Contrast in Japanese vowels*

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Phonological patterning reflects the feature specifications of the inventory of a language. I explain the behaviour of vowels in Japanese /a, i, u, e, o/ in terms of their featural specifications under the assumption of the theory of contrastive specification, a theory that incorporates hierarchical determination of features. The phonological processes of Japanese include epenthesis, coalescence and allophonic rules. We encounter contradictory evidence for phonological feature specification from the different processes. However, the contradiction can be solved by recognizing the different domains in which each phonological process takes place. Rules that apply in the lexical domain have access only to the underlyingly specified features, while post-lexical rules can also refer to the features that are underspecified in the lexicon. However, the features available in the post-lexical domain involve a wider set than those at the lexical level. The domain-based analysis allows us to maintain the idea of contrastive specification for the underlying representation. In examining the mutual relationship between the underlyingly specified features, it is proposed that there is more than one possible hierarchical ordering for the Japanese vowel system.

1. Introduction

The modern Tokyo dialect of Japanese has five vowels contrastively, /a, i, u, e, o/ (e.g. Fujisaki and Sugito 1977; Hattori 1979; Kawakami 1977; Kubozono 1999; Martin 1952; Ono 1977; Tsujimura 1996). The contrasts are shown in (1).

(1) /ka/ ‘mosquito’
    /ki/ ‘spirit,’ ‘tree’
    /ku/ ‘nine,’ ‘district,’ ‘phrase’
    /ke/ ‘hair’
    /ko/ ‘child’

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1. Japanese also has long vowels. However, I will not deal with the long vowels in this paper because their phonemic status is controversial. See, e.g., Hattori (1979: 157) and Vance (1987: 13-16) for treatments of phonetic long vowels in phonemicization.
The aim of this paper is to explain the phonological and phonetic (allophonic) patterning of these vowels in terms of their feature specifications.

There are several assumptions to make at this point. First, I assume monovalent features. Second, I assume contrastive specification (e.g., Avery and Rice 1989; Dresher, Piggott and Rice 1994; Dresher and Rice 1993; Walker 1993). Features are specified underlingly in such a way that minimum specification can make the segmental contrasts in the inventory of the particular language. Relevant to this is the concept of markedness. I assume that markedness is incorporated in the underlying structure of the inventory. In other words, marked features of the language are present in the underlying representation and can play a role in the phonological processes in a language, whereas unmarked features are absent from such a representation and they thus play no role in the phonology of a language. In order to attain the underlying representations of segments in a language, we examine the phonological processes found in that language. When we find that a feature is active in a phonological process (e.g., triggers assimilation), we assume this feature is specified on the segment of the language. The consequence of these assumptions is that, for example, if a language has a two-height system, then only one of the height features can be specified in the underlying representation, say, [low] OR [high], but not [low] AND [high]. Further, I assume that languages may differ in terms of underlying representations of their inventory: the same ‘sound’ may have different underlying specifications.

Finally, I assume that features resulted in the underlying representation are added in hierarchical order, with the hierarchy reflected in the phonological patterning of a particular language (Dresher 2002; Dresher and Zhang 2000).

Under these assumptions, I will examine what the featural representations of Japanese vowels are like. The structure of the paper is as follows. First, I examine three phonological processes in Japanese to see the features they require (§2). The processes include vowel epenthesis (§2.1), vowel coalescence (§2.2), and affrication and devoicing (§2.3). Based on these processes, we encounter a dilemma that seemingly contradicts the above assumptions. For example, epenthesis requires that the vowel /u/ be unmarked in terms of Place of articulation, while vowel coalescence requires it to be specified for Place. I propose a solution to these problems in section §3, where I argue that one must recognize different domains of rule application, namely lexical rules and post-lexical rules. The key notion here is that lexical rules have access only to contrastive, and thus underlingly specified, features and other features are filled in post-lexically and can become available at that point. Under this notion, I examine the characteristics of the phonological processes and the domain to which each rule belongs. Further, I show that underlying representations of Japanese vowels are obtained by determining what features must not be present rather than by considering what features must be present (§4). Lastly, given the underlying representations, I examine the hierarchy of the features in the Japanese vowel inventory (§5).

