The organization of this paper is as follows. In the first section we present -tari, -Ia, -te, alternations associated with the suffixes allows one to capture in an insightful and non ad hoc manner the morphophonemic how the application of certain principles and constraints within autosegmental show ing an analysis within the framework of autosegmental phonology with the aim of particular, we present synchronic approach to the verbal conjugation in Japanese. In this paper we provide a existing inflected verb forms. Also, from the viewpoint of child language acqui­ base a synchronic analysis on historical transition in accounting for the presently change of each verb form. On the one hand, such diachronic accounts are well-motivated to explain the historical change of the forms that he is acquiring. In this paper we provide a synchronic approach to the verbal conjugation in Japanese. In particular, we present an analysis within the framework of autosegmental phonology with the aim of showing how the application of certain principles and constraints within autosegmental theory allows one to capture in an insightful and non ad hoc manner the morphophonemic alternations associated with the suffixes -ta, -te, and -tari.

The organization of this paper is as follows. In the first section we present
an autosegmental analysis of the morphophonemic alternations associated with these three suffixes. (We focus here on the suffix -ta, but what we show pertains to -te and -tari as well.) In the second section we show how certain seemingly problematic aspects of our analysis are in fact not at all problematic given certain principles and constraints of autosegmental theory. These include the constraint on crossing association lines (Goldsmith (1976)) and the Linking Constraint (Hayes (1986)). Finally, in the third section we compare our analysis of these suffixes with various previous analyses of them. We show how four problematic aspects of these previous analyses are no longer problematic given the autosegmental analysis presented in this paper.

1. Analysis

The verbal conjugation which we will concentrate on in this paper involves the past tense (perfective) suffix -ta. The list in (1) shows the regular pattern (group a) and the “irregular” patterns (group b-d) of the inflectional suffix -ta.¹

<table>
<thead>
<tr>
<th>(1)</th>
<th>Root</th>
<th>Past Tense</th>
<th>Gloss</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>tabe-</td>
<td>tabeta</td>
<td>‘ate’</td>
</tr>
<tr>
<td>b.</td>
<td>mi-</td>
<td>mita</td>
<td>‘saw’</td>
</tr>
<tr>
<td>c.</td>
<td>kaw-</td>
<td>katta</td>
<td>‘bought’</td>
</tr>
<tr>
<td>d.</td>
<td>sin-</td>
<td>sinda</td>
<td>‘died’</td>
</tr>
<tr>
<td></td>
<td>yom-</td>
<td>yonda</td>
<td>‘read’</td>
</tr>
<tr>
<td></td>
<td>tob-</td>
<td>tonda</td>
<td>‘flew’</td>
</tr>
<tr>
<td></td>
<td>kak-</td>
<td>kaita</td>
<td>‘wrote’</td>
</tr>
<tr>
<td></td>
<td>kag-</td>
<td>kaida</td>
<td>‘sniffed’</td>
</tr>
<tr>
<td></td>
<td>kas-</td>
<td>kasita</td>
<td>‘rented’</td>
</tr>
</tbody>
</table>

The verbs in (1a) form their past tense simply by suffixing -ta to the root. Verbs in this group all end in a vowel, and no morphophonemic alternation occurs. In contrast, when -ta is suffixed to the verb roots in (1b-1d), which all end in a consonant, morphophonemic alternations do take place. This is because the concatenation of the consonant-initial suffix results in a phonotactically impermissible sequence of consonants. The exact nature of the alternations depends on the final consonant of the root. With the final root sounds in (1b) (i.e., /l/ or /w/), total assimilation takes place and creates a geminate. The forms in (1c), with roots ending in /m/, /n/, and /b/, show that the final consonants of the root all become the dental nasal when the suffix /ta/ is added. With this pattern, furthermore, the past tense suffix /ta/ always undergoes voicing, resulting in [da] in the phonetic representation (e.g., yonda). In the forms in (1d), where the roots end in a velar consonant or /s/, an epenthetic /i/ occurs before the suffix.

There are two remarks to be made with respect to this pattern: (a) the velar consonant (i.e., /k/ or /g/) deletes before the epenthetic /i/, while /s/ does not (i.e., kaita /kaida vs. kaśita); and (b) /ta/ undergoes voicing when it follows a voiced (velar) consonant (i.e., kaida).

We attempt to show in this section and the next that the variety of alternations that are associated with the suffix -ta (as well as -te and -tari) shown in (1b)-(1d) is understandable within the framework of autosegmental phonology. Two questions in particular concerning the past tense conjugation that we address are: (a) why does epenthesis only occur if the root ends in an /s/ or a velar consonant (as in (1d)); and, (b) why do roots that end in an underlying labial consonant surface with [n] in root-final position when the suffix is added (as in the second and third examples in (1c)). We will answer these questions in the course of the autosegmental analysis and discussion that we present in this paper.

We now turn to our analysis of the morphophonemic alternations shown in (1). First, consider the verbal roots in (1b). The relevant characteristic of verb roots in (1b) is that they end in a non-nasal sonorant (consonant), namely, /l/ or /w/. When the past tense /ta/ is suffixed to the root, as in /tor-ta/ and /kaw-ta/, the non-nasal sonorant becomes totally assimilated to the following /l/, and, in effect, creates a geminate. In autosegmental terms, the C-slot of the sonorant becomes delinked. This process can be termed Sonorant Delinking and is illustrated in (2).²
(2) **Sonorant Delinking**

\[ C + C V \]

\[ \{ w \} \]

As part of the rule, the following /t/ links to the original C-slot of the root final (non-nasal) sonorant consonant by way of autosegmental spreading. This means that all features of /t/ become associated with that C-slot thus yielding a geminate /tt/. This is illustrated in (3).

\[ (3) \]

\[ C + C V \]

\[ \{ w \} \]

The application of Sonorant Delinking to (1b) is shown in (4).

\[ (4) \]

\[ a. \quad C V C C V \rightarrow C V C C V \rightarrow C V C C C V \quad \text{tor+ta} \rightarrow \text{tota} = \text{tota} \]

\[ b. \quad C V C C V \rightarrow C V C C V \rightarrow C V C C V \quad \text{kaw+ta} \rightarrow \text{kata} = \text{kata} \]

Turning to the verbs in (1c), the root final consonants /n/, /m/, and /b/ all become [n] before the suffix /ta/ while the /t/ of the suffix becomes voiced. First, we can view the voicing of t -> d as progressive assimilation caused by the [+voice] feature in /n/, /m/, and /b/. This is formalized as in (5). (For ease of interpretation, we represent the laryngeal or voice features on a tier above the CV-tier. We will represent the place of articulation features, when relevant, on a tier below the CV-tier.)

