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ABSTRACT

Some Japanese examples of several common phonological phenomena (whispered vowels, nuclear friction, and consonant-vowel articulation) are examined. The segmental and transformational characterizations of these and related phenomena are reassessed and it is shown that by paying more careful attention to phonetic detail and abandoning conventional preconceptions about phonological segmentation, the diverse mechanisms used in previous analyses can be replaced by a more coherent, parsimonious, and empirically faithful account. This account combines the conceptual content of the prosodic phonology of J. R. Firth with the formal resources of unification grammars, and makes reference to a number of temporal/structural domains or units, including the mora and syllable, but not the segment. A 67-item bibliography is included. (MSE)

NON-PITCH EXPONENTS OF ACCENT AND STRUCTURE IN JAPANESE*

John Coleman

Overview In this paper I will examine some Japanese examples of a number of common (putatively universal) phonological phenomena:

1. *Whispered vowels*: in segmental accounts of Japanese phonology, it is said that close vowels are whispered or 'devoiced' when they occur either between voiceless consonants or utterance-finally after voiceless consonants, subject to certain accentual restrictions (e.g. /kikai/ pronounced as [ki̥ kai]).

2. *Nuclear friction*: this is a descriptive term for the phenomenon which is usually characterised as the accent-dependent deletion of close vowels following fricatives and affricates (e.g. /hasi/ pronounced as [haʃ:] or /hikooki/ pronounced as [çko:ki̥]).

3. *CV coarticulation*: the similarity between distinctive vowel qualities and the secondary articulation of neighbouring consonants.

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I reassess the segmental and transformational characterisations of these and related phenomena, and show that by paying more careful attention to phonetic detail, and abandoning conventional preconceptions about phonological segmentation, the diverse mechanisms that have been invoked in previous analyses can be replaced by a more coherent, parsimonious and empirically faithful account. This account combines the conceptual content of Firthian Prosodic Phonology with the formal resources of Unification Grammars (Shieber 1986) and makes reference to a number of temporal/structural domains or units, including the mora and syllable, but not the segment.

Japanese orthography suggests a way of simplifying the phonological analysis of whispered vowels. Observing that in moras with a voiced onset the vowel is never whispered, I distinguish two types of mora, 'voiced' and 'voiceless', and specify not when vowels are 'devoiced', but the circumstances in which vowels in 'voiceless' moras are exceptionally voiced. This integrates well with the Japanese accent system, in which plain voiced items are relatively marked, voicing being one of the exponents of accent. I have observed word-final "whispered high vowels" in Mandarin and Cantonese Chinese, and Swahili, in similar phonological structures and with similar phonetic exponents, and they are also reported to occur (or rather, to have occured) in Swazi (Ziervogel 1952:12), Zulu (Doke 1926:178-9) and other Bantu languages, including Lamba, Kaonde, Xhosa, Sotho, and Tswana (Doke p. 179). Since these languages have quite a similar phonotactic structure to Japanese, the present paper may be of interest in the analysis of a great many languages.

I show that the "vowel deletion" analysis of nuclear friction is unsupported on both theoretical and empirical grounds. Phonetically, the exponents of onset and rime are simply phased differently under different accentual circumstances. In unaccented moras, the friction of the onset and the vowel qualities of the nucleus may completely overlap. A non-derivational analysis which is not restricted to a linear sequential arrangement of consonants and vowels and which distinguishes phonological representations from their phonetic inter-

pretations can reflect this quite elegantly, whereas a derivational, segmental analysis is necessarily clumsy.

Phonologists and phoneticians have frequently argued that the regressive spreading of certain vowel qualities to neighbouring consonants is not determined phonologically, and have treated the phenomenon as an instance of putative universal coarticulation principles. I argue that the particular instances of CV coarticulation found in Japanese cannot be interpreted as *necessary* processes, and that this type of assimilation is a bona fide phonological phenomenon. In my analysis, some vowel and consonant features are specified for the entire mora. The secondary articulation of consonants derives not from spreading or copying of features from a vowel, but, just as in the analysis of phonatory features, from prosodic vocalic features of each mora. This results in a simpler, more parsimonious solution, achieved with greater phonetic fidelity.

Adoption of different subcategories of moras (through the annotation of mora-units with distinguishing prosodic features) also permits the distribution of particular types of mora within syllables and larger units to be stated extremely simply. Since all the vocalic features are specified for entire moras, the need for a CV tier is called into question.

I thus show that the mora in Japanese is not just an analytically convenient rhythmic or metrical construct (for example, a regular beat), but is also the structural domain for a number of interacting phenomena. I also show that these phenomena, though superficially diverse, form a unified class.

As in other components of Unification Grammar, the phonological formalism is *non-derivational* (and hence highly restrictive), *compositional* (and hence tractable), and careful to distinguish 'syntax' (phonological notation) from 'semantics' (phonetic denotation). In general, this gives it the flavour of a "type, token and distribution" approach to phonology, with the addition of an explicit theory of phonological *structure*.

1 Phonotactics

Japanese and western linguistic traditions alike view Japanese as being constructed from small phonological elements called moras. There are three mora patterns in Japanese: CV, V and C (1). The class of consonantal articulations found in C moras is quite different from those found in CV moras, C mora consonants being either mora nasals or mora obstruents, unspecified for place of articulation. These are therefore traditionally labelled as N and Q respectively, to distinguish them from the Cs of CV moras.

1) Japanese mora structures

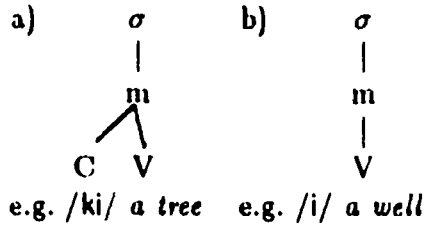
```
a)      m        b)      m        c)                m
       /\                |                          |
     C   V               V                          C
   e.g. /si/         e.g. /i/   e.g.   /Q/ in env. (C)V_ CV
                                       /N/ in env. (C)V_
```

We may also view Japanese as being constructed, like other languages, from syllables. Moras are combined to give the following basic syllable-structures:[1]

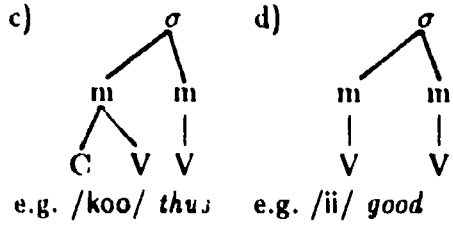
[1] I enumerate here only the syllable structures consisting of one and two moras. In addition to one- and two-mora syllables, a few words containing diphthongs in closed syllables (2V+1C=3 moras), triphthongs (3-moras), and apparent syllable-final consonants and clusters resulting from final vowel devoicing give rise to the existence of a small number of three- and four-mora syllables, such as /waiN/ *wine*, /baai/ *occasion, event*/, /yaei/ *bivouac*, /guai/ *condition, health*, /nai'/ *knife*, /ais/ *ice*, /toui'/ *bean curd*, /paNts'/ *pants*. These forms are almost without exception either loan-words from English or Chinese, or phonetically monosyllabic variants of disyllabic sequences, arising from 'devoicing' or 'eclipse' of the final vowel. The rationale for the analysis of the syllable-final fricatives and affricates as CV moras in e.g. [its.] is discussed at length below.

