Ms. written in 2012. Unfortunately rejected by Journal of Phonetics, which was, with handsight, for good reasons. Experiment I was separately published in the proceedings paper (Braver & Kawahara, AMP Proceedings 2014). Since the results of Experiment 2 are of some interest, I have decided to make this paper publicly available. The hypothesis that only post-lexical phonological processes can result in incomplete neutralization is something that is worth pursuing.

Complete and incomplete neutralization in Japanese monomoraic lengthening

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Abstract

Previous phonetic studies have found many cases of incomplete neutralization, in which phonologically neutralized segments show subtle phonetic differences on the surface. The current project adds a new case of incomplete neutralization to this body of literature. Following Mori (2002), Experiment I shows that the vowels of monomoraic nouns in Japanese are lengthened when they appear in isolation within a Prosodic Word, in order to satisfy a bimoraic minimality requirement (Poser, 1990). However, going beyond the scope of Mori's (2002) study, Experiment I also shows that the lengthened nouns' vowels are not as long as underlyingly long vowels. These results expand the typology of incomplete neutralization by showing that incomplete neutralization happens for duration-based length contrasts. Experiment II examines another lengthening phenomenon in response to the Japanese bimoraicity requirement, originally described in telephone number recitation (Itô, 1990), and found that this lengthening is completely neutralizing—lengthened vowels become at least as long as underlyingly long vowels. Taken together, the current project shows that the same language can possess two related phonological patterns, only one of which is incompletely neutralizing.

Keywords: neutralization; incomplete neutralization; prosodic minimality; Japanese; vowel duration.

1 Introduction

The current experiment offers a new case study on incomplete neutralization from Japanese. Incomplete neutralization refers to cases in which two segments that are apparently neutralized phonologically are realized with subtle phonetic differences on the surface. A classic case of incomplete neutralization is coda devoicing, which has been found in many different languages: Catalan (Dinnsen and Charles-Luce, 1984), Dutch (Warner et al., 2004), German (Port and O'Dell, 1985; Kleber et al., 2010), Polish (Slowiaczek and Dinnsen, 1985; Slowiaczek and Szymanska, 1989), and Russian (Dmitrieva, 2005; Dmitrieva et al., 2010). In these languages, devoiced consonants, which are underlyingly voiced, result in a different surface realization than underlyingly voiceless segments. For example, Port and O'Dell (1985) found that in German, vowels before devoiced stops are approximately 15 ms longer than those before underlyingly voiceless stops. They also found differences in aspiration duration, voicing duration, and closure duration—each of which mimicked (to a reduced degree) the differences found between voiced and voiceless consonants in non-devoicing contexts in German and other languages.

Since Port and O'Dell's classic finding on German coda devoicing, incomplete neutralization has been found in a number of other cases, including epenthesis in Levantine Arabic (Gouskova and Hall, 2009), flapping in American English (Braver, under review; Herd et al., 2010), insertion of intrusive stops in English (Fourakis and Port, 1986), tonal neutralization in Cantonese (Yu, 2007), voicing assimilation in Russian (Burton and Robblee, 1997), [ə]-insertion in English speakers' pronunciation of non-native clusters (Davidson, 2006), and coda aspiration in Eastern Andalusian Spanish (Gerfen, 2002).

While the vast majority of previously described cases of incomplete neutralization center on feature- and segment-level contrasts, our aim is to provide evidence of a novel case of incomplete neutralization in the domain of duration-based length contrasts. We also show that a single language can *incompletely* neutralize a given contrast in one phonological phenomenon, yet *completely* neutralize it in a different, related, process.

Our study centers on a prosodic constraint in Japanese which requires every Prosodic Word

to be minimally bimoraic. When monomoraic nouns appear in isolation, they must lengthen to meet this prosodic minimality requirement (Mori, 2002). Experiment I shows that these lengthened nouns are not as long as underlyingly long nouns, which constitutes a case of incomplete neutralization. This study expands the typology of incomplete neutralization by showing that duration-based length contrasts can be incompletely neutralized.[1] Experiment II examines another lengthening phenomenon, namely that of number recitation, which shows that lengthened vowels are as long as underlying long vowels. Taken together our results show that Japanese possesses two lengthening phenomena, both of which are in response to a prosodic minimality requirement, but only one of which is incompletely neutralizing.

2 Background

There is a large body of evidence showing that Japanese has a bimoraic minimality requirement on Prosodic Words (Itô, 1990; Poser, 1990; Mester, 1990; Itô and Mester, 1992; Mori, 2002). This bimoraicity requirement is observed in many word formation patterns, all of which are based on a bimoraic template, including nickname formation, geisha client name formation, loanword abbreviation, verbal root reduplication, scheduling compounds, and telephone number recitation.

For instance, in the nickname formation pattern, a full name must be truncated to two moras before suffix *-chan*[2] can be applied. For example, the five-mora name *Wasaburoo* can be truncated to two moras as in (1b), but not one, as in (1c). Similarly, the three-mora name *Kotomi* can be truncated to either two monomoraic syllables, as in (2b), or a single bimoraic syllable, as in (2c). *Kotomi* cannot, however, be shortened to a single mora, as in (2d).

[1] Myers (2005) shows a case where a short/long vowel length contrast surfaces as three different durations (short vowels, lengthened short vowels before NC sequences, and long vowels). As Myers himself argues, however, the distinction between lengthened and long vowels is best described as coarticulatory shortening of vowels in closed syllables (Fowler, 1983; Maddieson, 1985). Since this case is explained by factors of phonetic implementation, it does not constitute evidence of true incomplete neutralization of a duration-based length contrast.

[2] Here and throughout, Japanese morphemes are given in the standard Romaji romanization, except when enclosed in [square brackets], in which case, they are given in IPA.

(1) (a) wasaburoo (full name)

(b) wasa(-chan) (2 moras)

(c) *wa(-chan) (1 mora)

(2) (a) kotomi (full name)

(b) koto(-chan) (2 moras)

(c) koc(-chan) (geminate; 2 moras)

(d) *ko(-chan) (1 mora)

The bimoraicity requirement is evident, too, in telephone number recitation patterns (Itô, 1990). In the recitation of telephone numbers, monomoraic digits (e.g. *ni* 'two') are lengthened, as in (3a). Additionally, those digits which have both a monomoraic and a bimoraic allomorph (e.g., *shi*∼*yon* 'four') always surface as the bimoraic allomorph, as in (3b).