2. Phonological processes

This section examines the phonological processes to ascertain what features are required on Japanese vowels.
2.1 Epenthetic vowels in loan words: u as default

Epenthesis is often argued to be a diagnostic of the unspecified segment in an inventory (e.g. Archangeli 1984: 94; Causley 1999; McCarthy and Prince 1994). Epenthesis inserts an empty timing slot, and this slot is filled in by inserting a segment that is the least “intrusive” segment in the inventory, “intrusive” in the sense that it is unmarked, or least marked, in the system. Epenthesis provides an example of the emergence of the unmarked, often abbreviated as TETU (McCarthy and Prince 1994). Causley (1999: 67) makes the following remarks about epenthesis: “[i]n TETU environments, unmarked segments are selected over marked ones,” and “the selection of a segment as epenthetic … may be an indication of the unmarked status of that segment in a particular language.”

Under this assumption, we will look at epenthesis in loan words from English into Japanese. In Japanese, basic syllable structure is CV (C and V stand for consonant and vowel, respectively). In borrowings, Japanese adopts syllable structures other than CV by inserting vowels. In other words, in the process of borrowing an English syllable that is not CV, resyllabification occurs and a nucleus is created. For this newly-created nucleus slot, a vowel is inserted as an epenthetic vowel. Thus, English consonant clusters are parsed by inserting a vowel between the consonants, and a coda consonant is followed by an inserted vowel (Kubozono 2001; Hirayama 2001), as formalized in (2).

\[(2) \text{Resyllabification from English to Japanese} \quad \emptyset \rightarrow V / C \_ \left\{ C \right\} \# \]
\[
\text{to be interpreted as:}
\]
\[
\text{Onset: } C_1 C_2 \ldots C_n V \rightarrow C_1 V. C_2 V. \ldots . C_n V.
\]
\[
\text{Coda: } V C_1 \ldots C_n \rightarrow V. C_1 V. \ldots . C_n V
\]

(a dot before a C in the resyllabified structure indicates a syllable boundary and epenthetic vowels are underlined)

The vowels that can be inserted in these epenthetic slots are u, o, or i. However, as we will see below, the default epenthetic vowel is u, and o and i occur only in certain environments. Here the choice of epenthetic vowels is determined by the preceding consonant. The vowel i is inserted after English palato-alveolars /ʃ, tj, ɸ/ or after /k/ that follows a front vowel, see (3).4

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2. This assumption has to be modified if a language has more than one epenthetic vowel. However, if this is not the case, then the assumption that associates an epenthized timing slot with the vowel that has the simplest representation in the system can still be made as default.

3. Loan words from Chinese show the same characteristics in terms of vowel insertion. I will not examine the Sino-Japanese vocabulary in this paper because epenthesis there is historical and fossilized. Loan words from English represent a more recent influx, which is more suggestive of how Modern Japanese inserts vowels to incorporate English words into the Japanese system.

4. For the environment after /k/ that follows a front vowel, the vowel /u/ tends to be selected for newer borrowings. Thus, we see a number of doublets for these instances. Compare the examples in (3) with their doublets with u-epenthesis /sutoraiku/ (in baseball), /bureiku/ ‘short rest,’ /sutikk/ ‘a bar-looking thing.’ A similar situation is found after /ʃ/ as well. Compare /burasi/ ‘brush’ with /kurassh/ ‘crash (of cars, planes, etc.).’ The words with i-epenthesis in these environments can be considered to be lexicalized in current Japanese.
(3)  \( i \) insertion / \( \text{ʃ}, \text{tʃ}, \text{dʒ} \);  \( V \) \( k \) __

[front]

<table>
<thead>
<tr>
<th>English</th>
<th>Japanese</th>
</tr>
</thead>
<tbody>
<tr>
<td>/bɾaʃ/</td>
<td>‘brush’</td>
</tr>
<tr>
<td>/biʃ/</td>
<td>‘beach’</td>
</tr>
<tr>
<td>/dʒʌdʒ/</td>
<td>‘judge’</td>
</tr>
<tr>
<td>/keIk/</td>
<td>‘cake’</td>
</tr>
<tr>
<td>/straIk/</td>
<td>‘strike’</td>
</tr>
<tr>
<td>/breIk/</td>
<td>‘brake’</td>
</tr>
<tr>
<td>/stIk/</td>
<td>‘stick’</td>
</tr>
</tbody>
</table>

The vowel \( o \) is inserted after English /\( t, d, h \)/ as in (4).