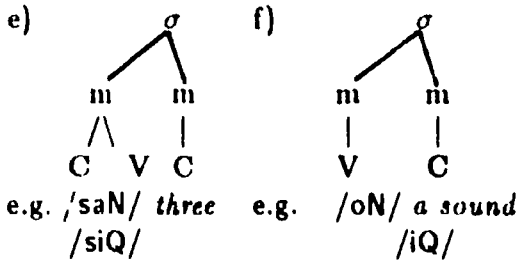
2) Syllable structures

One-mora syllables:



Two-mora syllables:





The analysis of three- and four-mora syllables is more problematic, and will not be pursued further here (cf. footnote 1).

In order to offer a "feel" for the implications and coverage of this analysis, consider the Japanese pronunciations of some familiar trade-names and loanwords, together with their analysis into moras and syllables:

3)

```
 s   s   s
 |   |   |
 m   m   m
/ \ / \ / \
C V C V C V
| | | | | |
s u b a r u
```

3 syllables, 3 moras

```
 s   s
 |   |
 m   m
/ \ / \
C V C V
| | | |
s u shi
```

2 syllables, 2 moras

```
 s   s   s
 |   |   |
 m   m   m
/ \ / \ / \
C V C V C V
| | | | | |
s u z u k i
```

3 syllables, 3 moras

```
 s   s   s   s
 |   |   |   |
 m   m   m   m
/ \ / \ / \ / \
C V C V C V C V
| | | | | | | |
f u j i y a m a
```

4 syllables, 4 moras

```
   s   s   s
  /\   |   |
 m  m  m   m
/ \ | / \ / \
C V V C V C V
| | | | | / |
d a i h a ts u
```

3 syllables, 4 moras

```
 s     s     s     s
 /\    |     /\    /\
m  m  m  m  m  m  m  m
| / \ / \ / \ | / \ |
V C V C V C V V C V V
| | | | | | | | | | |
e s u k u r e e t a a
```

'escalator'
4 syllables, 7 moras

```
 s       s
 |      /\
 m     m  m
/ \   / \ |
C V   C V N
| | /   | |
d a ts u n
```

2 syllables, 3 moras

```
   s      s
  /\     /\
 m  m   m  m
/ \ | / \ |
C V Q C V N
| | | | | |
n i p p o n
```

2 syllables, 4 moras

```
   s      s
  /\     /\
 m  m   m  m
/ \ | / \ |
C V Q C V N
| | | | | |
n i s s a n
```

2 syllables, 4 moras

Such a set of phonotactic structures can be defined by a context-free phrase structure grammar of the type familiar from sentence-level syntax. A first attempt at formulating such a grammar, which can be viewed equivalently as either a set of rewrite rules, or as a set of local tree constraints, is presented in (4).

4)

		Tree-constraints	Rewrite-rules
Rule 1)	Single-mora syllables	$\begin{array}{c}\sigma\\ \mid\\ m\end{array}$	$\sigma \rightarrow m$
Rule 2)	Branching, 2-mora syllables	$\begin{array}{c}\sigma\\ /\backslash\\ m \quad m\end{array}$	$\sigma \rightarrow m \quad m$
Rule 3)	V moras	$\begin{array}{c}m\\ \mid\\ V\end{array}$	$m \rightarrow V$
Rule 4)	CV moras	$\begin{array}{c}m\\ /\backslash\\ C \quad V\end{array}$	$m \rightarrow C \quad V$
Rule 5)	Nasal mora	$\begin{array}{c}m\\ \mid\\ N\end{array}$	$m \rightarrow N$
Rule 6)	Obstruent moras	$\begin{array}{c}m\\ \mid\\ Q\end{array}$	$m \rightarrow Q$

These 6 rules are not adequate:

- Rule 2 does not distinguish between subcategories of mora. It will be necessary to do so, since C moras may only occur syllable-finally, and if the second mora is CV, C must be voiceless, V close, and C and V coextensive in time. I shall refer to N, Q, nonsyllabic V and coextensive $\begin{array}{cc} C & V \\ [-voi] & [+high] \end{array}$ (e.g. /s(u̯)/, /f(u̯)/, /s(i̯)/ etc.) as 'marginal' moras, since they occur in syllable margins, and syllabic V and sequenced CV moras (e.g. /se/, /to/ etc.) as 'nuclear', since they contain a syllable nucleus. Rule 4 does not determine the marginal

vs. nuclear distinction between different types of CV mora. The above grammar sanctions all types of mora in both first and second place in a syllable, and thus overgenerates.

- Major similarities of distribution and behaviour of the nasal and obstruent moras (cf. (1) above) are also not adequately accounted for by rules 5 and 6.
- Similarly, further necessary contextual restrictions on the distribution of the obstruent mora (cf. (1) above) are lacking in rule 6.
- Although three-mora syllables (such as /naif(u)/ *knife*) have been disregarded here, their analysis may prove to have consequences for the analysis of one- and two-mora syllables.