(3) (a) 6 5 1 - 3 2 8 6

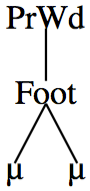
roku {**goo** / *go} ichi (no) san {**nii** / *ni} hachi roku

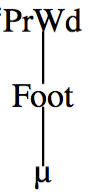
(b) 4 6 1 - 3 8 9 6

{**yon** / *shi} roku ichi (no) san hachi {**kyuu** / *ku} roku

This number recitation pattern is examined in more detail in Experiment II.

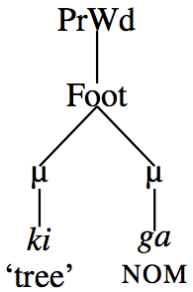
What nickname formation and telephone number recitation—as well as numerous other morphophonological processes in Japanese (Itô, 1990; Poser, 1990; Mester, 1990; Itô and Mester, 1992; Mori, 2002)—have in common is that they are all based on the requirement that a Prosodic Word must be binary at the moraic level. A Prosodic Word must contain at least one foot, and the foot must be binary (McCarthy and Prince, 1986, 1993) (at the moraic level in Japanese), as in (4).

(4) (a) 

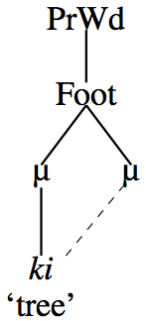
(b) 

In spite of this bimoraicity requirement, there are monomoraic nouns in the Japanese lexicon; e.g., [ki] 'tree', [i] 'stomach', and [e] 'picture'. Itô (1990) argues that the bimoraic minimality requirement holds only for morphologically derived words. However, Mori (2002) shows that when these monomoraic nouns appear in isolation within a prosodic word (e.g., without case particles), lengthening occurs. She found that monomoraic nouns lengthen in this context by 40–50%, while underlyingly bimoraic nouns do not show such lengthening in the same environment. Therefore, Mori concludes that this lengthening is caused by a phonological bimoraic minimality requirement: monomoraic nouns with a case particle in the same Prosodic Word satisfy the bimoraicity requirement (by virtue of the particle's mora), as in (5a), while monomoraic nouns must gain an additional mora to satisfy this requirement, as in (5b).

(5) (a) No lengthening with a particle



(b) Lengthening without a particle



Although Mori does not include underlyingly long vowels in her stimulus set, she does refer to previous studies (Beckman, 1982; Hoequist, 1983) which have shown that Japanese heavy syllables are are generally 66–80% longer than light syllables. A more recent phonetic study by Hirata (2004) shows that long vowels in Japanese can be up to 150% longer than short vowels. This difference between Mori's results (40-50% longer) and other studies on Japanese length distinctions implies, as Mori herself suggests, that we may be observing a case of incomplete neutralization. Experiment I sets out to directly test this hypothesis by comparing the vowel duration of lengthened nouns to that of underlyingly long nouns.

3 Experiment I

In this experiment, native speakers of Japanese were asked to read sets of sentences. Each set was constructed with a minimal triplet: (a) an underlyingly monomoraic, short noun with a particle, (b) an underlyingly monomoraic noun without a particle, and (c) an underlyingly bimoraic, long noun. From the previous studies discussed above, we expect that (i) monomoraic nouns are lengthened without case particles, as Mori (2002) found, but that (ii) the lengthened nouns are not as long as underlyingly long vowels.

3.1 Method

3.1.1 Stimuli

15 sets of minimal triplet sentences were constructed, each containing: (a) a monomoraic noun followed by the particle *mo* ('short/prt' condition), (b) a monomoraic noun without a particle ('short/Ø' condition), and (c) an underlyingly long noun without a particle ('long' condition). A sample set is given in Table 1.

	Condition	Japanese orthography	Transcription	Gloss
(a)	short/prt	木もなくしたよ。	ki mo nakushita yo	tree ALSO lost DISC
(b)	short/Ø	木なくしたよ。	ki nakushita yo	tree lost DISC
(c)	long	キーなくしたよ。	kii nakushita yo	key lost DISC

Table 1: Sample stimulus set from Experiment 1.

Within each set, the nouns' segmental content was identical, with the exception of vowel length in the long condition. We used non-approximant consonants as onsets (if present) in the target nouns to facilitate clear segmentation. Our previous study (Braver and Kawahara, 2013) used the nominative particle *ga*, since it is arguably the default case marker in Japanese subjects (Fukui, 1986; Inoue, 1997). In that study, however, we found that [g] sometimes spirantized, which made the segmentation more difficult. Therefore, in this study, we chose to use the commitative particle *mo* in the short/prt condition in order to facilitate segmentation. We did not include a particle in the

long vowel condition, because our main target comparison was between the short/Ø condition and the long condition.[3] Since Mori (2002) had already shown that long nouns are barely affected in duration by the presence/absence of case particles, we did not vary this dimension in our stimuli. All three items within a given set had the same predicate to control for any sentence-level duration compensation effects. The predicate always started with a non-approximant consonant to make the segmentation more straightforward. A sentence-final discourse particle [yo] was attached at the end of each sentence to make the stimulus sentences more colloquial, and to further make the absence of case particles more natural. The list of all the stimuli used in this experiment is provided in Appendix A.

3.1.2 Participants

Twelve native speakers of Japanese participated in the experiment. They were all undergraduate students at International Christian University (Tokyo, Japan). They were paid ¥500 for their time. They each signed a consent form before participating in the experiment.

3.1.3 Procedure

The recording session took place in a sound-attenuated room at International Christian University. We used Superlab version 4.0 (Cedrus Corporation, 2010) to present the stimuli. The stimuli were written in the standard Japanese orthography, with a mixture of kanji, katakana, and hiragana (see Appendix A).

In each block, every stimulus was presented once, and speakers were asked to read the stimuli as they were presented on the screen. The speakers were allowed to take a short break after each block. The order of the stimuli within each block was randomized by Superlab. Each speaker read each sentence a total of 7 times. Each speaker was assigned 30 minutes for the experiment.

Before the main session, as practice, each speaker read all the stimuli once to familiarize themselves with the stimuli and the task. After the practice phase, the experimenter (the second author)

[3]Due to an error, one stimulus set contained the particle *mo* in the long condition. A post-hoc analysis shows no substantial difference between this set and other sets.

answered any questions that they had. Their speech was directly recorded onto a portable recorder (TASCAM DR-40) with a 44k sampling rate and a 16 bit quantization level. The second author sat with each speaker throughout the experiment to monitor the progress of the recording.

The duration of each vowel was measured, starting at the offset of the preceding consonant and ending at the end of visible F2/F3, using Praat (Boersma and Weenink, 2009). A representative spectrogram is given in Figure 1.