(4)  \( o \) insertion / \( t, d, h \) __

Word-initial consonant clusters

<table>
<thead>
<tr>
<th>English</th>
<th>Japanese</th>
</tr>
</thead>
<tbody>
<tr>
<td>/tren/</td>
<td>‘train’</td>
</tr>
<tr>
<td>/draemə/</td>
<td>‘drama’</td>
</tr>
<tr>
<td>/hwaiʃ/</td>
<td>‘white’</td>
</tr>
</tbody>
</table>

Word-final

<table>
<thead>
<tr>
<th>English</th>
<th>Japanese</th>
</tr>
</thead>
<tbody>
<tr>
<td>/tɛnt/</td>
<td>‘tent’</td>
</tr>
<tr>
<td>/kaɛd/</td>
<td>‘card’</td>
</tr>
</tbody>
</table>

In other environments, the inserted vowel is \( u \), as shown in (5).

(5)  \( u \) insertion

<table>
<thead>
<tr>
<th>English</th>
<th>Japanese</th>
</tr>
</thead>
<tbody>
<tr>
<td>/paip/</td>
<td>‘pipe’</td>
</tr>
<tr>
<td>/blok/</td>
<td>‘block’</td>
</tr>
<tr>
<td>/bif/</td>
<td>‘beef’</td>
</tr>
<tr>
<td>/riθ/</td>
<td>‘wreath’</td>
</tr>
<tr>
<td>/krisməs/</td>
<td>‘Christmas’</td>
</tr>
<tr>
<td>/θrɪl/</td>
<td>‘thrill’</td>
</tr>
</tbody>
</table>

In the process of borrowing, it seems that the preceding consonant plays a decisive role (cf. Dupoux 2002). In this way, we can understand why vowels \( i \) and \( o \) are chosen over \( u \) in certain environments. For \( i \) insertion, by choosing this vowel, the palatality of English [ʃ, tʃ, dʒ] can be retained throughout the newly-created syllable. As for \( o \)-insertion after English [t, d, h], consider some allophonic rules involving /\( t, d, h \)/:
2.2 Vowel coalescence

The next phonological process to examine is vowel coalescence. The theoretical significance in examining coalescence processes lies in the assumption that coalescence reveals which features are specified phonologically. According to Causley (1999), the resolution of vowel hiatus should reflect feature specifications of the vowels involved. Features marked in underlying representation decide the quality of the resultant vowel, while unmarked features are inert in coalescence. Under this assumption, we examine vowel coalescence in Japanese. We look at the process (§2.2.1), then at the active features in the process, first in terms of the Height dimension (§2.2.2) and then the Place dimension (§2.2.3).

2.2.1 The process

Vowel coalescence is found in certain vocabulary in certain styles. The data in (8) is from Kubozono (1999: 98-99), Kubozono (2001: 115), McCawley (1968: 126) and my notes.

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5. There is still an unsolved question. Why the vowel o is chosen over e or a is not clear. By referring only to the allophonic rules in (6 and 7), this question cannot be solved: any of these three vowels may be equally chosen. I do not have an answer to this question at this time.

6. There is an analysis that treats the vowel /i/ as the epenthetic vowel (Archangeli 1984: 59ff; Tsujimura 1996: 128ff, 149ff; Tsujimura and Davis 1988). However, an alternative analysis is possible, that this /i/ has a morphological function, being part of the verbal conjugation system. The fact that the i-ending can be analyzed as morphological rather than phonological tells that if it is in morphology, it provides no evidence for lexical feature specifications.
Coalescence in Japanese is optional and stylistic. (8a) and (8b) are found in colloquial and casual speech. They are especially stigmatized as masculine, and sometimes called ‘tough guy speech’ (Vance 1987:26). (8c) is also colloquial. (8d) may occur in the opposite style to (8a) and (8b), in superpolite styles (Vance 1987:26). In Table 1 below, I tabulate the vowel hiatus and its resolution that I discuss in this paper. The vowel combinations indicated with ‘—’ do not coalesce but stay as they are under all circumstances. For example, /ue/ ‘above’ is always realized as [ue].

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7. There are two points to be made here. One is that there is another process which could be called vowel coalescence:

(i) Verb + te + verb, across morphemes

\[
\begin{align*}
\text{/eo/} & \rightarrow o.kai + te + oku & \text{‘I write it to keep it.’} & \rightarrow kaitoku \\
\text{/ea/} & \rightarrow a.kai + te + ageru & \text{‘I’ll write it for you.’} & \rightarrow kaitageru
\end{align*}
\]

However, I will not examine this because it is different from (8a–d) in that it results in only one timing slot and not two: it may simply be a deletion of the first element, and not coalescence.