With reference to rule 2, I shall describe the distribution of consonantal moras in branching syllables. The final mora of such syllables must be marginal, whereas the first mora must be nuclear. Let us adopt the syntagmatic feature specification $[+syl]$ ('syllabic') to indicate nuclear constituents, and $[-syl]$ ('non-syllabic') to indicate marginal constituents. Rule 2 must be replaced by the following rule (Rule 7):

Rule 7)

$$\begin{array}{c} \sigma \\ /\backslash \\ \begin{array}{cc} m & m \\ [+syl] & [-syl] \end{array} \end{array}$$

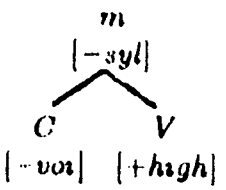
or

$$\sigma \rightarrow \begin{array}{cc} m & m \\ [+syl] & [-syl] \end{array}$$

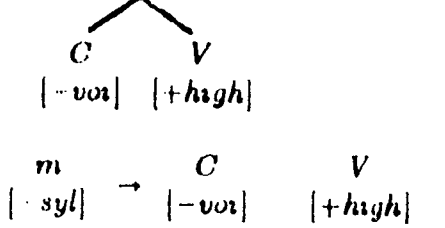
Rule 8 requires coextensive $[-voi]$ $[+high]$ moras and nasal and obstruent moras to bear the feature specification $[-syl]$:

C V

Rule 8a)



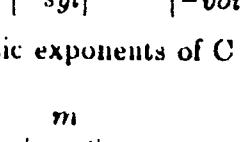
or



where the phonetic exponents of C and V are coextensive in time;

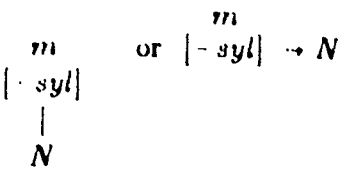
Rule 8b)

or

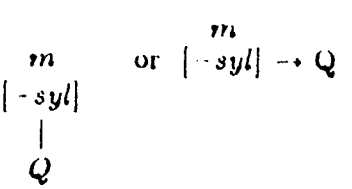


where the phonetic exponents of C and V are not completely co-extensive;

Rule 9)



Rule 10)



This almost gives us an adequate characterization of the nasal and obstruent moras. The following simplification will suffice at this point:

$$N = \begin{bmatrix} m \\ -syl \\ +nas \end{bmatrix} \qquad Q = \begin{bmatrix} m \\ -syl \\ -nas \end{bmatrix}$$

I shall defer further discussion of these representations and their phonetic interpretation until section 6.

Turning now to the combinatorial restrictions that operate within CV moras, table 1 shows many of the combinations of consonants and vowels that may form a mora. The categorisation of consonants and vowels is based on the most widely-employed phonemic analysis. The entries in this table are "reading transcriptions". Further detail is provided where relevant in the discussion below.

2 Variants of /i/ and /u/

In table 2 a selection of normalized extracts from my impressionistic phonetic records is presented. These are representative examples of the moras whose analyses are given in lines 3 and 4 of table 1. Each of these is attested in a number of variant forms, some of which can be shown to be context-specific.

The superscripted ^{i}, ^{u}, and ^{o} indicate the cavity resonance (that is, the 'secondary articulation' or 'vocalic colouring') of consonantal articulations. ^{i} indicates clear, palatal, front resonance, with no liprounding; ^{u} indicates dark, velar, back resonance with protruded spread lips; and ^{o} indicates a more central quality, with noticeable liprounding.

The most obvious variance is seen in the stricture of the nucleus in each case. I have distinguished fricative nuclei from whispered and voiced vocalic nuclei[2]. By 'nucleus', I mean the period of continuant

[2]Beckman and Shoji (1984) are typical in failing to distinguish whispered from fricative nuclei (cf. also Ohso 1973) For specific details of laryngeal activity, Yoshioka (1981) is more informative

Table 1: 'CV' and 'CyV' moras

		/a/	/i/	/u/	/e/	/o/
1		a	i	u	e	o
2	/k/	ka	ki	ku	ke	ko
3	/s/	sæ	ʃi	su	se	so
4	/t/	tæ	tʃi	tsu	te	to
5	/n/	næ	ɲi	nu	ne	no
6	/h/	ha	çi	Φu	he	ho
7	/m/	ma	mi	mu	me	mo
8	/y/	jæ		ju		jo
9	/r/	ra	ri	ru	re	ro
10	/w/	wa				
11	/ky/	kʲæ		kʲu		kʲo
12	/sy/	ʃæ		ʃu		ʃo
13	/ty/	tʃæ		tʃu		tʃo
14	/ny/	ɲʲæ		ɲʲu		ɲʲo
15	/hy/	çʲæ		çʲu		çʲo
16	/my/	mʲæ		mʲu		mʲo
17	/ry/	rʲæ		rʲu		rʲo

Notes:

1. [u] represents an *un*rounded close back vowel
2. [ʃ] represents voiceless alveo-palatal friction
3. [r] represents a light alveolar tap
4. [ɲ] represents palatal or alveo-palatal nasality
5. [k], [t] represent aspirated stops

Table 2: Variants of /i/ and /u/.

a) "tV" moras:	Front	Back
Fricative nucleus: (Syllabic continuant)	t ʃ:	t s:
Whispered nucleus:	t ʃ i	t s u
Close vocalic nucleus:	t ʃ i	t s u
Half-open vocalic nucleus:	t e	t o
Open vocalic nucleus:	t a	

b) "sV" moras:	Front	Back
Fricative nucleus: (Syllabic continuant)	ʃ:	s:
Whispered nucleus:	ʃ i	s u
Close vocalic nucleus:	ʃ i	s u
Half-open vocalic nucleus:	s e	s o
Open vocalic nucleus:	s a	

(There are also many context-specific variants of the moras with half-open and open vocalic nuclei, but that variance is beyond the scope of the present paper.)

articulation (i.e. vocalicity or friction) that gives a mora its duration. Nucleus whispering in Japanese is a very commonly described phenomenon: in segmental terms, it is often said that close vowels are whispered or 'devoiced' when they occur either between voiceless consonants or utterance-finally after voiceless consonants, subject to certain accentual restrictions (Ueda 1976, Hasegawa 1979a, 1979b, and Haraguchi 1984). Nuclear friction is a descriptive term for the phenomenon which is usually presented as the accent-dependent deletion of close vowels following fricatives and affricates (Ueda 1976 ex. 4). Note, however, that in fricative nuclei the so-called 'deleted' vocalic quality is actually *present* and audible in the secondary articulation of the fricative nucleus (Schane 1970:510). If this observation is of phonological relevance (and I shall argue that it is), in a segmental, derivational account it would have to be proposed that the vocalic quality of the vowel is copied to the consonant as palatal secondary articulation (velar in the case of 'back-nucleus' moras), before the vowel is deleted (cf. Ohso 1973).

Furthermore, if an analysis of nuclear friction includes the proposal that a segment or timing unit is deleted, the material which remains after such deletion ought to be of shorter duration than a CV mora. This is not the case: notice in table 2 the increased duration of the period of friction in fricative-nucleus moras relative to their whispered and close vocalic counterparts. In short, if a vowel deletion rule is proposed, there must also be a rule that assigns extra duration to the friction units, or a compensatory lengthening rule (Ingria 1980, de Chene and Anderson 1979; Prince 1984; Fukui 1986; Wetzels and Sezer *eds.* 1986; Poser 1986, 1988) to account for its somewhat increased duration.