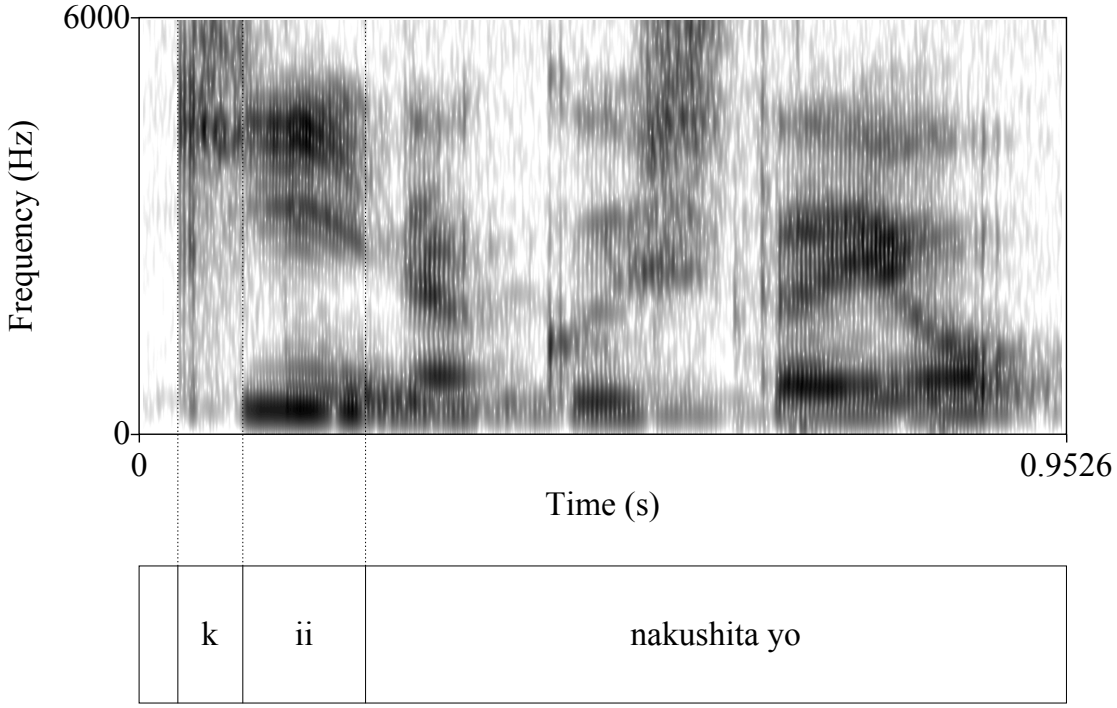


Figure 1: Experiment I: A representative segmented spectrogram. Speaker 43, *kii nakushita yo* (long), repetition 7.

3.1.4 Statistical analysis

Statistical significance was assessed with a linear mixed model (Baayen, 2008) in which vowel duration was regressed against condition (short/prt, short/Ø, long) as a fixed factor and with speaker and item as random factors. Condition was treatment coded to produce comparisons between

short/prt vs. short/Ø (to assess whether lengthening occurs) and short/Ø vs. long (to assess whether lengthened nouns are as long as underlyingly long nouns). Since the way to calculate degrees of freedom for these analyses are not yet known (Baayen, 2008), the significance values are calculated by the Markov Chain Monte Carlo method using the `pvals.fnc()` function of the `languageR` package (Baayen, 2009).

3.2 Results

Figure 2 shows the overall results, averaging over all speakers and all items. We observe that short nouns are lengthened when they appear without case particles and hence are longer than short nouns that appear with particles (mean difference: 69.98 ms, $t = 15.692, p < 0.001$). However, the lengthened nouns are not as long as underlyingly long vowels (mean difference: 32.47 ms, $t = 7.047, p < 0.001$). Therefore, the Japanese lengthening pattern instantiates a case of incomplete neutralization.

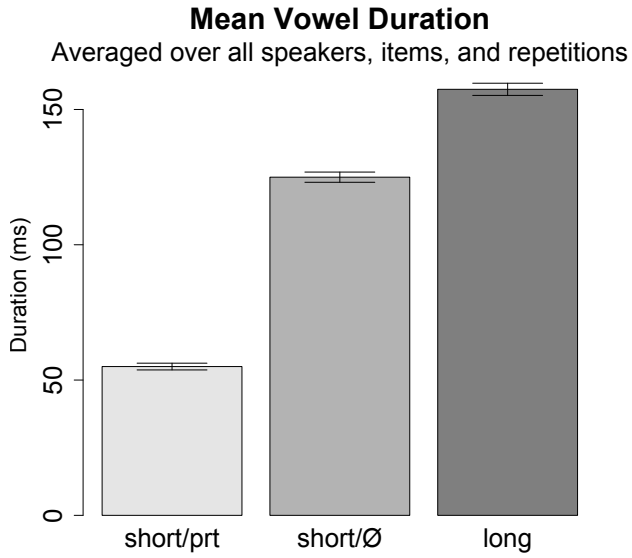


Figure 2: Experiment I: Vowel duration over all speakers and all items.

To investigate whether this tripartite distinction holds across speakers, Figure 3 shows the patterns of all 12 speakers analyzed. We observe that all speakers show incomplete neutralization:

lengthened nouns are not as long as underlyingly long nouns for any speaker.[4]