The other note concerns the hiatus of ei and ou. These are realized as ee and oo, respectively. However, I
Table 1 Vowel coalescence in Japanese

<table>
<thead>
<tr>
<th>Second vowel</th>
<th>a</th>
<th>i</th>
<th>u</th>
<th>e</th>
<th>o</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>—</td>
<td>ee</td>
<td>oo</td>
<td>ee</td>
<td>—</td>
</tr>
<tr>
<td>i</td>
<td>—</td>
<td>—</td>
<td>uu</td>
<td>ee</td>
<td>—</td>
</tr>
<tr>
<td>u</td>
<td>—</td>
<td>ii</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>e</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>o</td>
<td>—</td>
<td>ee</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

2.2.2 Height

First we focus on the Height features. Height in vowel coalescence (8a-d) is a fusion process. We observe that the vowels e, a, and o form a natural class in that they always give their height to the resultant vowel. This suggests that Japanese is a two-height system. Recall the assumption that we made in the beginning of the section: only marked features are maintained in the resultant vowel quality, whereas unmarked features are inert in the process. Under this assumption, I conclude that in terms of Height, the feature that is shared by the vowels e, a, and o is specified on these vowels. I will call this feature [low] in this paper. Diagrams in (9a-g) show that [low] is active on vowels e, o and a.⁸

8. Place features are ignored in the representations in (9).

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²². Height

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(9) a. /ai/ → ee  b. /oi/ → ee

```
  a i → e e
  [low] [low]
```

(c. (/aku/ →) au → ou → oo

```
a,o u → o o
  [low] [low]
```

d. /ie/ → ee

```
i e → e e
  [low] [low]
```

do not discuss them in this paper because they are different from the others in (8) in that they are diachronic processes. In addition, these are always realized as monophthongs in current Tokyo Japanese. Kawakami (1977) observes diphthongal realizations in very careful pronunciation. This may, however, be influenced by orthography: the orthography is based on the historical pronunciation.

⁸. Place features are ignored in the representations in (9).
This is true coalescence: [low] always surfaces regardless of whether it is lexically associated with just the first vowel (9a-c), just second vowel (9d), or both (9e); only if no low vowel is present can a high vowel appear (9f and g).

In (10), I schematize the feature specifications of the inventory for Height. We can see that this positive specification of [low] on e, o and a conforms to the evidence from epenthesis. Recall from section 2.1 that epenthesis suggests that the vowel u is unmarked, and (10) shows that u is unspecified in terms of Height with respect to coalescence as well.

(10) i u
     [low] e o
     a

2.2.3 Place

In determining the place of articulation that results from vowel coalescence, directionality is important—the place on the rightmost segment is retained in the resultant vowel. This importance of directionality for Place in vowel coalescence is also true cross-linguistically (Causley 1999, from Casali’s (1997) insights). We can formalize the rule in the form of feature geometry, as in (11).

(11) Place assimilation
    X    X
    PL  PL

Going back to the Japanese data, I propose that vowels i and e have a feature, which I call [coronal] in this paper. This is supported by the data in (8a) to (8c), which I illustrate in (12). The diagrams in (12) show the representations after the deletion of the Place feature on the left-hand vowel.

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9. I use the features [Coronal] and [Peripheral] as Rice (2002) defines them. By phonetic implementation, [coronal] is realized as palatality, and [peripheral] as dorsality or labiality or both.
When we look at (12a) and (12b) particularly, the vowel \(i\) must have a Place feature. If it did not, the resultant vowel would have no Place feature, since the Place in the resultant vowel comes from the rightmost element, as we saw in (11). Given the Height feature from \(a\), i.e., [low], the resultant vowel of the hiatus \(ai\) (12a) and \(oi\) (12b) should have [low] for Height and nothing for Place. What is the vowel in the Japanese inventory that has these featural specifications? When we consider the contrastive specifications for vowels that have [low], such a vowel must be \(a\). We saw in section 2.2.1 that there are three low vowels in Japanese. Rice (2002) proposes that, in three-place system, the front vowel has [coronal], the back vowel [peripheral] and the central vowel is unspecified.\(^1\) I will assume these specifications for Place, since, as we will see in depth in section 4, it conforms to our analysis of Japanese vowels too. In (12a) and (12b), we observe that the resultant vowel is not \(aa\) but \(ee\). This suggests that the vowel \(i\) has a Place feature. For the same reason, (12d) suggests that the vowel \(e\) has a place feature: otherwise the sequence of \(ae\) would have resulted in \(aa\). In (12a) and (12b), we see that the vowel \(e\) has the same Place feature as /i/. Therefore I hypothesize that /e/ has [coronal] as well as /i/.