Classical phonemic accounts of Japanese phonology invariably encounter difficulties in analysing the patterns (illustrated in table 2) of palatalization and affrication of voiceless coronal consonants before close (high) vowels. If each mora is analysed as the simple concatenation of consonantal onset and vocalic nucleus, the phonetic realizations of t-line (line 4) moras as [tæ], [tʃi], [tsu], [te], [to], and s-line (line 3) moras as [sæ], [ʃi], [su], [se], [so] suggest context-

dependent variation[3] of the form:

/t/ is realized as:

- [tʃ] before [i][4],
- [ts] before [u],
- [t] before any of the other vowels.

/s/ is realized as:

- [ʃ] before [i],
- [s] before any of the other vowels.

For instance, Daniels (1958:58-9) writes:

> "In all cases, [ts] may be regarded as a variant of [t] ...under the influence of [u] or [ɯ] ...When prefixed to [i] or [ɪ] ..., [tʃ] may be regarded as a variant of [t], ...and [ʃ] as a variant of [s], under the influence of these vowels".

[3]Bloch (1950) and Jinushi (1967) are exhaustive and thorough in detailing these variations.

[4]Hattori (1967) disputes this analysis (which originated essentially with Trubetzkoy (1939), but was endorsed and popularized by Bloch (1950)), due to the occurence of [ti] in loanwords such as [pa.ti]'party'. Though I agree with both Bloch and Hattori tha t some place in the phonology loanwords that have been fully incorporated into t. lexicon must be accounted for in the same terms as native forms, Bloch actually anticipated Hattori's objection by showing that 'innovating' and 'conservative' speakers make different distinctions between [ti] and [ɪʃi]. I shall consider native Japanese and S no-Japanese elem and systems only For the 'innovating' speakers, the [ti] of [pa ti] is analogous to the nasal vowels produced by innovating English speakers in pronouncing certain loans from French. We would not propose, however, that nasal vowels have systemic status in English generally, even for 'innovating' speakers

Problems arise in placing the Sino-Japanese moras [tʃæ], [tʃu], [tʃo] (line 13), [ʃæ], [ʃu], [ʃo] (line 12) into this scheme, for there is now, apparently, a set of mora-initial consonantal contrasts with [tæ], [tsu], [to], [sæ], [su] and [so]. Numerous analyses (e.g. Bloch 1946, 1950; McCawley 1968) have proposed to represent the distinctively palatalized series of onsets as /ty/, /sy/ and so on, giving a repertoire of moras that includes the following:

CV:	/ta/.	/ti/.	/tu/.	/te/.	/to/
	/sa/.	/si/.	/su/.	/se/.	/so/
CyV:	/tya/.		/tyu/.		/tyo/
	/sya/.		/syu/.		/syo/

In this analysis the treatment of palatalization has not been carried through to include /ti/ and the other /Ci/ moras. In /ti/, the initial consonant is interpreted as the 'naturally' palatalized variant of /t/ that occurs before /i/, whereas for /tya/, /tyu/ and /tyo/, palatality is attributed to the presence of a 'glide' /y/.[5]

3 Transformational account of palatalization and affrication

I shall now consider how a transformational analysis might address the problems considered above. An advocate of the transformational approach would hope to be able to arrive at redundancy-free lexical entries and a minimal grammar by employing a suitable feature-system, incrementally deriving the intended surface (allophonic) representations through the successive application of rules of the re-

[5] In Jinushi's (1967) study, this failing of earlier analyses is expressed in the following words: "the traditional analyses of "shibilants" are hard to accept from our point of view, because they exhibit instances of phonemic overlapping For instance, [ʃ] is interpreted as a single phoneme /s/ before a high front vowel, and as a sequence /sy/ before other vowels The same difficulty is also found in the interpretation of the prepalatal affricate". (Jinushi 1967.13)

quired generality and parsimony to lexical (morphophonemic) representations. For example, (5) applies irrespective of voicing and backness, compressing in a single formula the specification of affrication of coronal stops (/t/, /d/), before high vowels (/i/, /u/).

5) Affrication 1

$$\begin{bmatrix} C \\ +obs \\ -cnt \\ +cor \end{bmatrix} \rightarrow [+del\ rel] / \_ \begin{matrix} V \\ [+high] \end{matrix}$$

[*del rel*] is a feature that has attracted much criticism, (Ewen 1980, 1982; van der Hulst and Smith 1982a:5 for a summary and further references) since it is the only feature in the SPE system (Chomsky and Halle 1968) with an implicitly dynamic interpretation. Its utility is dependent on considerations such as the following:

Suppose that instead of rule (5) a rule such as (6), which explicitly inserts a coronal continuant between the initial stop and the nuclear vowel, is employed.

6) Affrication 2

$$\emptyset \rightarrow s / t\_ \begin{Bmatrix} i \\ u \end{Bmatrix}$$

A fuller, more general expansion of this would be:

7) Affrication 3

$$\emptyset \rightarrow \begin{bmatrix} C \\ +obs \\ +cnt \\ +cor \\ \alpha voi \end{bmatrix} / \begin{bmatrix} C \\ +obs \\ -cnt \\ +cor \\ \alpha voi \end{bmatrix} \_ \begin{matrix} V \\ [+high] \end{matrix}$$

By familiar argumentation, (5) is judged preferable to (7) since it is more parsimonious. Furthermore, using [*del rel*], the functional, distributional and structural unity of affricates is captured and a simple two-segment CV mora-structure is maintained.

However, (7) also has certain advantages:

i) It states the unity of place of articulation of affricates explicitly, rather than implicitly as with [*del rel*]. The advantage of this explicitness for a phonetically general and well-founded phonological theory is that phenomena such as nasal or lateral release, such as [t^n] and [t^l], can be represented using feature-matrices that directly parallel that which specifies [ts].

ii) The cooccurence of the features [+*del rel*] and [-*cnt*] seems counterintuitive, if column-vectors are intended to represent features that are cotemporal, for the whole point behind the [+*del rel*] representation of affricates is that it obviates segment-internal structure such as:

$$\begin{bmatrix} +obs \\ -cnt \end{bmatrix} \begin{bmatrix} \\ +cnt \end{bmatrix}$$

iii) A tempting reason for representing the affricate [ts] as a sequence of two feature-matrices is that in Japanese the distinct item /s/ is also palatalized before /i/, just like the affricate [ts]. In other words, (6) feeds (8), which is independently required, so that greater parsimony and integration than the rigidly phonemic analysis is achieved.