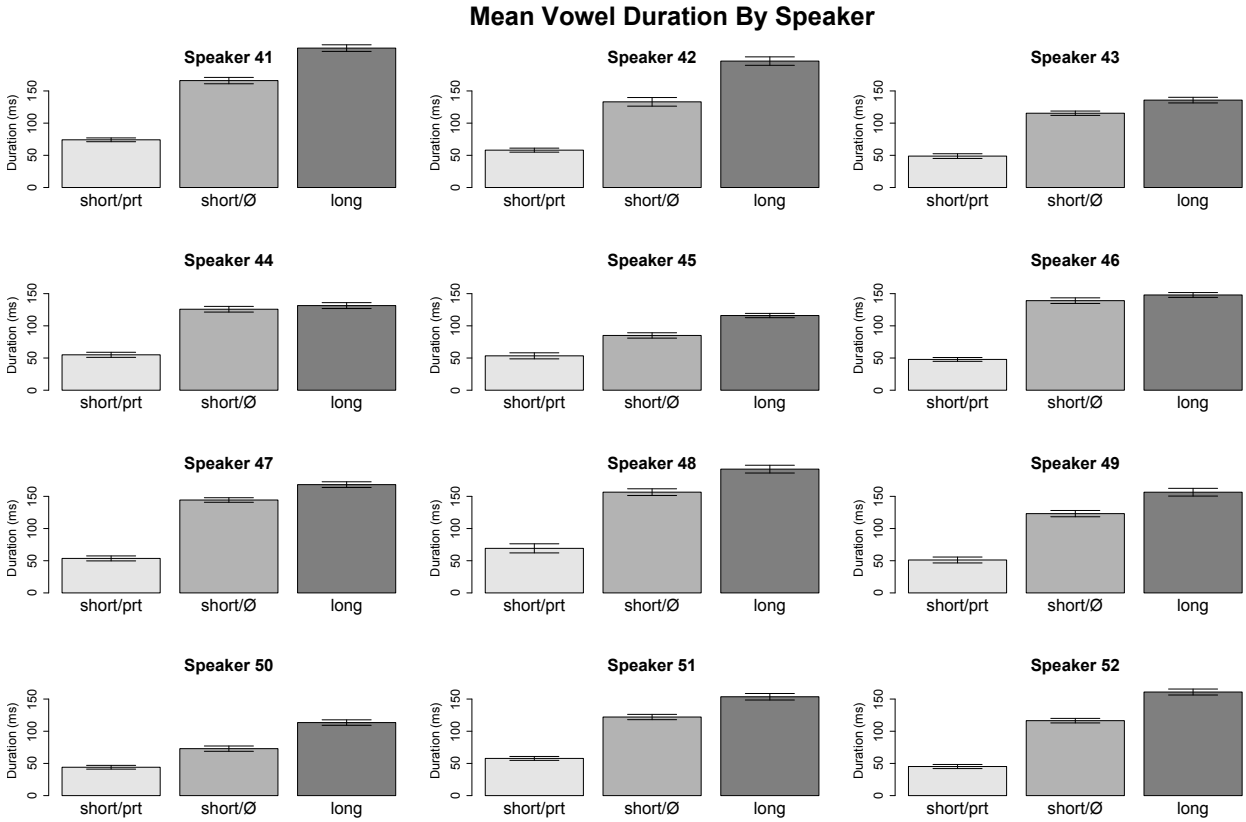


Figure 3: Experiment I: Vowel duration by speaker, averaged across items.

Finally, to investigate the item effect, Figure 4 shows a by-item analysis, with results for each of the 15 lexical sets. We again observe that within each set, all short nouns are lengthened without particles, but they are not as long as underlyingly long nouns.

3.3 Discussion

3.3.1 Looking deeper into the data

We first take a deeper look at the data, discussing some aspects of our stimulus sets and our results.

[4]The two speakers with the smallest mean differences between short/Ø and long vowels were speakers 44 and 46. The difference for speaker 46 is significant (short/Ø mean: 139.12, long mean: 147.94, mean difference: 8.82, $t = 19.43, p < 0.001$). The difference for speaker 44 trends in the same direction as the other speakers, but does not reach significance (short/Ø mean: 125.79, long mean: 131.45, mean difference: 5.66, $t = .928, n.s.$).

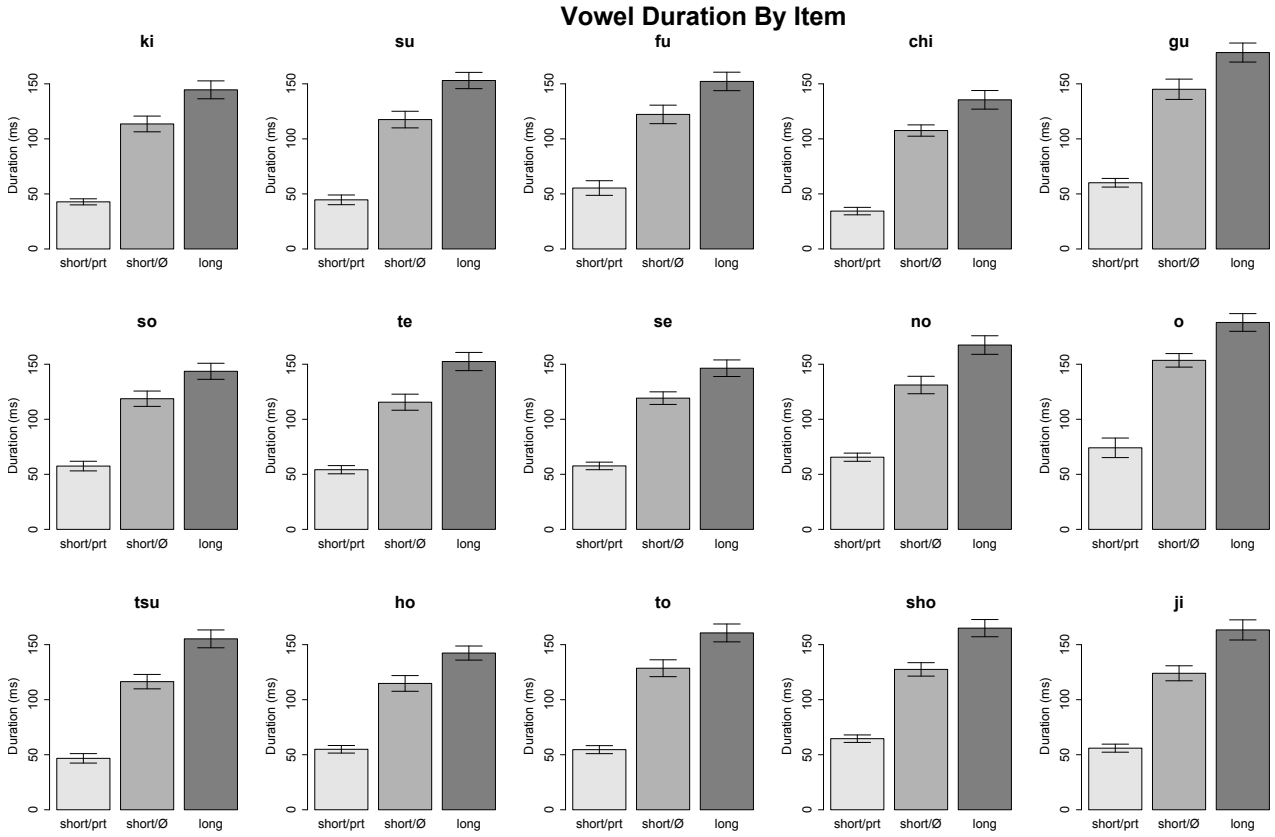


Figure 4: Experiment I: Vowel duration by item, averaged across speakers.