(5) **Voicing Assimilation**

\[ [+voice] \rightarrow [+voice] \]

\[ C + C \rightarrow C + C \]

The Voicing Assimilation in (5) delinks the [-voice] feature of the consonant with subsequent spreading of the preceding [+voice] feature to the C-slot. As a result of the application of this rule to the verbs in (1c), all the instances of /ta/ surface as [da] (i.e., sin-da, yom-da, tob-da). Notice that Voicing Assimilation must apply after Sonorant Delinking, or else the /t/ of the suffix would be incorrectly voiced in (1b).²

Second, the root-final labial consonants in (1c) (/m/ in yom- and /b/ in tob-) become [n] in the suffixed form. This suggests that the place of articulation feature ([+labial] for these consonants) is assimilated to the [+coronal, +anterior] place features associated with the /t/ of the suffix. We term this operation Labial Delinking which is illustrated in (6). (The symbols x and y represent elements on the phoneme tier.)

(6) **Labial Delinking**

\[ C + C \rightarrow C + C \]

Voicing Assimilation in (5) and Labial Delinking in (6) will derive yonda from yom+ta, as illustrated in (7).

(7) **Labial Delinking**

\[ C + C \rightarrow C + C \]

\[ [+voice] \rightarrow [+voice] \]

\[ C V C + C V \rightarrow C V C + C V \rightarrow C V C + C V \]

\[ y o m t a \rightarrow y o m t a \rightarrow y o m d a = y o n d a \]

\[ [+labial] \rightarrow [+labial] \rightarrow [+labial] \]

\[ y o m + t a \rightarrow y o m + t a \rightarrow y o m + d a = y o n d a \]

\[ [+cor] \rightarrow [+cor] \rightarrow [+cor] \]

\[ [+ant] \rightarrow [+ant] \rightarrow [+ant] \]
On the other hand, the application of (5) and (6) to /tob+ta/ will yield a wrong result, as demonstrated in (8).

(8) [+voice] [−voice] [−voice]  
\[ \begin{array}{c|c|c|c|c|c} 
  C & V & C & + & C & V \\
  \hline 
  t & o & b & t & a & \rightarrow \text{toda} \\
  +[labial] +[cor] +[ant] +[labial] +[cor] +[ant] 
\end{array} \]

The correct form should be [tonda], not *[toda]. In order to account for the correct form we suggest that the root-final consonant /b/ becomes linked to a [+nasal] feature. The question that immediately arises is where does this [+nasal] feature come from. We take the view, like that in Lieber (1983), that morphemes can have a floating autosegment as part of their lexical representation. We posit that a floating [+nasal] autosegment is part of the lexical representation of the past tense suffix -ta (as well as of the suffixes -te and -tari). The [+nasal] autosegment links to a root-final stop consonant as shown in (9).

(9) Nasal Linking

\[ \begin{array}{c|c|c|c|c|c} 
  \text{[+nasal]} & C & + & C &  \\
  \hline 
\end{array} \]

The derivation of /tob+ta/ is described in (10).

(10) \[ \begin{array}{c|c|c|c|c|c} 
  \text{[+nasal]} & \text{[+nasal]} & \text{[+nasal]} &  \\
  \text{[+voice]} & [−voice] & [−voice] &  \\
  \hline 
  C & V & C & + & C & V  \\
  \hline 
  t & o & b & t & a & \rightarrow \text{tob d a} \\
  +[labial] +[cor] +[ant] +[labial] +[cor] +[ant] 
\end{array} \]

Note that Nasal Linking applies vacuously to the other forms in (1c). We hold off until Section 2 the discussion of why Nasal Linking fails to apply to the forms in (1b).

Finally, we analyze the verbs in (1d). All the forms in (1d) appear with the vowel /i/ before the suffix. We account for the forms in (1d) by the rule of I-ellipsis, stated in (11). (The symbols x and y represent elements on the phoneme tier.)

(11) I-Epenthesis:

\[ \phi \rightarrow V / i \\
\| x \| y \\
\| [+hi] [−back] \]

The formulation of this rule as only applying between two consonants that do not share the same place of articulation prevents it from applying to the forms in (1b) and (1a) where the two adjacent C-slots do share the same place of articulation node. We discuss this further in Section 2. In the forms in (1d) in which [i] is epenthesized before /ta/, the root-final consonant deletes just in case it is velar. This process can be characterized as Velar Deletion in (12).

(12) Velar Deletion:

\[ \begin{array}{c|c|c|c|c|c} 
  C & \rightarrow \phi / V & C &  \\
  \hline 
  x \| i \\
  \| [−cor] [−ant] 
\end{array} \]
Thus, while the verbs in group (1d) all undergo i-Epenthesis, the rule of Velar
Deletion only applies to the first two forms in (1d). The derivations of the
examples in (1d) are shown in (13).

