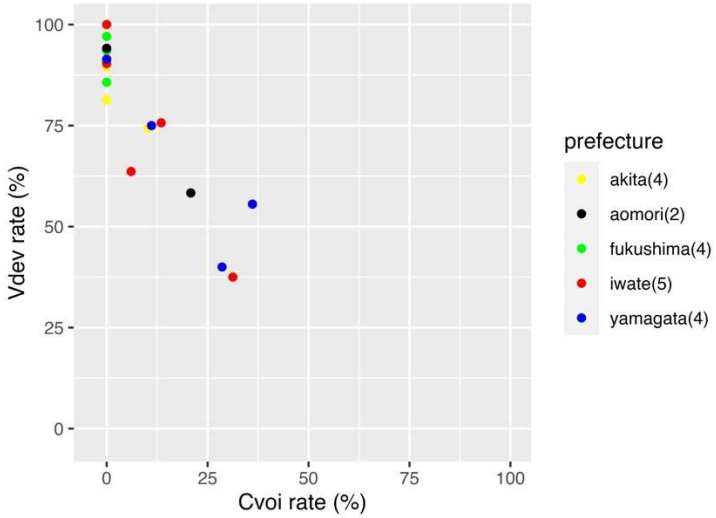

Figure 1. Vdev rate against Cvoi rate

3.3 Statistical Analysis

We conducted a statistical analysis using a linear mixed effect model with *lmerTest* package (Kuznetsova et al., 2017) in R (R Core Team, 2019: version 4.1.3). The dependent variable was VOT. The optimal model was determined using backward selection. Fixed factors of the selected model include *phonological context* (Types A, B, or C in Table 1), *segment* (/t/ or /k/), and an interaction term between *phonological context* and *prefecture*. The random factors were the *speaker* and *item*.

The results showed that the main effect of *phonological context* was not significant. The VOTs of /t/ were significantly shorter than those of /k/ (estimate = -10.8, s.e. = 3.73. p<.005). The interaction effect between *phonological context* and *prefecture* was significant, depending on the combination, indicating that the effects of *phonological context* varied by prefecture.

Pairwise comparisons were performed using the *emmeans* (Lenth et al., 2019) function with Bonferroni corrections to examine the interaction effect between phonological context and prefecture in more detail. Comparisons were performed for all prefectures, but significant results were obtained only for Yamagata. Table 4 presents the results.

Prefecture	Phonological context	Estimate	SE	*p*-value	
Yamagata	Type A - B	-1.116	4.25	0.79	
	Type A - C	-8.294	4.02	0.05	.
	Type B - C	9.411	2.11	<.0001	** *

Table 4. A part of the results of the pairwise comparisons

The difference between Types B and C in Yamagata was significant; VOTs of intervocalic plosives in Type B words (e.g., /kiku/) were shorter than that of Type C (e.g., /kita/), which is consistent with the description in Table 1. Moreover, the difference between Types A and C in Yamagata reached slight significance, which indicates that the VOTs of plosives in Type A (e.g., /neko/) were shorter than that of Type C (e.g., /kita/). This is consistent with the results in Table 1. In summary, the statistical analysis revealed that the tendencies described in Table 1 are strong in Yamagata.

4 Discussion

4.1 Interaction of Cvoi and Vdev and Its Diachronic Changes

The current study examined the interaction between Cvoi and Vdev in Tohoku Japanese. First, we confirmed that Vdev is almost always preferred over Cvoi if the vowel after the intervocalic plosive is [-high], such as /kita/,

consistent with previous studies (Saito 1990, Ohashi, 2002). However, if the vowel after the plosive is [+high], such as /kiku/, the Cvoi rate was not as high as reported in previous studies. Instead, the Vdev rate was high.

Table 5 compares Saito (1990), Ohashi (2002), and this study. In reports published a few decades ago, Cvoi was maintained; Cvoi rates were 90−100% among older adult speakers, and Vdev rates were low in Type B. In contrast, this study shows that the Cvoi rate is low, and the Vdev rate is high in Type B. This might be because Cvoi is currently decreasing due to language standardization. Thus, the gradual decrease in Cvoi over the past few decades, creating Vdev environments, may have led to a higher rate of Vdev in Type B.

Phonological context	Example	Saito (1990) Ohashi (2002)	This study (2023)	Type
Only the Cvoi condition is met.	/neko/	Cvoi	Cvoi: 12%	A
Both conditions are met and the vowel after /t, k/ is [+high].	/kiku/	Cvoi	Cvoi: 8% Vdev: 80%	B
Both conditions are met and the vowel after /t, k/ is [-high].	/kita/	Vdev	Vdev: 98%	C

Table 5. A comparison of previous reports and this study

4.2 Geographical Variation

Geographical variation was found. Vdev was almost always preferred over Cvoi in Akita and Fukushima, whereas Cvoi and Vdev were preferred in Yamagata and Iwate. Further research is needed to determine the reason for this variation.

5 Conclusion

This study aimed to test how vowels and intervocalic plosives are realized when Cvoi and Vdev are used. We confirmed that these two processes bleed each other. Moreover, vowel devoicing occurred even in an environment where prior research reported that intervocalic voicing was preferred over vowel devoicing. This finding suggests that the gradual decrease in intervocalic voicing over a few decades due to diachronic changes, which have created vowel devoicing environments, may have led to a higher devoicing rate.

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