3.3.1.1 Distribution of conditions within each speaker One might argue that this case of incomplete neutralization derives from optional application of vowel lengthening. If speakers apply lengthening of short/Ø nouns optionally, they would produce both short and long nouns in the short/Ø condition—averaging over these tokens would result in an intermediate duration between the short/prt and long conditions. To address this possibility, Figure 5 provides histograms of each condition for each speaker. This alternative hypothesis predicts that lengthened nouns should show a bimodal distribution—one portion of the short/Ø tokens overlapping with the short/prt condition and the other portion overlapping with the long condition.

We observe that, contrary to the hypothesis entertained above, lengthened nouns have a unimodal distribution which is intermediate between the short condition distribution and the long condition distribution.

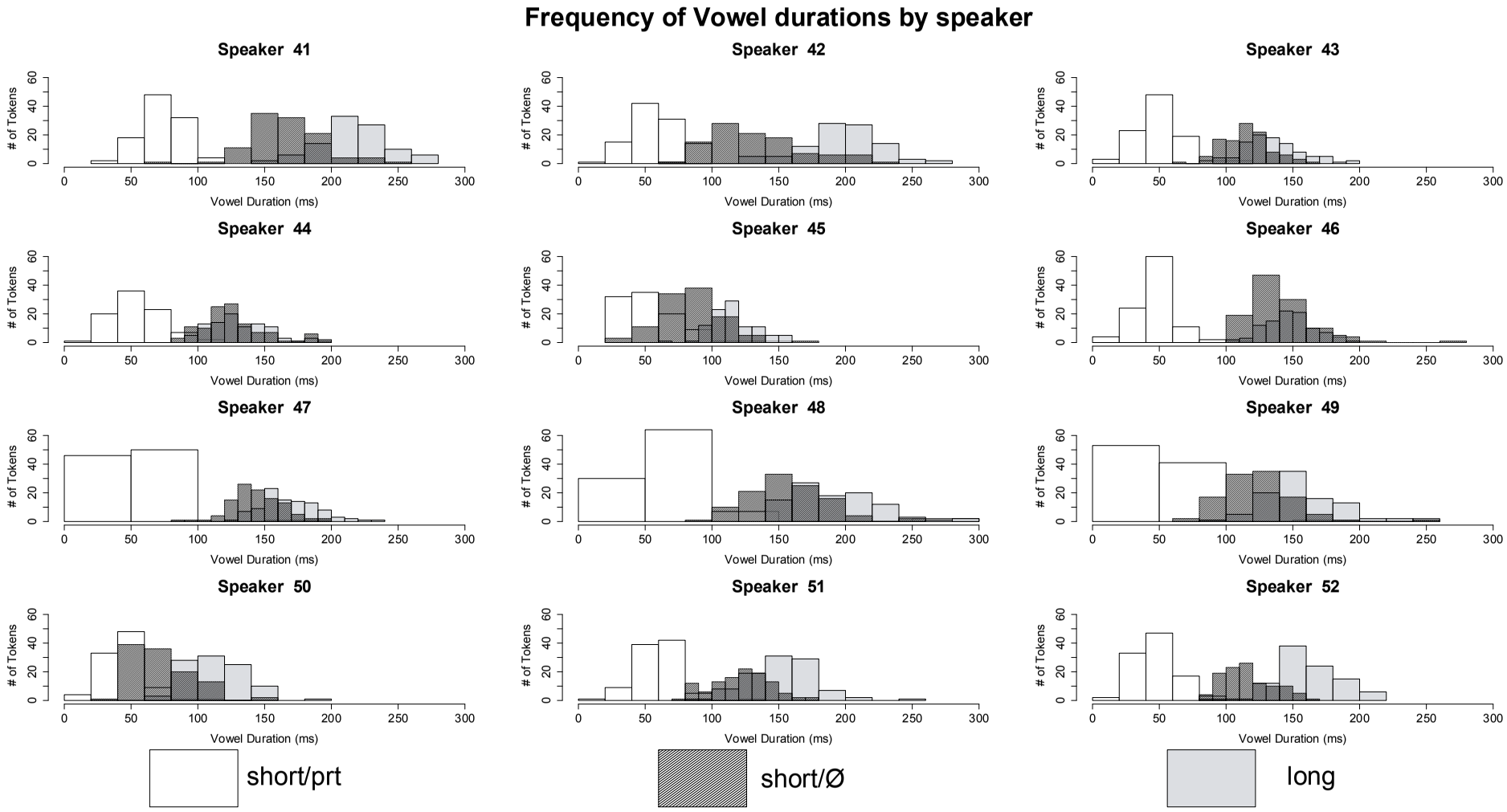


Figure 5: Experiment I: Distribution of vowel duration by condition, for each speaker.

3.3.1.2 Orthographic diphthongs According to Japanese writing convention, some long vowels are represented as 'orthographic diphthongs' when spelled out in the hiragana syllabary. For example, *nou* [noo] 'brain' would be written in hiragana as 'のう' (no + u). Some long vowels in our experiment, had they been written in hiragana, would have been rendered this way (e.g., *nou* as above, and *tei* [tee] 'base' as 'ていʼ (te + i)), however, all long target stimuli were rendered in logographic kanji or the katakana syllabary which renders long vowels with a length mark (ー). These orthographic diphthongs are generally pronounced as long vowels (Labrune 2012; see Vance 2008, pp. 63–68 for discussion), and thus were not expected to be a confound. Recall from Figure 4 that the tripartite incomplete neutralization holds for all lexical sets—only some of which would have had orthographic diphthongs had they been written in hiragana. Incomplete neutralization holds in both the 7 sets where orthographic diphthongs would have been present had we used hiragana for the long nouns, as well as in the 8 remaining sets where the writing system did not call for orthographic diphthongs (see Table 2).

		Duration		Difference		
Orthographic diphthong sets ($n = 7$)	short/prt:	60.53ms	}	66.60ms	$t = 3.87$,	$p < 0.001$
	short/Ø:	127.13ms	}	32.65ms	$t = 8.01$,	$p < 0.001$
	long:	159.78ms				
Non-orthographic diphthong sets ($n = 8$)	short/prt:	51.12ms	}	72.91ms	$t = 5.78$,	$p < 0.001$
	short/Ø:	124.03ms	}	31.67ms	$t = 13.89$,	$p < 0.001$
	long:	155.70ms				

Table 2: Experiment II: Results from sets containing orthographic diphthongs in long vowel conditions, and those without orthographic diphthongs.