(13) a. \[+nasal\] \[+nasal\]

\[
\begin{array}{cccc}
\text{CVC} & + & \text{CV} & (9) \\
\text{kakita} & \rightarrow & \text{kakita} & (11)
\end{array}
\]

\[
\begin{array}{cccc}
\text{[+cont]} & \text{[+ant]} & \text{[+back]}
\end{array}
\]

b. \[+voice\] \[-voice\] \[+voice\] \[-voice\] \[+nasal\]

\[
\begin{array}{cccc}
\text{CVC} & + & \text{CV} & (5) \\
\text{kagita} & \rightarrow & \text{kagita} & \text{kagida}
\end{array}
\]

\[
\begin{array}{cccc}
\text{[+cont]} & \text{[+ant]} & \text{[+cont]} & \text{[+ant]} & \text{[+back]}
\end{array}
\]

c. \[+nasal\] \[+nasal\]

\[
\begin{array}{cccc}
\text{CVC} & + & \text{CV} & (11) \\
\text{kasita} & \rightarrow & \text{kasita} & \rightarrow \text{kaita}
\end{array}
\]

\[
\begin{array}{cccc}
\text{[+cont]} & \text{[+ant]} & \text{[+back]}
\end{array}
\]

The derivation in (13b) differs from (13a) in that only in the former is the
environment for Voicing Assimilation met. In the derivation in (13c) only the
environment for i-Epenthesis is met. None of the other rules apply. (Recall that
Nasal Linking cannot apply to link the [+nasal] autosegment onto a phoneme
that is [+continuant]. See note 4.)

As for rule ordering, Voicing Assimilation, i-Epenthesis, and Velar Dele­
tion must be extrinsically ordered. First, Voicing Assimilation (which must
follow Sonorant Delinking, as noted earlier) precedes i-Epenthesis for the
following reason. If the order of the two rules in question are reversed, the
epenthetic V would prevent the [+voice] feature from spreading onto the /t/ in

\[\text{[+nasal]} \text{[+nasal]} \text{[+cont]} \text{[+ant]} \text{[+back]}

In the derivation of (14), the appearance of V between C and C prevents

\[\text{Voicing Assimilation from applying since its environment is no longer met, and}
\]

*\text{[kaita]} is derived. Hence, Voicing Assimilation must be ordered before i-Epenthesis.

Second, with respect to i-Epenthesis and Velar Deletion, the former pre­

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\]

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Second, with respect to i-Epenthesis and Velar Deletion, the former pre­

predicted the latter since the former crucially creates the environment for Velar
Deletion to apply. Moreover, as we will discuss in Section 2, i-Epenthesis must apply after both Labial Delinking and Sonorant Delinking in order to be prevented from applying to the forms in (1b) and (1c). Finally, Voicing Assimilation applies before Nasal Linking. The crucial example bearing on this is [kaita] (from /kak+ta/). If Nasal Linking applied first converting the root final /k/ to [ŋ], then Voicing Assimilation would subsequently apply converting the initial /t/ of the suffix to [d], eventually yielding *kida. The correct form, [kaita], is accounted for by ordering Voicing Assimilation before Nasal Linking. 

The crucial rule ordering proposed here is summarized in (15).

(15) 1. Sonorant Delinking (2 & 3) 
2. Voicing Assimilation (5) 
3. Nasal Linking (9) 
4. Labial Delinking (6) 
5. i-Epenthesis (11) 
6. Velar Deletion (12)

2. Autosegmental Principles

In this section we show how two seemingly problematic and ad hoc aspects of our analysis in Section 1, the application of i-Epenthesis to only the forms in (1d) and the failure of Nasal Linking to apply in (1b), actually follow from more general principles of autosegmental phonology. Specifically, we show how the crossing lines constraint (Goldsmith 1976) blocks the application of i-Epenthesis to the forms in (1b) and (1c), and how the Linking Constraint (Hayes 1986) blocks Nasal Linking from applying to the forms in (1b).

One of the seemingly problematic aspects of our analysis of the morphophonemics of /ta/ presented in Section 1 is the failure of i-Epenthesis (11) to apply to the forms in (1b) and (1c). It would appear, at least at first glance, that these forms all meet the environment for i-Epenthesis since they all contain two adjacent consonants with a morpheme boundary intervening. For example, why should i-Epenthesis be blocked from applying to forms like *yonda ‘read’ to yield *yonida? The Japanese rule of i-Epenthesis, though, can only split up two adjacent consonants

if those two consonants do not share the same place of articulation features. In the framework of autosegmental phonology this can be understood if place of articulation features are located on a single tier and epenthesis involves the insertion of a set of place of articulation features (for the vowel /i/ these are the features +high, -back). Then, when two adjacent consonants both share the same place of articulation features the insertion of a vowel (or rather a V-slot plus vowel features) between them would lead to a violation of the crossing lines constraint. This constraint, proposed in Goldsmith (1976), disallows representations in which association lines cross. To see this, consider (16a) in which i-Epenthesis is shown applying between consonants sharing the same place of articulation features, and compare it to (16b) in which epenthesis applies between consonants not sharing place of articulation features. (Again, the symbols x and y represent elements on the phone tier.)

(16) a. C + C —> C V C
       \ /    x y
      [a place] [a place] [+hi -back]

b. C + C —> C V C
       \ /    x y
      [a place] [β place] [+hi -back]

It thus follows from theautosegmental constraint on crossing association lines that epenthesis can only occur between two consonants that have not undergone place of articulation assimilation. None of the root final consonants in (1d) have assimilated in place of articulation with the initial /t/ of the suffix; thus, epenthesis occurs in these forms. On the other hand, since the root-final consonants of forms in (1b) and (1c) have all undergone (at least) place assimilation, the two adjacent consonants share one set of place of articulation features and thus cannot be split up by i-Epenthesis; or else, the crossing lines constraint would be violated. Hence, epenthesis cannot break up the geminates created by Sonorant Delinking in (1b) nor can they break up the place-assimilated clusters created by Labial Delinking in (1c). (Also other researchers, such as Steriade (1982), have
noted that both totally and partially assimilated clusters can fail to undergo epenthesis rules.

An additional observation, however, must be made regarding (1c). In (1c) the forms [yonda] (from /yom+ta/) and [tonda] (from /tob+ta/) have both undergone place assimilation via Labial Delinking (6)—with derivations provided in (7) and (10), respectively; because the two adjacent consonants in these forms have assimilated, i-Epenthesis cannot apply or else the crossing lines constraint would be violated. What about, though, the first form in (1c) sinda? Given the rules in Section 1 (and summarized in 15), nothing prevents i-Epenthesis from applying to sinda to derive *sinida, as shown in (17).