We also observe that vowel \(u\) has a feature specified for Place, which I term [peripheral]. This is suggested by (8e), illustrated in (13). (13a) specifically tells us that

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10. For a two-place vowel system, she proposes that either the front vowel has [Coronal] or the non-front vowel has [Peripheral].
the vowel \(u\) has to have a Place feature. Along the same lines as the argument for the Place specification on the vowels /i/ and /e/ above, if it did not have a Place feature, the resultant vowel of the hiatus of \(a(k)u\) would be \([low]\), the vowel that has [low] (from /a/) for Height and nothing for Place. However, as we can see in (13a), \(a(k)u\) results in \(oo\), not \(aa\). It follows from this that the vowel \(u\) has a Place feature [peripheral].

(13) a. (/aku/ \(\rightarrow\)) \(au \rightarrow ou \rightarrow oo\) b. (/siku/ \(\rightarrow\)) \(siu \rightarrow sjuu\)

Lastly, since we do not have the attested data with \(a\) or \(o\) as the second element of coalescence, we do not know what features are specified on them.

In Table 2 below, I summarize the features referred to in vowel coalescence process.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Feature</th>
<th>i</th>
<th>e</th>
<th>a</th>
<th>o</th>
<th>u</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>Low</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Place</td>
<td>Coronal</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Peripheral</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Consider the representation of /u/ in Table 2. We face a problem in terms of the feature specification. As we have seen thus far, the vowel \(u\) has to have a place feature specified in the vowel coalescence process. However, in section 2.1 epenthesis suggested that /u/ is unmarked for Place. A solution to this contradiction will be suggested in section 3. There we will see that the feature [peripheral] on \(u\) is underspecified in epenthesis, while, in coalescence, this feature is filled in and can be referred to by rule (11).

2.3 Affrication and devoicing rules

This section looks at rules of affrication of consonants and devoicing of vowels. These rules suggest that the vowels /i/ and /u/ form a class.

Coronal plosives /t, d/ are affricated before high vowels, /i, u/ (e.g. Kubozono 1996: 76ff; Sugito 1996: 123ff; Vance 1987). The realization rules for these consonants are given in (14) below.

(14) Coronal Plosive /t, d/ \(\rightarrow\) Palatal Affricate \([\ddot{c}c, \ddot{j}z]\) / _ i, j

| Affricate [ts, dz] Alveolar / _ u | Plosive [t, d] Dental / _ elsewhere (e, a, o) |

| Affricate [ts, dz] Alveolar / _ u | Plosive [t, d] Dental / _ elsewhere (e, a, o) |
In this rule, the feature [high] is active, since only high vowels trigger affrication. Reference to the feature [high] is also found in a devoicing rule in Japanese. High vowels /i, u/ are devoiced between voiceless obstruents (e.g. Kubozono 1999: 40, Sugito 1996, Vance 1987: 48ff), as exemplified in (15a) and stated in (15b).\(^{11}\) In this rule, too, the feature [high] is needed, since only high vowels are affected.

\[(15)\]
\[
\begin{align*}
\text{a. } & /\text{kutusita} / 'sock(s)' \rightarrow [\text{ku}t\text{su}c\text{t}a] \\
\text{b. } & /i, u/ \rightarrow [- \text{voice}] / C \_ \_ C , # \\
& [\text{vl, obstr}] [\text{vl, obstr}]
\end{align*}
\]

At this juncture, we again see a problem in terms of feature specification on vowels. We have seen that we need a feature [high] to be specified in the processes introduced in this section. However, in vowel coalescence, we saw that vowels e, o and a patterned together as [low]. Assuming that Japanese is a two-height system, this feature specification contradicts the concept of contrastive specification: contrastive specification has no way of yielding two height features, [high] and [low], in a two-height system. I will propose a solution to this problem in the next section, a solution that also solves the problem we encountered about the specification of the vowel /u/.

### 3. Levels of rule application

The phonological processes in the previous section present a conundrum with respect to feature specifications for both Height and Place dimensions. I first summarize the problems, and then propose a solution to them. I will propose that a solution can be made by recognizing different levels of rule application, namely lexical versus post-lexical rules.