3.3.1.3 Accent mismatches Finally in some sets, short nouns and long nouns differ in accent (e.g., *fu* is unaccented while *fu'u* is accented) (see Appendix A). However, since the effect of accent on Japanese vowel duration is minute (8% increase in Hoequist 1983) and 12 out 15 sets are controlled in terms of their accentuation, our finding of a durational difference between lengthened nouns and long nouns cannot be attributed to accentual differences. Recall again that the tripartite

incomplete neutralization holds in all sets, regardless of whether the short nouns and long nouns agree in accent. Incomplete neutralization holds in the 3 sets with accent mismatches, as well as in the 12 sets with no such mismatch (see Table 3).

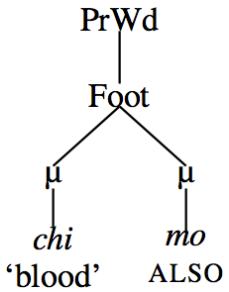
		Duration		Difference		
Accent mismatch sets ($n = 3$)	short/prt:	50.19ms	}	74.79ms	$t = 2.03$,	$p < 0.05$
	short/Ø:	124.98ms	}	30.39ms	$t = 5.08$,	$p < 0.001$
	long:	155.37ms				
Non-accent mismatch sets ($n = 12$)	short/prt:	56.12ms	}	68.86ms	$t = 6.90$,	$p < 0.001$
	short/Ø:	124.98ms	}	33.05ms	$t = 14.91$,	$p < 0.001$
	long:	158.03ms				

Table 3: Experiment II: Results from sets accent mismatches, and those without accent mismatches.

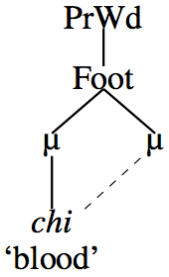
3.3.2 General implications

The current results suggest that the short/long vowel length distinction in Japanese is incompletely neutralized when monomoraic nouns without case particles are lengthened: these lengthened nouns must have two moras on the surface to meet the Japanese bimoraicity requirement (Itô, 1990; Poser, 1990; Mester, 1990; Itô and Mester, 1992; Mori, 2002), yet their vowel durations are intermediate between those of underlyingly short and underlyingly long vowels. As an example, take the set given in (6). Since *chi mo* (short/prt), in (6a), and *chii* (long), in (6c), both have two underlying moras within their Prosodic Word, no lengthening occurs in these conditions. In order to meet the bimoraicity requirement, *chi* (short/Ø), in (6b) must link to a second additional mora, since there is no other available underlying segmental content. This study shows, however, that lengthened vowels like those in (6b), are not as long as underlyingly long vowels, like those in (6c).

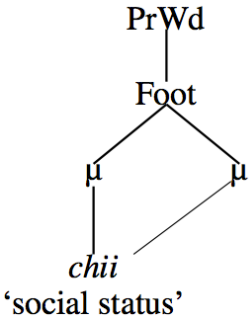
(6) (a) short/prt



(b) short/Ø



(c) long



Having established that the Japanese case is indeed a case of incomplete neutralization, some remarks are in order. First the current results expand the typology of processes that can lead to incompletely neutralized contrasts to include not just processes at the segment- and feature-level, but also processes motivated by suprasegmental structure.

Second, since the lengthening is triggered by a clearly phonological constraint, it cannot be treated as a matter of phonetic implementation—unlike a number of proposed cases of incomplete neutralization. For example, Ohala (1974) and Fourakis and Port (1986) treat the case of intrusive stops in English as a matter of phonetic implementation. Similarly, Davidson (2006) treats [ə]-insertion in English speakers' pronunciation of non-native clusters, which results in an apparent case of incomplete neutralization, as resulting from gestural mis-coordination. If the phenomenon in question is a matter of phonetic implementation, it is not strictly speaking a case of incomplete neutralization, as two segments are not neutralized phonologically.

In the current case, however, lengthening is motivated by a clearly phonological, rather than phonetic, bimoraic minimality constraint in Japanese. The constraint is deeply tied into the morphophonology of Japanese, as it governs many Japanese morphophonological patterns (Itô, 1990; Poser, 1990; Mester, 1990; Itô and Mester, 1992; Mori, 2002). We thus conclude that lengthening is phonological, as it is triggered by a phonological constraint, and cannot be relegated to a matter of phonetic implementation.

4 Experiment II

Experiment I has shown that lengthened vowels are not as long as underlyingly long vowels, thus constituting a case of incomplete neutralization. Experiment II tests whether another lengthening phenomenon, observed by Itô (1990), shows incomplete neutralization. As exemplified in (7), repeated from (3), Itô (1990) pointed out that when Japanese speakers read out a sequence of numbers, as in telephone number recitation, monomoraic numbers (*ni* '2' and *go* '5') are lengthened. She further argues that for those digits with both a monomoraic and a bimoraic allomorph ('4' can be *shi* or *yon*; '9' can be *ku* or *kyuu*), the bimoraic allomorphs are preferred in this context.

(7) (a) 6 5 1 - 3 2 8 6

roku {**goo** / *go} ichi (no) san {**nii** / *ni} hachi roku

(b) 4 6 1 - 3 8 9 6

{**yon** / *shi} roku ichi (no) san hachi {**kyuu** / *ku} roku

Experiment II was designed to test whether these patterns hold and, if lengthening occurs, whether it results in incomplete neutralization as in Experiment I.

4.1 Method

Experiment II was conducted right after Experiment I, with the same set of participants. All aspects of Experiment II are identical to those in Experiment I, except as noted below.

4.1.1 Stimuli

The stimuli in Experiment II are grouped into four sets. The two 'main' sets consist of (a) an underlyingly monomoraic number in a non-lengthening context, (b) an underlyingly monomoraic number in a lengthening context, and (c) an underlyingly long noun, as shown in Table 4 (with

targets in bold). As with Experiment I, the target words in these sets shared identical segmental content, with the exception of vowel length in the long condition. The non-lengthening context consisted of the target digit preceded by '10' [ʤu] (thus forming a 'teen', e.g., [ʤu-go] = 'ten-five' = 'fifteen'). Since this unit consists of two moras, lengthening is not predicted. In the lengthening context, the target digit was the second in a list of four digits, each of which was pronounced as its own prosodic unit. Within each set, the frames surrounding the target words in each stimulus in the lengthening and long contexts had the same total number of moras to control for any phrase-level length effects.

We also prepared a 'bimoraic' set, which used the underlyingly bimoraic [san] '3' in both the lengthening and non-lengthening contexts, to be used as a comparison. Finally, we prepared an 'alternators' set, with '4' ([shi]∼[jon]) and '9' ([ku]∼[kjuu]) in the lengthening context, to ensure that bimoraicity is preferred in this environment. Across all stimulus sets, the target was always the second morpheme, following one of {*ichi* '1', *ju-* '10', or *ano* 'that/those'}. The full list of stimuli is provided in Table 4.