8) Palatalization

$$s \rightarrow \int / \quad i$$

In the case of the partially derived affricate [t-ʃ], it must also be specified that the initial [t], in its turn, is palatalized:

9) Regression of Palatalization

$$t \rightarrow t^{j} / \_\int$$

This rule would not be required in an analysis which employed [*del rel*].

Using [*del rel*] to express affrication, the 'spreading' or 'regression' of palatalization to the stop portion becomes chimerical, and we may express (8) more generally as (10):

10) Self-feeding palatalization

$$C \rightarrow \begin{bmatrix} +high \\ -back \end{bmatrix} / \begin{bmatrix} +high \\ -back \end{bmatrix}$$

(10) is fully regressive. That means it can iteratively apply over any string of consonants that precedes $\overset{V}{\begin{bmatrix} +high \\ -back \end{bmatrix}}$.

This is phonetically plausible, since consonants immediately preceding /Ci/ moras (i.e. obstruent or nasal mora consonants) *are* palatalized e.g. in [matt∫i] "matches" or [genki] "health". Since the palatalization rule is, in its simplest form (10) self-feeding, representing affricates as sequences of segments is an attractive possibility.

Without pursuing this discussion any further, it is clear that due to the segmental basis of the transformational model, there is no motivated way to choose between these two possible analyses of affrication in that model's own terms. The advantages of the feature [*del rel*] are its abbreviatory value and the fact that it reflects the functional unity of affricates; but these benefits are more-or-less negated by the cost of lost generalizations.

4 Coarticulation

Phonologists and phoneticians have frequently argued that the regressive spreading of palatality before high front vowels is not phonologically relevant (e.g. Campbell 1972 n. 11, Ladefoged 1975:49), and have treated the phenomenon as an instance of universal coarticulation principles (Gay 1978; but see Hattori 1965:542 for an appealing counter-argument). In other words, palatalization or fronting of consonants is held to be completely predictable before [i]. This does not hold before non-high vowels, however, and so where palatalization occurs in such an environment, it must be specified explicitly. The supposed /y/-glide employed in phonemic analyses of Japanese is defended in these terms.

I shall now argue, however, that in derivational models, certain clearly phonological, non-automatic processes must follow the particular case of regressive palatalization under consideration, which therefore cannot plausibly be interpreted as a *necessary* coarticulatory process.[6]

The self-feeding palatalization rule, (10), is simpler than the more restrictive self-bleeding (11).

11) Self-bleeding palatalization

$$C \rightarrow \begin{bmatrix} +high \\ -back \end{bmatrix} / \_ \begin{bmatrix} V \\ +high \\ -back \end{bmatrix}$$

(10) is also observationally more satisfactory, since it will correctly spread palatality to all preceding consonants. (11) would necessitate the operation of a further, later rule in order that immediately preceding consonants also become palatalized. But if a later rule is to apply, then (11) cannot possibly represent a 'mechanical'

[6]Many striking examples of non-coarticulation could also be presented in defence of this claim.

coarticulation process, since such a process could only plausibly operate at the very end of a derivation.

Even if (10) is employed, it can still be argued that a later rule may operate. The description of the phenomenon given here is from a transformational fragment of Japanese phonology in Ueda (1976):

> "[i] and [u] normally disappear between a preceding voiceless consonant and a following voiceless consonant. This may be formulated as:
>
> 12)[7]
>
> $$\begin{matrix} V \\ [+high] \end{matrix} \rightarrow \emptyset \; / \; \begin{bmatrix} C \\ -voi \\ -nas \\ +cnt \end{bmatrix} - \begin{bmatrix} C \\ -voi \\ -nas \end{bmatrix}$$
>
> Words like *Mississippi* 'Mississippi', *tukusi* 'horsetail' are thus pronounced [miʃʃppi], [tskuʃi]."

Further examples given by Ueda include *kisusi* [kisʃ] 'kissing', which demonstrates that the respective ordering of palatalization (PAL) and high vowel deletion (HVD) must be:

$$/\text{kisusi}/ \overset{\text{PAL}}{\Longrightarrow} \text{kisuʃi} \overset{\text{HVD}}{\Longrightarrow} [\text{kisʃ}]$$

and not:

$$/\text{kisusi}/ \overset{\text{HVD}}{\Longrightarrow} \text{kiss} \Longrightarrow ?$$

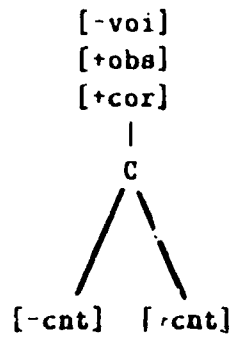
for in the latter case there is no following high front vowel to palatalize the final [s]. Again, if a phonological rule can be established which

[7] Similar attempts to formulate this rule appear in Ohso (1973), Hasegawa (1979a.127, 1979b.388) and Haraguchi (1984.147).

must follow palatalization, as Ueda's analysis suggests, then palatalization itself must be a bona fide phonological process, not merely an automatic coarticulatory artefact.[8]

5 An Autosegmental Formulation

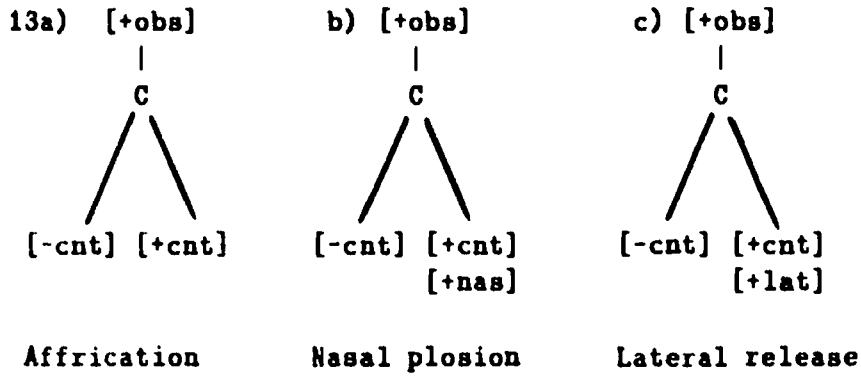
The problems of the SPE-type analysis might be attributed to the naïvety of its surface phonological representations. Given the nature of the phenomena under discussion, an Autosegmental analysis (Goldsmith 1976) might be more satisfactory than a transformational analysis. For instance, the canonical autosegmental treatment of affrication (Clements and Keyser 1983) unites the sequence of features $[-cnt][+cnt]$ under a single C node, which itself bears a single matrix of features that encapsulates the homorganic articulation of an affricate. [ts], for example, can be represented in multilinear fashion along several simultaneous tiers (Prince 1984) as:



The values of the feature $[cnt]$ are written on a tier below the C node, as they express sub-segmental information. Thus the feature

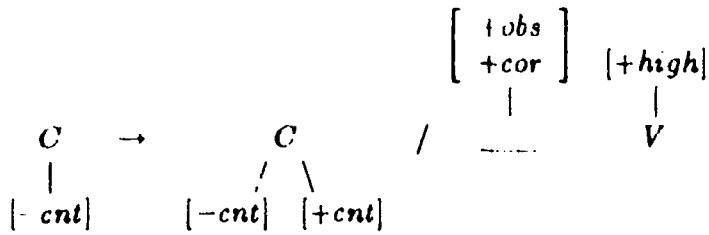
[8]Beckman and Shoji (1984) also notice that this ordering paradox presents a great problem for a derivational theory of phonological organization, but they simply accept this as evidence that phonological rules may follow coarticulation "rules", rather than question the validity of derivational models.