Consider Height first. The problem is that different processes require opposite features to be specified, but this is contradictory to the theory of contrastive specification. The process of epenthesis suggests that the feature [high] is not specified, since the epenthetic vowel \(u\) is a high vowel and, under my assumptions, this feature is unmarked. The process of coalescence also suggests that the feature [low] is present; this does not raise any problems with the evidence from epenthesis because both suggest that [high] is not present in the lexicon. On the other hand, the rules of affrication and devoicing require that the feature [high] is present. This raises a contradiction under the assumption of two-height system and contrastive specifications: either one of the features [low] or [high], and not both, can be specified in the underlying representation.

With regard to the Place dimension, we also have a dilemma in terms of feature specifications. Epenthesis suggests that a feature for Place is not specified on the vowel /u/: an epenthetic vowel is unmarked. On the other hand, coalescence suggests that a Place [peripheral] feature be specified on /u/. So, the question is: why is it that different processes refer to different and opposite features?

An account for these problems can be sought by taking into account domains of rule applications. Phonologists have proposed that lexical and post-lexical rules can refer to

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\(^{11}\) This rule can be affected by the accentuation, the quality of the adjacent vowel and morpheme structure.
different features. See, for instance, Kiparsky (1985), Lombardi (1996), Pulleyblank (1983), Rubach (1985), among others. According to them, only underlyingly specified features can be referred to in the lexical phonology, whereas at the post-lexical level, rules can refer not only to the underlyingly specified features but also to their opposite features. This is because, in the post-lexical domain, all features including the underspecified ones are filled in, and thus are available to the rules that apply at this level. Following this dichotomy, I now re-consider the nature of the Japanese processes discussed in section 2.

Pulleyblank (1983: 7) gives a list of properties that distinguish rules applying lexically and rules applying post-lexically:

(16) Lexical                  Post-lexical
    a. may refer to word-internal    a. cannot refer to word-internal
       structure                    structure
    b. may not apply across words   b. may apply across words
    c. may be cyclic                c. cannot be cyclic
    d. if cyclic, then subject to strict
cyclicity                        d. non-cyclic, hence across-the-
                                 board
    e. structure-preserving         e. need not be structure-preserving
    f. may have lexical exceptions  f. cannot have lexical exceptions
    g. must precede all post-
       lexical rule applications   g. must follow all lexical rule

Recall that affrication and high vowel devoicing are allophonic. According to the criteria in (16), specifically to the criterion in (16e), allophonic rules are categorized as post-lexical rules because they are not structure-preserving in the sense that the allophones are not members of the phoneme inventory of the language. If this is correct, the different feature reference in terms of Height can be solved because the allophonic rules are post-lexical and in this domain not only the underlyingly-specified feature ([low]) but also the opposite feature ([high]) are both present. The allophonic rules are simply referring to one of the available features in this domain.

Turning now to coalescence, vowel coalescence in Japanese is variable and depends on style differences. According to Lombardi (1996: 26), “an optional process, depending on style and speed” is variable, and “it must be at least post-lexical.” Under this criterion, coalescence in Japanese must be categorized as post-lexical and not lexical. If this is correct, then we can account for the contradictory feature specifications on the vowel /u/. The Place feature [peripheral] is underspecified on /u/ lexically, but can be referred to in the coalescence process since this is a post-lexical rule: by the time this rule applies, the underspecified feature for Place has been filled in on \( u \).

To sum up the discussion of featural specifications so far, Table 3 below shows the feature specifications at the post-lexical level. The feature [high] on \( i \) and \( u \) is suggested by the allophonic rules of affrication and devoicing. The feature [low] on \( e, a, \) and \( o \) and the Place features on \( i, e, o, \) and \( u \) are suggested by coalescence. Note that the vowel \( o \) has to have a feature in terms of Place: otherwise the vowels \( a \) and \( o \) cannot be distinguished. Since \( o \) surfaces with the feature [peripheral] in the process /aku/ \( \rightarrow oo \) (13a), I hypothesize that \( o \), as well as \( u \), has [peripheral].
4. Underlying representation of Japanese vowels

Now, consider epenthesis. This process is lexical because it involves syllabification, which I assume to be lexical. Epenthesis suggests a lexically-unmarked segment in the system (§2.1). In thinking of underlying representations of Japanese vowels, the absence of lexical processes prevents us from examining the underlying featural specifications positively by considering what features must be present there, because this has to be done by examining only lexical processes where only underlyingly specified features can be referred to. The only lexical process that we have seen for Japanese is epenthesis and epenthesis simply suggests the segment whose features are not specified underlyingly. However, we can still attain the underlying specifications negatively by considering what features must not be present. Under the assumptions of contrastive specification, they can be determined through epenthesis.