(17)  
\[
\begin{array}{ccccccc}
  & C & V & C & + & C & V \\
  s & i & n & d & a \\
\end{array} \rightarrow \begin{array}{ccccccc}
  & C & V & C & V & C & V \\
  s & i & n & i & d & a \\
\end{array}
\]

The form in (17) does not undergo Labial Delinking like the other forms in (1c). What then prevents i-Epenthesis from applying in (17) since the two adjacent consonants seemingly have not undergone place assimilation? In order to explain the failure of i-Epenthesis in (17) we make reference to the Obligatory Contour Principle (OCP) as elaborated in McCarthy (1986). The OCP is a principle that rules out the occurrence of adjacent identical elements on the same tier. In the representation of sinda in (17) the place features of the adjacent consonants /l/ and /d/ are identical. This violates the OCP. In order to fix up this OCP violation, one of the two consonants loses its place features and acquires that of its neighbor. This is illustrated in (18).

(18)  
\[
\begin{array}{ccccccc}
  & C & V & C & + & C & V \\
  s & i & n & d & a \\
\end{array} \rightarrow \begin{array}{ccccccc}
  & C & V & C & C & V & C & V \\
  s & i & n & i & d & a \\
\end{array}
\]

The output of (18) is still sinda; however, the [n] and the [d] now share the same set of place features. This blocks i-Epenthesis from applying since if it does apply the constraint on crossing association lines would be violated, as shown in (19).

(19)  
\[
\begin{array}{ccccccc}
  & C & V & C & + & C & V \\
  s & i & n & d & a \\
\end{array} \rightarrow \begin{array}{ccccccc}
  & C & V & C & C & V & C & V \\
  s & i & n & i & d & a \\
\end{array}
\]

We see, then, that sinda, like the other forms in (1c) (and (1b)) have undergone place assimilation. Hence, the only forms in (1) where i-Epenthesis actually applies are the forms in (1d). It is only in these forms, where the adjacent consonants have not undergone place assimilation, that i-Epenthesis can apply between the adjacent consonants without violating the constraint on crossing association lines. We take this as a fundamental insight of our analysis, that i-Epenthesis can only apply when place assimilation does not.

The second seemingly problematic aspect of our analysis in Section 1 is the failure of Nasal Linking (9) to apply to the forms in (1b). If the rule of Nasal Linking has the effect of nasalizing a final root consonant immediately before the suffix /-ta/, one would expect that it would apply to the roots /tor-/ and /taw-/ in (1b) to yield tonta and kanta rather than the correct totta and katta. This is shown below in (20).

(20)  
\[
\begin{array}{ccccccc}
  & +n a s & +n a s & +n a s \\
  a . & C & V & C & + & C & V \\
  & t o r & t a \rightarrow & t o r & t a \rightarrow & t o t & t a = * t o n t a \\
\end{array}
\]

a. CVC+CV  
\[
\begin{array}{ccccccc}
  & +c o r & +c o r & +c o r \\
  s & i & n & d & a & \rightarrow & s & i & n & i & d & a \\
\end{array}
\]

b. CVC+CV  
\[
\begin{array}{ccccccc}
  & +c o r & +c o r & +c o r \\
  k a w & t a & \rightarrow & k a w & t a \rightarrow & k a t & a = * k a n t a \\
\end{array}
\]
However, Nasal Linking fails to apply to the words in (1b) in which the suffix-initial /t/ has become a geminate. In order to account for the failure of Nasal Linking to apply to these forms, we point out that its failure is predicted by the Linking Constraint proposed in Hayes (1986) and shown in (21).

(21) Linking Constraint—Association lines in structural descriptions are interpreted as exhaustive.

(The Linking Constraint was proposed to account for the phenomenon of geminate inalterability—i.e., the observation noted by Hayes and others that geminates often fail to undergo rules that would normally be expected to apply to them).

Hayes (1986) provides many examples where the Linking Constraint prevents a rule from applying to a geminate. One example is spirantization in Tigrinya (a South Semitic language spoken in Eritrea). The rule of spirantization in Tigrinya turns a postvocalic velar into a fricative. Hayes’s (1986) formulation of it is given in (22).

(22) \[
\begin{array}{c}
V \ C \\
\text{-son} \rightarrow [+\text{cont}] / \\
\text{+back} \\
\end{array}
\]

For example, the Tigrinya verb /bata+kna/ ‘we cut’ is realized phonetically as [bataxna]. The rule, though, fails to apply if the postvocalic velar is a geminate, thus it does not turn fakkara ‘he boasted’ into faxkara. This is because the geminate /k/ in fakkara is represented autosegmentally as in (23).

(23) \[
\begin{array}{c}
C \\
/ \\
/ \\
/ \\
k \\
\end{array}
\]

Given the Linking Constraint in (21) it follows that (22) would only apply to a postvocalic velar consonant that is singly-linked (i.e., a nongeminate with one C-slot) and not to one that is doubly-linked (i.e., a geminate with two C-slots).

The Tigrinya spirantization rule then would not apply to the geminate /k/ in fakkara because the structural description of the spirantization rule involves only one C-slot.

The Linking Constraint is relevant for explaining the failure of Nasal Linking to apply to the words in (1b). Recall that Nasal Linking is formulated as in (9), repeated below in (24).

(24) Nasal Linking
\[
\begin{array}{c}
\text{[+nasal]} \\
\text{C + C} \\
\end{array}
\]

Note that the rule is formulated so that the [+nasal] autosegment associates to a root-final C-slot whose consonant phoneme is distinct from that of the suffix-initial C-slot. Crucially, Nasal Linking applies after the rule of Sonorant Delinking (3) but before the rule of Labial Delinking (6). Sonorant Delinking has the effect of totally assimilating the root-final (nonnasal) sonorant to the /t/ of the suffix. This means, for example, that the form [katta] (from /kaw+tə/) would have the representation in (25) after Sonorant Delinking has applied.

(25) \[
\begin{array}{c}
C \\
/ \\
/ \\
k \\
\end{array}
\]

Since the original root-final (nonnasal) sonorant in the words in (1b) has totally assimilated to the following /t/, as exemplified in (25), the two adjacent C-slots are linked to the same phoneme. This means that Nasal Linking cannot apply since the phoneme of the root-final C-slot is no longer distinct from that of the suffix-initial C-slot. In other words, after the application of Sonorant Delinking, the words in (1b), as exemplified in (25), no longer meet the structural description of the rule of Nasal Linking. The geminate /t/ in (1b) then shows the same
inalterability effects as the geminate /k/ in the Tigrinya example. Thus the failure of Nasal Linking to apply to the forms in (1b) is predicted given the Linking Constraint.