[*del rel*] is obviated, and affricates are treated as paradigmatically unitary, but syntagmatically binary. The phonetic parallels between affricates and stops with nasal or lateral release is reflected in representations such as (13a–c):



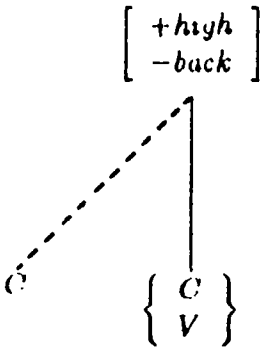
The affrication rule, reexpressed in autosegmental terms, is:

14) Affrication 4



(15) expresses the regressive association of palatality with consonants:

15) Regressive palatalization 1



(15) may apply over a sequence of consonants, just like (10). This example shows that Autosegmental Phonology allows more solutions than transformational phonology in cases of assimilation (but cf. Anderson 1982). Because it is constructed on transformational foundations, it may use copying rules (e.g. 10), or, alternatively, its own device, association rules (e.g. 15). (15) differs from (10) in employing autosegmental association, rather than copying. In uniplanar representation, association is more restrictive than copying, since it falls under the strictures of the WFC (see below for further discussion), and is consequently always locally bounded, whereas copying may be completely unbounded.

What, then, of the 'vowel elision' phenomenon reported by Ueda that results in such forms as [kisʃ]? How is the leftward spreading of palatalization blocked? The following structural restriction must be formally instantiated:

> *Palatality may extend as far back as the final consonant of a preceding syllable, but not so far as that syllable's initial consonant.*

An autosegmental analysis might propose that the constituents of a /Ci/ mora can be represented by two syllable terminals, labelled C and V. In [tʃi], the first of these is associated in lexical representations with the segmental matrix for [t], and the second with the matrix $\begin{bmatrix} +high \\ -back \end{bmatrix}$.

This does not settle whether C and V units or their features are to be represented on one tier, or on two independent tiers. I shall consider each of these possibilities in turn. With just two tiers — the CV tier and a segmental tier — the derivation proceeds as in 16a–d.

16a)

```
C      V
|      |
t   [+high]
    [-back]
```

PALATALIZATION (15) ⇓

b)

```
C     V
|\    |
| \   |
|  \  |
t  [+high]
   [-back]
```

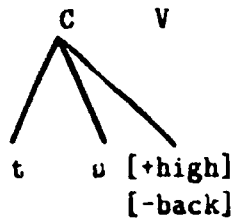
AFFRICATION (14) ⇓

c)

```
C     V
/\    |
/ \   |
t  s [+high]
     [-back]
```

DEVOCALIZATION ⇓

d)



At this stage, in order for the fricative [s] to be associated to the floating V node (compensatory lengthening), the association line linking $\begin{bmatrix} +high \\ -back \end{bmatrix}$ with the C node must be 'swung out of the way', to ensure that it is not crossed by the association line between [s] and V.[9] The position of the V-features relative to the C-features on the diagram is unimportant, as long as they are associated with each other via the CV-tier. Observe how the derivation proceeds if the vocalic and consonantal features are set apart, on independent tiers. In (18) I have written the V-features above the CV tier, and the C-features below the CV tier. Since 'consonant' and 'vowel' features are not restricted to C and V slots respectively, and since they are not necessarily intercalated, but may co-occur, I term 'consonant' and 'vowel' features stricture and resonance features, accordingly. (The form of 14 will consequently be adjusted to:

[9]This constraint, known as one of the clauses of the Well-Formedness Constraint, or WFC (Goldsmith 1976:27), is usually taken to be of fundamental importance in restricting the range of permissible phonological representations. In Coleman and Local (1989), however, it is shown that the WFC follows as a necessary consequence of more fundamental graphical assumptions underlying Autosegmental Phonology It is argued that the WFC is equivalent to a restriction on the embedding of graphs in planes, and has no place within linguistic theory If autosegmental representations are limited entirely to graphs embedded in the plane, then the no-crossing condition is vacuous. But if 'three dimensional' representations (Halle and Vergnaud 1980; Archangeli 1985) are admitted, then the no-crossing condition ceases to restrict the range of possible representations, because any graph can be embedded without crossings in three-dimensional space (Wilson 1972), Pulleyblank's (1986:14) comments notwithstanding.

17) Affrication 5

$$\begin{array}{ccccccc} & & & & & & [+high] \\ & & & & & & | \\ C & \rightarrow & C & / & \underline{\quad} & & V \\ | & & / \ \backslash & & | & & \\ [-cnt] & & [-cnt] \ [+cnt] & & \begin{bmatrix} +obs \\ +cor \end{bmatrix} & & \end{array}$$

to accord with this decision.)

18a)

```
        [+high]
        [-back]
           |
C          V
|
t
```

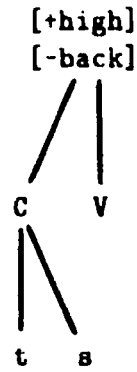
PALATALIZATION ⇓

b)

```
[+high]
[-back]
 /  |
C   V
|
t
```

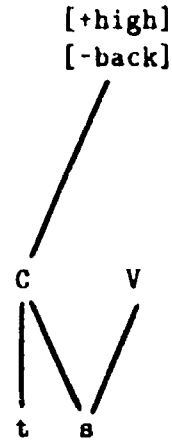
AFFRICATION ⇓

c)



DEVOCALIZATION AND
COMPENSATORY LENGTHENING ⇓

d)



Analysis (18) is clearly more satisfactory than analysis (16). In the multiplanar mode of representation, stricture (consonantal) and resonance (vocalic) features are represented on separate tiers: this allows such phenomena as 'vocalic colouring' of consonants, consonantal syllabics, and vowel-fricative alternation to be characterised with ease. The motivation for this decision was, however, to avoid violating the

restriction that association lines may not cross. But if such a restriction is to carry any force, it should not be possible to subvert it by transferring any subgraphs whose association lines are likely to cross onto separate tiers or planes.