The procedure for doing this is as follows. We look at the Height dimension first. Assuming that Japanese is a two-height system, the contrast in terms of Height is made between /i/ and /u/, ignoring /a/ for the moment. Under the assumptions of contrastive specification and privative features, we need either [high] or [low] specified underlyingly to distinguish two heights. Epenthesis tells us that /u/ is unmarked in terms of Height. Therefore, the opposite feature of [high], namely, [low], is forced to be underlyingly specified, at least on /o/ and likely on /e/. Now taking /a/ into account, coalescence tells us that the system is a two-height system, since /a/, /e/, /o/ form a natural class. So, /a/, as well as /o/ and /e/, is likely to have [low] underlyingly.

We examine the Place dimension next, looking at high vowels first. There are two vowels, i.e., /i/ and /u/. Assuming contrastive specification, we need only one feature for Place specified underlyingly. Epenthesis suggests that /u/ is unmarked. So, /i/ must have a place feature, [coronal]. Next consider low vowels. There are three vowels that have [low], i.e., /e/, /a/, /o/. Thus, under the assumption of contrastive specifications, we need two features to make the three-way contrast between them. The contrasts in the inventory force a place feature on /e/. The feature [coronal] is suggested for this by the coalescence process where /i/ and /e/ share a place feature (12a, b). (Note, however, that the coalescence is post-lexical. The very presence of a three-way contrast among the low vowels requires that two of them have Place features). We do not know whether /a/ or /o/ has a feature, but either of them, and not both, must have a feature underlyingly, otherwise /a/ and /o/ cannot be distinguished in the system. Recall that /o/ has [peripheral] in the post-lexical domain (Table 3). I thus suggest that /o/ has [peripheral] underlyingly. Lastly, /a/ is unspecified for Place. I summarize thus proposed underlying representations for five Japanese vowels in Table 4.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Feature</th>
<th>i</th>
<th>e</th>
<th>a</th>
<th>o</th>
<th>u</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>Low</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Place</td>
<td>Coronal</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Peripheral</td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Table 3 Feature specifications in post-lexical domain
Given the underlying representations proposed in the previous section, we can examine the hierarchy of features in Japanese vowel system. The assumption here is that features are organized hierarchically and a different feature hierarchy yields a different set of markings on segments (Dresher, Piggott and Rice 1994). Thus, in turn, phonological patterning in a particular language reflects the particular hierarchy of the inventory in the language. The hierarchical structure can be attained with an algorithm, proposed by Dresher (2002) and Dresher and Zhang (2000):

(17) Successive Division Algorithm (Dresher and Zhang 2000: 10)
   a. In the initial state, all sounds are assumed to be variants of a single phoneme.
   b. If the set is found to have more than one phoneme, a binary distinction is made on the basis of one of the universal set of distinctive features; this cut divides the inventory into a marked set and an unmarked set.
   c. Repeat step (b) in each set, dividing each remaining set until all distinctive sounds have been differentiated.

I will show, following Dresher, Piggott and Rice (1994), the consequences of various cuts as reflecting different hierarchical structures. The examples employed here are for five-vowel system /a, i, u, e, o/ with three heights. For this height system, under the assumption of contrastive specifications and privative features, we need two features specified underlyingly to make the three-height contrast. We call these features [high] and [low]. For each height, there are no more than two vowels, so, for the Place dimension, we need only one feature, say [peripheral], underlyingly.

I demonstrate two example inventories in terms of different specifications. Let us imagine a language where we find (a) a phonological rule referring to a as active, i.e., a triggering a phonological process, (b) a phonological rule referring to i and u as active, and (c) a rule referring to o and u as active. Then the underlying representation of vowels in this inventory would be:

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Feature</th>
<th>i</th>
<th>e</th>
<th>a</th>
<th>o</th>
<th>u</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>Low</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Place</td>
<td>Coronal</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Peripheral</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>
When we consider the hierarchy of features that captures this phonology, one possibility is that of [low] > [high] > [peripheral]. This hierarchy can be attained by following the algorithm (17). I illustrate the successive cuts in (19). The phonological process of (a) provides the first cut that divides \( a \) from the other vowels, then the process (b) cuts the non-low area into [high] and non-high, lastly the process (c) divides the non-low vowels into [peripheral] versus non-peripheral.