A final observation to note about Nasal Linking is that, given the Linking Constraint, it must apply before Labial Delinking (6). Recall the proposed derivation for [tonda] (from /tob+ta/) in (10) where Nasal Linking precedes Labial Delinking. If the order of these two rules were reversed, the Linking Constraint would block Nasal Linking from applying. Consider the application of Labial Delinking to /tob+da/ below in (26).

\[
\begin{align*}
1 & \quad \text{[+nasal]} \\
2 & \quad \text{C V C + C V} \\
3 & \quad \text{t o b d a} \quad \text{Labial Delinking}
\end{align*}
\]

In (26) it is shown that after the application of Labial Delinking, /tob+da/ becomes todda. Assuming that the OCP would apply, todda would have the representation in (27).

\[
\begin{align*}
1 & \quad \text{C V C C V} \\
2 & \quad \text{t o d a}
\end{align*}
\]

Nasal Linking then would fail to apply to todda (to convert it to [tonda]) because of the Linking Constraint. That is, Nasal Linking only applies if the two adjacent C-slots are not linked to the same phoneme, unlike (27). Thus, in order for [tonda] to be derived from /tob+ta/ Nasal Linking (9) must precede Labial Delinking (6) as originally shown in (10). 10

In this section we have tried to show how two seemingly problematic aspects of our analysis of the morphophonemics of /ta/ presented in Section 1—

the failure of epenthesis to apply to the forms in (1b) and (1c) and the failure of Nasal Linking to apply to (1b)—are really not at all problematic given that their failure to apply is due to the fact that their application would lead to a violation of various autosegmental constraints. The application of the \(E\)-Epenthesis rule to (1b) and (1c) would lead to a violation of the crossing lines constraint and the application of Nasal Linking to (1b) would violate the Linking Constraint.

3 Previous Analyses

Researchers such as McCawley (1968), Ashworth (1976), Maeda (1979), Yoshiwa (1983), Tabata (1983), and Poser (1986) have offered analyses accounting for the morphophonemic alternations triggered by the initial consonant in suffixes like -ta, -te, and -tari. A number of problems emerge from these analyses. We discuss the following four. First, none of the researchers can offer a principled account on why epenthesis occurs only after root-final /s/ and root-final velar consonants. Second, some analyses resort to positing segments that never actually occur on the surface. For example, McCawley (1968) posits spirantized velar consonants and Ashworth (1976) posits prenasalized consonants. Third, analyses differ in trying to account for the nasalization phenomena associated with /ta/. For example, Yoshiwa (1983) has a transformational rule that changes a -biquence to [n] while Tabata (1983) has a rule that introduces the feature [+nasal] onto a voiced obstruent. Finally, researchers are not uniform on accounting for the voicing of the /t/ in /ta/. McCawley (1968) and Yoshiwa (1983) formalize the rule as a general rule of progressive voicing assimilation, while Ashworth (1976) and Poser (1986) relate voicing to prenasalization.

In the following subsections we show how each of these (seemingly) problematic aspects of the morphophonemics of /ta/ has a principled account under our analysis.

1.1 Epenthesis

One of the major problems with all previous accounts is that they are unable to offer an explanation why the vowel [i] occurs before the suffix when the root ends in a velar or /s/ (like in the words in (1d)), but not when the root ends in other consonants. Some analyses, like McCawley (1968) and Tabata (1983), account for the [i] by a specific rule of epenthesis. Such analyses, though, merely stipulate that [i] is inserted after a root final velar consonant or /s/ and
fail to account for why [i] only appears after these root-final consonants and not others. Maeda (1979) offers a different account of the forms in (1d). He notes that the old forms of the past tense were very regular. They all ended in the suffix -tari, and i-Epenthesis occurred between the root-final consonant and the suffix of all the words in (1b)-(1d). Thus, the first word in each of (1b)-(1d) was realized as toritari, sinitari, and kitakari, respectively. Maeda accounts for the change from these older forms to the modern ones (in (1)) by suggesting that originally there was a compound boundary between the root and the suffix -tari and the i-Epenthesis rule only applied over a compound boundary. What happened, then, according to Maeda, was that a compound boundary before the past tense suffix changed to a morpheme boundary, and thus the i-Epenthesis rule could no longer apply to the past tense forms; assimilation applied instead. While this proposal might work for the forms in (1b) and (1c), it has problems dealing with the forms in (1d) because epenthesis still applies to these. Maeda is forced to suggest that, for example, the rule that reduces a compound boundary to a morpheme boundary (before the past tense suffix) in fact does not apply if the root ends in an /s/. Thus, Maeda’s solution seems ad hoc and provides no principled account for why epenthesis only occurs with roots ending in a velar consonant or /s/.

Given our autosegmental account presented in Section 1 there is a principled reason why [i] appears after root final velars and /s/ (i.e., the words in (1d)), and why it does not appear after the other root-final consonants (i.e., the words in (1b) and (1c)). The root final consonants in (1b) and (1c) have undergone assimilation, either total (as in (1b)) or partial place assimilation (as in (1c)). This means that the root-final consonant shares place of articulation features with the suffix-initial consonant, as shown below (features are given only when relevant).

(28) a. yonda C V C C V

Since the two adjacent consonants share the same place of articulation features no vowel insertion can occur between such consonants for such would violate the constraint on crossing association lines. This is shown in (29).

(29) a. *yonida C V C V C V

b. *katita C V C V C V

Under our autosegmental account in Section 1, the occurrence of epenthesis with velar-final and /s/-final roots falls out automatically. These are the only forms where there is not at least place of articulation assimilation. Since no place of articulation assimilation occurs when the final root consonant is a velar or an /s/, there is no sharing of the place of articulation features. Thus, epenthesis can occur in these forms without a violation of the well-formedness conditions. This is seen below. (30a is shown before Velar Deletion has applied.)
Note that in (30b), [s] and [t] do not share the same place node since, unlike the [n] and [d] in yonda, [s] and [t] are really not articulated in the same place: /s/ is alveolar and /t/ is dental.11,12 (See Jorden & Noda 1987.)