Set	Japanese orthography	Transcription	Gloss
Main (*ni*)	１２番から １２３６ あのにいさんたち	ju-**ni** ban kara ichi **ni** san roku ano **nii**-san tachi	ten-two NUMBER from one two three six those older brother-HON PL
Main (*go*)	１５番から １５７８ あの豪くんたち	ju-**go** ban kara ichi **go** nana hachi ano **gou** kun tachi	ten-five NUMBER from one five seven eight those (name) NAME.SUFFIX PL
Bimoraic *(san)*	１３番から １３６４	ju-**san** ban kara ichi **san** roku shi/yon	ten-three NUMBER from one three six four
Alternators	１４３２ １９８０	ichi **shi/yon** san ni ichi **ku/kyuu** hachi zero	one four three two one nine eight zero

Table 4: Experiment II: All stimulus sets.

4.1.2 Procedure

The recording procedure was almost identical to that of Experiment I, except that for items in the lengthening environment, condition (b), speakers were instructed to read the stimuli as if they were reading hotel room numbers. In this context, each digit of a number is read separately (e.g., *ichi ni san roku* 'one two three six') rather the whole word being read as one number (e.g., **sen nihyaku sanjyuu roku* 'twelve hundred thirty-six' for the second item in Table 4).

4.2 Results

Figure 6 shows the overall results, averaging over all speakers and all items in the main sets. We observe that vowels in monomoraic numbers lengthen when they appear in the lengthening 'hotel room' context, and hence are longer than those in monomoraic numbers when they are part of the bimoraic unit in the 'short' context (mean difference: 75.92 ms, $t = 10.586, p < 0.001$). The difference between vowels in lengthened and underlyingly long numbers was not significant (mean difference: 13.85 ms, $t = 1.90, n.s.$).[5] This two-way distinction, which holds for both 'main' stimulus sets, suggests that vowel length is completely neutralized in number recitation in Japanese.

In order to examine whether the lengthening effects of the 'lengthening' condition were indeed due to the bimoraic minimality requirement rather than some other factor of the lengthening environment, we examined the 'alternators' set which placed digits with both short and long allomorphs in the lengthening context. It was predicted that the bimoraic allomorph would be preferred in the lengthening environment since it could fulfill the bimoraicity requirement, while the monomoraic allomorph could not. All speakers produced all tokens of all items using the bimoraic allomorph (i.e., [jon] for '4' and [kjuu] for '9'), and no speaker ever used the monomoraic allomorph (i.e., [shi] for '4', and [ku] for '9'). This supports the observations of Itô (1990), and also suggests

[5]Lengthened numbers were slightly longer than underlyingly long numbers, though this difference was not statistically significant (see Figure 6). We therefore examined the bimoraic set, and found a comparable difference between numbers in the hotel room condition and underlyingly long numbers (hotel room numbers were 13.85 ms longer in the main sets, and 15.92 ms longer in the bimoraic set). The hotel room condition, therefore, may induce lengthening of approximately 15 ms—beyond that due to the bimoraicity requirement.

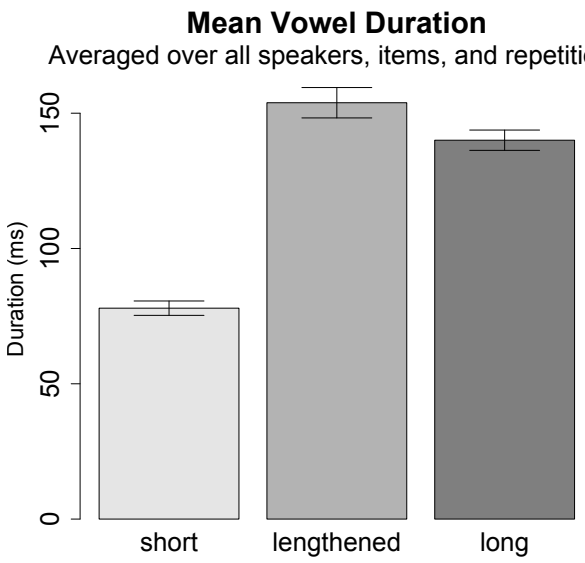


Figure 6: Experiment II: Average vowel duration over all speakers and all items in the *main* stimulus set.

that the lengthening context used in this task does, indeed, enforce a preference for two moras per Prosodic Word.

4.3 Discussion

These results suggest that the short/long vowel length distinction in Japanese is completely neutralized when monomoraic digits are recited in lengthening contexts: the numbers lengthen to meet the Japanese bimoraicity requirement (Itô, 1990; Poser, 1990; Mester, 1990; Itô and Mester, 1992; Mori, 2002), becoming similar in duration to underlyingly long digits.

Given that the monomoraic digits in the main stimulus sets lengthened and that only the bimoraic allomorphs were used in the lengthening context in the alternators set, it is clear that lengthening here, as in Experiment I, is due to the Japanese bimoraic minimality requirement.

This result does, however, contrast with the finding of an incompletely neutralized vowel length distinction in the nouns in Experiment I: we find incomplete neutralization in Experiment I, but complete neutralization in Experiment II. We believe this to be the first demonstration of a single language possessing two related phonological processes, only one of which is incompletely

neutralizing.

5 General discussion and conclusion

5.1 Summary

The two current experiments show that the short/long vowel length distinction in Japanese is incompletely neutralized in the context of monomoraic noun lengthening (Experiment I), but is completely neutralizing in number recitation (Experiment II). These results constitute two novel findings: (a) duration-based length contrasts can be incompletely neutralized, as shown in Experiment I, and (b) a given contrast that is incompletely neutralized in one phonological process may be completely neutralized in related processes in the same language (Experiments I and II).

5.2 Where does the difference come from?

A question that arises is what causes the difference between the incomplete neutralization found in noun lengthening on the one hand (Experiment I), and the complete neutralization in number recitation on the other (Experiment II).