Many other problems can be avoided if statements of sequence are kept quite separate from statements of association of items in separate tiers. We have seen, for instance, that Japanese has CV, but not VC moras. In lexical representations, constant duplication of the information that C precedes V in CV moras is highly costly, since if a C and V are parts of one mora, it is completely predictable that their relative surface order is "C first, V second", as there are no VC moras. Where vowel-consonant sequences do occur, there is always a mora-boundary between the vowel and consonant, as that consonant either begins the next mora, or is a complete mora itself. The relative order of consonants and vowels within a mora is thus totally predictable, as is the location of mora-boundaries. Consequently, the most parsimonious analysis of Japanese is one in which consonants and vowels are grouped into moras, syllables etc., but not explicitly ordered.

The informational content of linear precedence in phonological representations has to my knowledge never been discussed in Autosegmental phonology. It is just assumed that linear precedence in phonological or phonetic structure is represented by the order of printed items at no notational cost (cf. Cheng 1971).

6 A Prosodic-Structural Analysis

If stricture and resonance features are factored on to separate tiers, distinct C and V units may turn out to be unnecessary; that is, they may be susceptible to a configurational definition. In anticipation of this, let us now reconsider the phonotactic structure of the Japanese syllable. The syllable-structures I proposed in section 1 are rather different from the more usual pattern of Onset–Rime/Nucleus–Coda

widely attested in other languages (and in Japanese too, according to Abe 1986). However, the Japanese pattern can be felicitously considered a stereoisomer of the more common case.

Employing a level of structure at which the mora is defined as an autonomous category, we can express tautomoraic palatalization simply by adding the "long-domain" or "prosodic" feature-cluster $\begin{bmatrix} +high \\ -back \end{bmatrix}$ to the mora node:

19)

```
        m
     [+high]
     [-back]
       / \          e.g. /si/
      /   \                /ti/
     C     V
  [-voi]
  [+cor]
  [+obs]
```

The idea is that such "factorized" features are common to both daughters in the manner of grammatical agreement features in syntactic theory. This could be achieved in the phonetic interpretation function, or by a feature inheritance mechanism:

20)

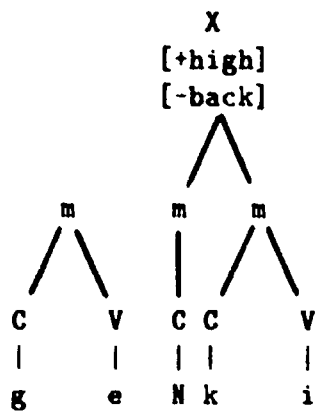
```
        m
     [+high]
     [-back]
       / \          e.g. /si/
      /   \                /ti/
     C     V
[+high] [+high]
[-back] [-back]
[-voi ]
[+cor ]
[+obs ]
```

The 'spread of palatality' to a preceding consonantal mora could then be reformulated as (21).

21) 'Regressive' palatalization 2

For example:

22)



The status of the node labelled X is at present unknown. It may turn out to be warranted as an autonomous prosodic category, or it may be that the domain of palatality represented in (21) is too limited, and needs to be extended to some more familiar domain,

such as the foot. Alternatively, the Unification formalism offers the possibility that X is not a constituent node at all, but a reentrant (i.e. doubly-dominated) nonterminal node representing a category which is shared between two moras.

The spread of palatalization in [matt∫i] and [geɲki], and its absence in [kis∫], is only correctly defined if Ueda's vowel deletion rule (12) is reformulated so that at least the V remains, ensuring that the mora still includes both C and V, and not just a C.

23)

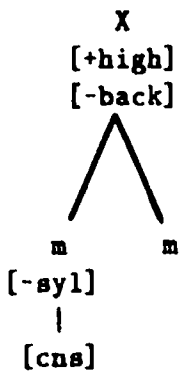
```
    m          m          m
[+high]    [+high]    [+high]
[-back]    [+back]    [-back]
  /  \       /  \       /  \
C     V    C     V    C     V
|          |          |
k          s          s
           ----------
           Inappropriate environment
           for regressive palatalization
           condition (21) due to remaining
           presence of internal V-unit.
```

Phonological constituent structure can thus be used to set principled and motivated limits to the spread of palatality. When representations such as (19) are sanctioned, [*rnd*] too can be specified at the mora-level in Japanese, for its value can be specified for the whole mora. This removes the need for a further regressive assimilation rule, and, since all the vowel-features can be specified for entire moras, calls into question the need for CV elements on the timing tier at all. This proposition has been defended at length by Hy-

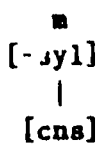
man (1985)[10], and now has some support both within Autosegmental Phonology (cf. Prince 1984) and in "rival" frameworks, notably Dependency Phonology (Anderson and Ewen (*eds.*) 1980; Anderson and Durand (*eds.*) 1988).

Such a development prohibits formulation of regressive palatalization as (21), which refers crucially to the presence of a single C-unit. A simple reformulation of (21), however, permits an adequate statement to be made:

24) Regressive palatalization 3

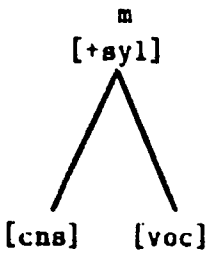


Mora consonants can thus be characterised as:

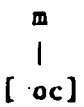


The former CV-mora structure is:

[10]Further support for the distinguished status of the mora as a phonological domain in Japanese is presented in Cheng (1971), Yoshiba (1981), Pierrehumbert and Beckman 1988.118-121, and Kubozono (1989)



with vowel- and consonant-quality features dominated by *m*. Former V-moras are now:



but with no consonantal features dominated by *m*. This reformulation also permits restrictions on the distribution of moras within words to be stated extremely simply, since [+*syl*] moras may constitute a word, and may appear word-initially, whereas [−*syl*] moras only ever occur after a [+*syl*] mora. $\begin{bmatrix} -nas \\ -syl \end{bmatrix}$ moras, in addition, only ever occur before a [+*syl*] mora i.e. between two [+*syl*] moras.

Although it represents a departure from derivational phonology, the declarative nature of this analysis is extremely satisfying. There is no CV tier, and it is therefore a relatively more parsimonious analysis. Traditional vowel and consonant features are specified for the entire mora: that is, the secondary articulation of initial consonants derives not from regressive spreading of features from a vowel, but from 'vowel' features directly anchored in mora-tier units. This results in a more satisfactory analysis, achieved more simply, and with greater phonetic fidelity.