<table>
<thead>
<tr>
<th>(18) Underlying representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>i e a o u</td>
</tr>
<tr>
<td>Low</td>
</tr>
<tr>
<td>High</td>
</tr>
<tr>
<td>Peripheral</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(19) The first cut: [low] vs. non-low</th>
</tr>
</thead>
<tbody>
<tr>
<td>i u</td>
</tr>
<tr>
<td>e o</td>
</tr>
<tr>
<td>[low] a</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>The second cut: [high] vs. non-high</th>
</tr>
</thead>
<tbody>
<tr>
<td>[high] i u</td>
</tr>
<tr>
<td>e o</td>
</tr>
<tr>
<td>[low] a</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>The third cut: [peripheral] vs. non-peripheral</th>
</tr>
</thead>
<tbody>
<tr>
<td>[high] i [peripheral] u</td>
</tr>
<tr>
<td>e o</td>
</tr>
<tr>
<td>[low] a</td>
</tr>
</tbody>
</table>

In another language with the same five-vowel and three-height system, the underlying representations may look quite different from this. Let us assume that in this language we find (a’) a phonological rule referring to \( i \) and \( u \) as active, (b’) a phonological rule referring to \( a, u, \) and \( o \) as active, and (c’) a rule referring to \( a \) as active, then the underlying representations of this inventory would be:

<table>
<thead>
<tr>
<th>(20) Underlying representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>i e a o u</td>
</tr>
<tr>
<td>High</td>
</tr>
<tr>
<td>Peripheral</td>
</tr>
<tr>
<td>Low</td>
</tr>
</tbody>
</table>

The hierarchy of features that captures the processes in this language can be, for example, [high] > [peripheral] > [low]. Following the algorithm (17) again, the process of
(a’) makes the first cut that marks [high] vowels as opposed to the others, the process of 
(b’) makes the second cut to captures a, o, and u as patterning together marked as 
[peripheral], and the process of (c’) makes the last cut that marks a as [low]. I give the 
procedure schematically in (21).

(21)

<table>
<thead>
<tr>
<th>First cut: [high] vs. non-high</th>
<th>Second cut: [peripheral] vs. non-peripheral</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="firsticut.png" alt="Diagram" /></td>
<td><img src="secondicut.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

Third cut: [low] vs. non-low

<table>
<thead>
<tr>
<th>First cut: [high] vs. non-high</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="thirdicut.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

In either of the two inventories just introduced, we can attain the five vowels 
distinguished, and thus the contrasts are captured. At the same time, we have seen that the 
different feature reference in phonological processes found in the two languages may be 
attributed to the different underlying representations that each inventory has.

Similarly, we can examine the featural hierarchy of Japanese vowel inventory. We 
require the underlying representations shown in Table 4, where we see three features, 
namely [low], [coronal] and [peripheral], need to be specified. The feature [low] divides 
the Height dimension as [low] versus non-low, the feature [coronal] groups front vowels i 
and e as marked, and lastly the feature [peripheral] marks the vowel o from a. With 
respect to the ordering of the features, [peripheral] has to be ranked lowest, otherwise the 
vowel u would have to be specified as [peripheral] underlyingly, which is not supported 
by epentheses. However, which one of [low] and [coronal] is ordered above the other 
cannot be determined, since in either way the hierarchy can capture the natural classes 
found in Japanese phonology; one class comprising [low] vowels and the other [coronal] 
vowels. I thus propose that the hierarchy for the Japanese vowel inventory is either [low] 
> [coronal] > [peripheral], or [coronal] > [low] > [peripheral]. In any case, the successive 
cuts complete in the specifications in Table 4, shown schematically in (22).
(22) [low] > [coronal] > [peripheral], or [coronal] > [low] > [peripheral]

\[
\begin{array}{c|c|c}
\text{[low]} & \text{e} & \text{a} \\
\text{[coronal]} & \text{i} & \text{u} \\
\text{[peripheral]} & \text{o} & \\
\end{array}
\]

6. Conclusion

In this paper, I examined the featural specifications of Japanese vowels under the assumptions of contrastive specification, privative features and markedness as incorporated in underlying structure. We have found contradictory evidence for feature specification based on different processes. A solution to this contradiction was proposed by recognizing different levels of rule application. The domain-based analysis allows us to have a way of maintaining the idea that contrast drives lexical specifications. Further, we have seen that post-lexical processes work with a fuller set of features than lexical processes (compare Table 3 (post-lexical) and Table 4 (lexical)). With respect to the hierarchy of features, it was proposed that there were two possible orderings between the features that could capture the phonology of Japanese vowels.

References