Thus, on our account epenthesis is formulated as a general rule. Its failure to apply in (1b) and (1c) is accounted for because the rule's application to (1b) and (1c) would violate the constraint on crossing association lines. That is, since the two adjacent consonants share the same place of articulation, no vowel epenthesis can occur between them or else the constraint would be violated. Other analyses have no principled explanation on why epenthesis only occurs in (1d). They fail to see the necessary connection between assimilation and the failure of epenthesis.

3.2 Nonoccurring Segments

Several of the previous treatments are quite abstract in that during the course of a derivation they posit segments that are nonoccurring in Tokyo Japanese. Such segments are posited either based on historical evidence or to make a rule more general. For example, Ashworth's (1976) diachronic account of the derivation of [kaida] (from /kag+t+a/) posits a stage where voiced consonants were prenasalized, so that [kaida] is derived from a form like "ka+gita". (The [i] before the suffix is historically a theme vowel.) While such a form may be historically accurate, as argued by Ashworth (1976), it leads to a complicated and abstract derivation of modern [kaida]. Ashworth has the following stages in deriving [kaida] from "ka+gita": vowel nasalization, shift of a prenasalized obstruent to a simple nasal, velar consonant deletion, nasal spreading, voicing, and denasalization. The derivation would be as follows.

(31) vowel prenasal velar

kagita \( \rightarrow \) \( \rightarrow \) kaida

nasalization shift deletion

voicing denasalization

Though our analysis may not reflect diachrony, we believe it captures the synchronic state more accurately.

Besides Ashworth (1976), another account that utilizes nonoccurring segments is McCawley (1968). Specifically, in accounting for the occurrence of [i] after root final velars or /s/, McCawley proposes a velar spirantization rule (that spirantizes root final velars) and a subsequent epenthesis rule that inserts [i] after a root final continuant. Spirantized velars do not surface phonetically in Japanese. It seems that McCawley's intent in spirantizing velars is to make the epenthesis rule more general (i.e., it applies after all root-final continuants). Our analysis, though, has a general epenthesis rule that avoids positing nonoccurring spirantized velars. We have shown earlier how the constraint on crossing association lines has the effect of blocking the epenthesis rule from applying in cases like (1b) and (1c) where at least place of articulation assimilation has taken place between the root-final and suffix-initial consonants. There is no need to posit spirantized velars.

While Ashworth's analysis may be historically accurate, it is extremely complex from the synchronic point of view. It posits a prenasalized velar as well as nasalization and denasalization processes that do not seem to occur otherwise in the language. Our analysis of the derivation of [kaida] is more straightforward: we do not posit nonoccurring prenasalized velars nor do we require otherwise unattested nasalization phenomenon. We require only three crucial rules in deriving [kaida] from /kag+t+a/. They are Voicing Assimilation, i-Epenthesis, and Velar Deletion, as follows. (We ignore here Nasal Linking since it is not crucial to the derivation.)

(32) Voicing i-Epenthesis

kagta \( \rightarrow \) kaida

Assimilation

Velar

Deletion

Though our analysis may not reflect diachrony, we believe it captures the synchronic state more accurately.
3.3 Nasalization

Different researchers have proposed different ways to handle the nasalization phenomenon associated with the suffix /tal/. Specifically, why does a root-final /b/ nasalize? Historical-based accounts, such as Ashworth (1976), point out that this is probably due to the voiced consonant being prenasalized. However, as we discussed in Section 3.2, allowing for prenasalized consonants in a synchronic account of Tokyo Japanese leads to a high degree of complexity.

Other analyses have varied in accounting for the nasalization phenomenon associated with /tal/. Yoshiba (1983) proposes what is essentially a very complicated transformational, mora consonant formation rule (ordered after velar deletion) which has the effect of taking a root-final stop consonant plus epenthetic [i] and changing them into a single consonant. His rule is given below (somewhat simplified).

\[
\begin{align*}
\text{+cons} & \quad \text{-voc} \\
\text{+ant} & \quad \text{<-cor>} \\
\text{-mora} & \quad \alpha \text{ nasal} \\
\text{-cont} & \quad \text{+high} \quad \rightarrow \\
\text{+cons} & \quad \text{-voc} \\
\text{+ant} & \quad \text{<-cor>} \\
\text{-mora} & \quad \alpha \text{ nasal} \\
\end{align*}
\]

One effect of this rule is that it takes a root-final /b/ plus epenthetic [i] and changes it to [n]. (It should be mentioned that Yoshiba has a general epenthesis rule that would apply to all the verbs in (1b)-(1d).) The shortcoming of Yoshiba's transformational rule, besides its complexity, is that it offers no explanation why root-final /b/ ends up nasalized but not root-final /t/. Further, there is no principled reason why the rule applies to stops and not to fricatives.

Tabata (1983) offers a different analysis of the nasalization phenomena associated with /tal/. He posits an analysis whereby the feature [+nasal] is introduced onto the first of two consecutive voiced consonants during the course of a derivation. The introduction of the feature [+nasal] would apply after voicing assimilation. Simplifying somewhat, his derivation of [ tonda ] from /tobta/ can be stated as follows.

\[
\begin{align*}
\text{tobta} & \rightarrow \text{tobda} \\
\text{voicing} & \rightarrow \\
\text{assimilation} & \rightarrow \\
\text{tobta} & \rightarrow \text{tonda} \\
\text{[+nasal]} & \rightarrow
\end{align*}
\]

Though Tabata's analysis of this form is a lot simpler than Yoshiba's, his account is not able to explain why it is the feature [+nasal] that is introduced and not some other feature.

In our analysis proposed in Section 1, the connection between the suffix /ta/ and nasalization phenomena is due to the suffix possessing a floating [+nasal] autosegment as part of its lexical representation. As we discussed earlier, the floating autosegment links to a root-final (nongeminate) stop consonant. It cannot link to a fricative because the [+continuant] feature of the fricative is incompatible with nasality. (See note 4.) There is no need to introduce a [+nasal] feature during the course of the derivation, as Tabata does, since a floating [+nasal] autosegment is already part of the lexical representation of the suffix.