One possible explanation comes from the level—lexical vs. post-lexical (Kiparsky, 1982a,b, 1985; Mohanan, 1982; Kaisse and Shaw, 1985)—at which the two processes described in this paper apply. Monomoraic noun lengthening as described by Mori (2002) occurs post-lexically—nouns lengthen when syntactic particles are omitted or dropped. Itô (1990) argues that lengthening in number recitation, however, is due to morphological derivedness, and therefore applies at the lexical level. Recall also that the bimoraicity requirement in number recitation affects allomorph selection (e.g., *shi*∼*yon*)—further evidence that this requirement holds at the lexical level. This distinction—between application at the lexical vs. post-lexical level—could determine whether a contrast is or is not allowed to be incompletely neutralized.[6]

[6]This idea has some similarity to Structure Preservation (Kiparsky, 1982a, 1985)—namely that processes at the lexical level are constrained to a more restricted set of outputs than those at the post-lexical level. In traditional Structure Preservation, that means lexical processes cannot introduce segments not already belonging to the language's

This hypothesis enjoys some broader typological support as well. For example, devoicing in Russian, which is incompletely neutralizing (Dmitrieva, 2005; Dmitrieva et al., 2010), occurs across word-boundaries (Padgett, 2011), and is therefore post-lexical. Similarly, flapping in American English is incompletely neutralizing (Braver, under review; Herd et al., 2010) and occurs both within words (e.g. 'sitting' → si[ɾ]ing), and across word boundaries (e.g., 'sit in the park' → si[ɾ] in the park).[7] On the other hand, manner neutralization in Korean codas—which Kang (1993) argues is a lexical-level process—is incomplete (Kim and Jongman, 1996).[8] Although it is beyond the scope of this paper to fully defend this typological claim, it opens up new predictions to be tested in future research.

5.3 Conclusion

We conclude with two brief remarks. First, we note that the typology of processes susceptible to incomplete neutralization must be expanded to include processes—like monomoraic noun lengthening—that affect a contrast of length or prosodic structure. Second, a given phonological contrast within a language can be completely neutralized by one process, while at the same time being incompletely neutralized by another.

Appendix A: Stimuli from Experiment I

Japanese orthography	Transcription	Gloss
木もなくしたよ。	**ki'** mo nakushita yo	tree ALSO lost DISC
木なくしたよ。	**ki'** nakushita yo	tree lost DISC
キーなくしたよ。	**ki'i** nakushita yo	key lost DISC

(continued...)

underlying inventory, and in the hypothesis sketched here, lexical-level neutralization is barred from creating an output intermediate between two such segments.

[7] These examples of flapping are due to Kaisse and Shaw (1985).

[8] One possible counterexample to this view comes from the near merger of tone in Cantonese (Yu, 2007), which is incomplete but signals a change in meaning (and therefore must be lexical). Whether a case of near merger should serve to disqualify a hypothesis regarding incomplete neutralization is beyond the scope of this paper.

Japanese orthography	Transcription	Gloss
酢も見つけたよ。	**su’** mo mitsuketa yo	vinegar ALSO found DISC
酢見つけたよ。	**su’** mitsuketa yo	vinegar found DISC
スー見つけたよ。	**su’u** mitsuketa yo	Sue found DISC
麩も残したよ。	**fu** mo nokoshita yo	gluten ALSO left DISC
麩残したよ。	**fu** nokoshita yo	gluten left DISC
封残したよ。	**fu’u** nokoshita yo	seal left DISC
血も捧げたよ。	**chi** mo sasageta yo	blood ALSO dedicated DISC
血捧げたよ。	**chi** sasageta yo	blood dedicated DISC
地位捧げたよ。	**chi’i** sasageta yo	social.status dedicated DISC
具も出したよ。	**gu** mo dashita yo	ingredients ALSO served DISC
具出したよ。	**gu** dashita yo	ingredients served DISC
グー出したよ。	**gu’u** dashita yo	fist served DISC
ソも確かめたよ。	**so’** mo tashikameta yo	so ALSO confirmed DISC
ソ確かめたよ。	**so’** tashikameta yo	so confirmed DISC
層確かめたよ。	**so’u** tashikameta yo	layer confirmed DISC
手も測ったよ。	**te’** mo hakatta yo	hand ALSO measured DISC
手測ったよ。	**te’** hakatta yo	hand measured DISC
低測ったよ。	**te’i** hakatta yo	base measured DISC
背も違うよ。	**se’** mo chigau yo	height ALSO is-different DISC
背違うよ。	**se’** chigau yo	height is-different DISC
性違うよ。	**se’i** chigau yo	gender is-different DISC
野も持ってるよ。	**no’** mo motteru yo	field ALSO have DISC
野持ってるよ。	**no’** motteru yo	field have DISC
脳持ってるよ。	**no’u** motteru yo	brain have DISC
尾も出てきたよ。	**o’** mo detekita yo	tail ALSO appeared DISC
尾出てきたよ。	**o’** detekita yo	tail appeared DISC
王出てきたよ。	**o’u** detekita yo	king appeared DISC
津も買収したよ	**tsu’** mo baishuushita yo	Tsu ALSO bought/bought.off DISC
津買収したよ	**tsu’** baishuushita yo	Tsu bought/bought.off DISC
通買収したよ。	**tsu’u** baishuushita yo	expert bought/bought.off DISC

(continued...)

Japanese orthography	Transcription	Gloss
帆も叩いたよ。	**ho'** mo tataita yo	sail ALSO hit DISC
帆叩いたよ。	**ho'** tataita yo	sail hit DISC
ほおも叩いたよ。	**ho'o** tataita yo	cheek hit DISC
都も独占したよ。	**to'** mo dokusenshita yo	city ALSO monopolized DISC
都独占したよ。	**to'** dokusenshita yo	city monopolized DISC
塔独占したよ。	**to'u** dokusenshita yo	tower monopolized DISC
書も独占したよ。	**sho'** mo dokusenshita yo	book ALSO monopolized DISC
書独占したよ。	**sho'** dokusenshita yo	book monopolized DISC
章独占したよ。	**sho'u** dokusenshita yo	chapter monopolized DISC
字も公開したよ。	**ji'** mo koukaishita yo	letter ALSO publicized DISC
字公開したよ。	**ji'** koukaishita yo	letter publicized DISC
爺公開したよ。	**ji'i** koukaishita yo	grandpa publicized DISC

All stimulus sets from Experiment 1. Target nouns are in boldface. Accents are shown for target nouns only.

We presented a previous version of this experiment to the Tokyo Circle of Phonologists (TCP) in May 2012, where we also discussed the current stimulus sets with Prof. Shosuke Haraguchi, who offered much needed help at that time. Prof. Haraguchi passed away shortly after the meeting, and therefore we would like to dedicate this article to him. We are also grateful to the audience at TCP and Seoul National University for comments on this project. Remaining errors are ours. A previous version of the Experiment I, which used a smaller number of stimuli and speakers, is reported in Braver and Kawahara (2013).

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