3.4 Voicing

Previous analyses vary in accounting for why /ta/ sometimes surfaces as [da]. Ashworth (1976) relates voicing to prenasalization. For example, in his derivation of [kaida] from "ka'gita", as discussed in Section 3.2, voiceless consonants become voiced after nasalized vowels. From the synchronic point of view this analysis is quite complex and abstract since the vowels do not surface as nasalized.

Instead of relating voicing to prenasalization (which perhaps is diachronically accurate) we capture the voicing of the /t/ in /ta/ by following McCawley (1968) and Yoshiba (1983) in having a simple progressive voicing assimilation rule. The suffix /ta/ surfaces as [da] just in case the root-final consonant is voiced. It should be noted that the rule is not triggered by root-final /w/ or /r/ (e.g., kaw+ta → katta, tor+ta → totta). We account for this by ordering Voicing Assimilation after Sonorant Delinking. The rule, then, can be stated as a simple
progressive voicing assimilation rule based on adjacency.

We conclude that the four problems that emerge from previous analyses which we discussed in this section (i.e., lack of an explanation for epenthesis, the need for abstract segments, the relation of -ta with nasalization, and the account of voicing assimilation) are not at all problematic under our analysis. Ours is the only analysis that can explain why epenthesis just occurs after root-final /s/ and velars. We explain this by showing how the occurrence of epenthesis is related to the lack of place assimilation. Moreover, unlike McCawley’s or Ashworth’s analyses, we do not need to posit abstract segments. We show that there is no need for spirantized velars or prenasalized consonants. Further, the relationship between -ta and nasalization is explained by positing that the morpheme -ta has a floating [+nasal] autosegment in its lexical representation. There is no need to account for the nasalization phenomena by positing complex transformational rules or (synchronously) abstract prenasalized consonants. Finally, we follow McCawley (1968) and Yoshiha (1983) in positing a simple progressive voicing assimilation rule to account for why the initial consonant of -ta/ appears as voiced in certain environments.

We readily admit that our analysis is not a historical one. In fact, in at least three places it can be considered counter-historical. First, we do not posit any relationship between voiced obstruents and prenasalized stops (as does Ashworth 1976). Second, our voicing rule is conditioned by adjacency. According to Ashworth this is not historically accurate. And third, we have assumed that the past tense forms like [katta] have a root-final /w/ (Kaw+ta). Historically, though, these roots ended in a /p/. Synchronically, root-final /p/ cannot be motivated since none of the allomorphs of the root surface with [p].

Our intent in this paper, though, has not been to provide an account of the morphophonemics of the suffix /ta/ that accurately reflects diachrony. We have shown that positing a synchronic analysis that reflects diachrony leads to a great deal of complexity and abstractness. Rather, our aim has been to show how certain principles and constraints of autosegmental phonology can make for a precise and explanatorily adequate synchronic account of Japanese verbal conjugations. We hope that we have succeeded in taking a first step toward this end.

Notes

1 The contribution of the first author was supported in part by an NIH Training Grant NS-07134-09 to Indiana University at Bloomington. We acknowledge the helpful comments of the anonymous referees.

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1 Following the works of McCarthy (1981), Steriade (1982), Clements & Keyser (1983), and others, we view phonological representations as consisting of a CV-tier (which encodes the consonant-vowel structure of the morpheme or word) and a phoneme tier (or a root node tier as in Clements (1985)), with elements of the latter tier being linked to the units on the CV-tier. Furthermore, following some of the recent work on the geometry of phonological features, as in Clements (1985), Sagey (1986), and others, we hold that phonemes have hierarchical representations in terms of features, with place features being represented on one autosegmental tier, while voicing features are represented on a laryngeal tier, and manner features (according to Clements (1985)) are represented on a different tier. The place and manner features comprise the supralaryngeal tier. Both the supralaryngeal and laryngeal tier link to the root node (or phoneme) tier, which, in turn, is linked to the CV-tier. In our representation of phonemes, we only indicate their hierarchical feature structure when it is relevant for the discussion (and, even then, we do not explicitly show the root node); otherwise, we employ phonemic transcription symbols as in (2). Our fuller representations reflect more the Clements’ (1985) model of feature geometry as opposed to that of Sagey (1986). Nothing crucial hinges on this, although the representations and choice of features would be different had we employed the Sagey model.

We are of the view that phonological rules can be extrinsically ordered. A reviewer suggests that rather than having the two rules extrinsically ordered, one can follow Ito & Mester (1986) who argue that /r/ and /w/ fail to trigger voicing assimilation because they are unspecified for the feature [voice]. While positing that sonorant consonants are unspecified for [voice] would allow us to avoid the extrinsic ordering of Sonorant Delinking with Voicing Assimilation, the evidence that sonorant consonants are unspecified for [voice] is conflicting. On the one hand, the facts of Rendaku (sequential voicing) as analyzed by Ito & Mester crucially assume the underspecification of sonorants for [voice]. On the other hand, the fact that nasal consonants can trigger voicing assimilation with a certain group of suffixes (i.e., -ta, -te, and -tari) as exemplified by the first two words in (1c) suggests that sonorant consonants can be specified for the feature [voice]. (An analysis of data like that in (1c) without specifying [+voice] on the
nasal consonant is posited by Borowsky (1986:34-35). However, her analysis crucially depends on the nasal and following obstruent sharing the feature \([\text{voice}]\). But if \([\text{voice}]\) has the interpretation unspecified for \([\text{voice}]\), it is unclear how two sounds can share a feature that is not specified. Given the contradictory evidence regarding the specification of the feature \([\text{voice}]\) on sonorant consonants, we take a conservative view that \([+\text{voice}]\) is specified on sonorant consonants. (A re-analysis of Rendaku is beyond the scope of this paper.) Even if this view turns out to be incorrect, nothing about our analysis would change other than Sonorant Delinking and Voicing Assimilation not being extrinsically ordered with respect to one another.

4 The \([+\text{nasal}]\) autosegment cannot link to a fricative since nasal fricatives do not occur. (If the autosegment cannot link, it will eventually delete.) A similar phenomenon is found with Welsh mutations. In the “nasalized” series of Welsh consonant mutations, stops become nasalized but continuants remain unchanged. The analysis of this might be that a floating \([+\text{nasal}]\) autosegment can only link to stop (\([-\text{continuant}]\)) consonants because the feature \([+\text{nasal}]\) and \([+\text{continuant}]\) are normally incompatible.

5 Ito & Mester (1986) suggest an analysis whereby \([\text{tonda}]\) is derived from /tob+ta/ by the following stages: /tob + ta/ \(\rightarrow\) tobda \(\rightarrow\) todda \(\rightarrow\) [tonda]. They posit a voiced geminate stage ([toda]) and a rule that has the effect of taking the first part of a voiced geminate and converting it into a nasal. While they do present evidence for such an analysis, a potential problem with their analysis is that the voiced geminate is represented as one phoneme (or one set of features) linked to two elements on the CV-tier. Given such a representation of a geminate, it seems problematic to have the first part of a geminate affected in terms of its features without concomitantly affecting the features of the second part of the geminate.

6 The feature \([+\text{voice}]\) need not be specified on the vowel as part of the epenthesis rule since the feature \([\text{voice}]\) is always redundant for vowels.

7 Since the root-final velar consonant deletes, any effect of Nasal Linking (9) is lost.

8 In this derivation it may appear that the linking of \([+\text{voice}]\) by Voicing Assimilation should prevent the application of \([\text{i-Epenthesis}]\). However, since \([\text{i-Epenthesis}]\) does not insert voiceing features the linking of \([+\text{voice}]\) by Voicing Assimilation has no effect.

9 It is worth pointing out that verbs with root-final /\(l/\) — such as mat - “wait” (which are not exemplified in (1)) — also do not undergo \([\text{i-Epenthesis}]\) when the suffix -ta is concatenated. Thus the past tense of mat - is matta. We assume that in such forms the occurrence of two /\(l/\)'s adjacent to one another on the phoneme tier violates the OCP, and thus one of the /\(l/\)'s becomes delinked from its C-slot triggering autosegmental spreading, as shown in (i) below. The rule of \([\text{i-Epenthesis}]\) then cannot occur between the root-final /\(l/\) and the suffix-initial /\(l/\) since such would violate the constraint on crossing association lines, as is shown in (ii).

\[
\begin{align*}
(i) & \quad \text{C V C C V} \quad \text{OCP} \quad \text{C V C C V} \\
& \quad \text{m a t a m a t a}
\end{align*}
\]

\[
\begin{align*}
(ii) & \quad \text{C V C C V} \quad \text{i-} \quad \text{C V C C V} \\
& \quad \text{m a t a E p e n t h e s i s m a t a}
\end{align*}
\]

10 Our derivation of \([\text{tonda}]\) from /tob+ta/ in (10) is quite different than that found in McCawley (1968). He derives \([\text{tonda}]\) by rules of voicing assimilation, obstruent gemination, and voiced geminate nasalization as follows.

\[
\begin{align*}
(iii) & \quad \text{tobta} \quad \text{tobda} \quad \text{todd} \quad \text{tonda} \\
& \quad \text{a s s i m i l a t i o n} \quad \text{g e m i n a t i o n} \quad \text{n a s a l i z a t i o n}
\end{align*}
\]

The problem for an autosegmental treatment that mimics these rules (such as that of Ito & Mester (1986) discussed in footnote 5, above) is that an extra step is needed between the obstruent gemination rule and the voiced geminate nasalization rule because after the obstruent gemination rule there is only one phoneme /d/ on the phoneme tier that is shared (with all its features) by the two adjacent C-slots. The extra step would have to at least split up the nasal tier that is shared by the geminate /d/.

11 In terms of features, dental and alveolar can be distinguished by \([\text{distributed}]\).

12 Alternatively, it may be that the reason \([s]\) and \([t]\) do not share the same place node (as opposed to \([n]\) and \([d]\)) is that place assimilation rules only occur if both sounds are \([-\text{continuant}]\).
A New Experimental Study of Japanese Verb Morphology

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ABSTRACT

In an earlier experiment (reported in Vance 1987), Japanese speakers had considerable difficulty choosing analogically correct forms of made-up *godā* (consonant-stem) verbs. The results were interpreted as consistent with two claims: (a) that regular Japanese verb forms are stored in the lexicon; and (b) that Japanese speakers can operate with phonotactically inadmissible morphs. This paper reports the results of two new experiments. The first was a substantially revised version of the 1987 experiment, and the results, while consistent with claim (a), provide no support for claim (b). The second was a supplementary experiment designed to test whether made-up *iōda* (vowel-stem) verbs are easier to handle than made-up *godā* verbs. The results indicate that because of an unavoidable complicating factor, there is no straightforward answer to this question.

(Areas of interest: Morphology, Phonology)

1. Introduction

Chapter 12 of An Introduction to Japanese Phonology (Vance 1987:199-208) reports the results of an experiment designed to test how successfully Japanese speakers can recognize analogically correct forms of four made-up verbs: *komu*, *hoku*, *yonu*, and *kapu*. The important aspects of the responses can be summarized as follows.

(a) The subjects had considerable difficulty recognizing analogically correct forms.

(b) Although no real verb has a nonpast form ending in *-pu*, the forms of *kapu* did not prove significantly more difficult than the forms of *hoku* and *yonu*.

(c) Subjects who chose all the analogically correct forms for *komu* and *hoku* also chose all the analogically correct forms for *kapu*.

On the basis of these results, the following tentative conclusions were offered.

(a) The difficulty in recognizing analogically correct forms is consistent with the view that even regular inflectional forms are stored in the lexicon and that regularities come into play as productive rules only when a speaker forgets a form or is forced to deal with an unknown item (Vennemann 1974:389).  

(b) When forced to use the regularities in existing Japanese verb forms productively, speakers seem to extrapolate in the same way from nonpast forms...