7 Sequence and Phasing

In the previous sections I discussed affrication and coarticulation informally in terms of a feature-based constituent- tructure account of Japanese phonotactics. I proposed that each mora should be represented as an unlinearized structure of strictu e and resonance features, and that phonological categories should be structured by supr egmental phonotactic rules. These decisions have a number of impo tant consequences:

i) Palatalization is not treated as a directed (regressive) assimilatory copying process.

ii) Fricative nuclei do not result from vowel-deletion.

iii) Sequence redundancies are removed from lexical representations.

I shall now show how whispered vowels and fricative nuclei can be incorporated into this framework.

The traditional claim that nucleus whispering or friction only occurs in voiceless/tense environments is not quite correct. On a number of occasions, I have observed nucleus whispering and friction before lax, voiced items. One example, which records nucleus friction in accelerated speech and whisper in slower speech, before a lax, voiced item in both cases, is given in (25). In this example, the first mora is accented (it is of greater intensity than the second mora, it is voiced, and may have a rising pitch-contour). It is more accurate, then, to state that nucleic whisper or friction occurs *more readily* before tense, voiceless items than lax, voiced items[11].

[11] Similarly, although it is typically only high vowels which devoice, on occasions this phenomenon extends to mid vowels too, though rarely It is clear that the tendency to devoice is accent-dependent, but as a full consideration of this matter lies beyond the scope of this paper, I shall continue to speak only of high vowels devoicing in voiceless environments.

25) It's an insect (mushi desu)

mu∫(i)dɛs

↑

complete fricative in faster speech

In all cases, however, nucleic friction or whisper only occur after tense, voiceless onsets in unaccented moras. The relationship between the voicing of a mora's onset and the possibility that its nucleus will also be voiceless is obviously not accidental, but neither is it simply a case of automatic assimilation, since it is accent-governed.

The traditional segmental analysis of whispered or devoiced vowels is predicated on the twin assumptions that i) vowels are by default voiced — that is, voiceless vowels are universally the exception rather than the norm; ii) voicing is specified segment-by-segment. By questioning both of these assumptions, I shall show that a more satisfactory analysis can be achieved.

Plain voicing is rather rare in Japanese. Shapiro's (1973) analysis, which accords with my own observations, proposes that 'tensity', and not 'voicing', is the primary paradigmatic distinction between 'tenues' and 'mediæ' in Japanese. Indeed, various other types of excitation, including aspiration, voiceless oral friction, pharyngeal friction, breathy voice, creaky voice and whisper are much commoner than simple voice or voicelessness. The so-called 'voiced' or 'lax' non-nasal onsets are actually only very rarely properly voiced; they are virtually restricted to accented moras, reduplication forms and other compounds; and they are specially marked in the orthography. Moras with voiced non-nasal onsets are written using the symbol for the mora with the corresponding voiceless onset, together with a mark called 'nigori'[12]. So 'ga' is written just like 'ka', but with the addition of the voicing diacritic. According to the assumptions presented in the previous paragraph, this is simply an irrational idiosyncracy of the Japanese writing system. But in fact 'nigori' can be viewed as marking not just the 'laxness' of the onset, but as also

[12] A nominal form of the verb "nigoru", *to make muddy*.

encoding the information that the nucleus is never devoiced. Taken together, these facts suggest that 'voicing' operates in Japanese as a mora-domain (rather than a segmental-domain) feature; and b) 'voicing' is an exponent of accent. The normal state of affairs is:

```
        Accented mora
          /   \
Voiced onset   voiced nucleus

      Unaccented mora
          /   \
Voiceless onset   voiceless nucleus
```

In addition to these, there is also the 'marked' case:

```
        Accented mora
          /   \
Voiceless onset   voiced nucleus
```

As in the orthography, then, I shall make the feature [voi] a mora-level feature, and specify not when vowels are devoiced, but rather when vowels in voiceless moras are exceptionally voiced.

Now I shall incorporate fricative nuclei into this analysis of voicing and accent. As with whispered vowels, rather than being an all-or-nothing assimilation phenomenon, the present analysis views fricative nuclei as one option in a tempo- and accent-dependent strength hierarchy:

Voiced vocalic nuclei	Accented
Whispered vocalic nuclei	Unaccented
Fricative nuclei	Unaccented/Accel. speech

This hierarchy is phonetically quite natural. In traditional articulatory terms, the distinction between fricatives and vowels is a difference in the degree of approximation of the active and passive articulators: close approximation in the case of fricatives, and open approximation in the case of vowels.

In the present analysis, moras will be represented as graphical structures (directed, acyclic graphs, or dags) whose nodes are sets of ordered pairs of features and their values. Two entirely equivalent forms for the representation of dags are used in the Unification formalism: tree-like unordered graphs (possibly with reentrant nodes), and feature-value structures. Both forms of diagram are used below. In lexical phonological structures, feature-values will be specified when not predictable, or unspecified when predictable: consequently only features with semantically distinctive function are included in representations of lexical phonological structure. Predictable features are not added in an incremental, procedural fashion to representations, but are incorporated in declarative fashion on the basis of satisfaction of constraints, such as defaults or implicational statements.

In lexical representations, each mora is a redundancy-free structure of distinctive features. In the commonest type of mora, CV-moras, each mora's feature-structure is partitioned into two substructures. One of these subsets contains the category-valued feature [*voc*], the other [*cns*]. In the case of consonantal moras i.e. moras of gemination, as in [matt∫i], or the nasal mora consonant, as in [geŋki], only the [*cns*] category-valued feature is lexically specified (regression of palatality may add *voc* features); in V-moras, only the category-value of [*voc*] is lexically specified. The features in the value of [*cns*] partially define distinctions in the stricture parameters of speech production, and are thus called stricture or obstruence features.[13].

This set of features includes specification of the place and degree of stricture, but not the "manner of articulation". The [*voc*] feature-structure is complementary to the [*cns*] feature-structure, in that its features partially define distinctions in the resonance parameters of speech production, and are called resonance features[14].

[13]These features might equally well be called obstruction features (Griffen 1985) C-features or consonantal features.

[14]Similarly, resonance features might equally well be termed sonorance-, V- or vocalic features.

Phonotactic structures are represented using dags, which are rather like unordered trees, in order to export temporal ordering from lexical phonological representations. This is because surface moras in which an obstruence maximum precedes a resonance maximum, as in [tʃi], will be considered as exponents of the same abstract representation as the corresponding moras with fricative nuclei, such as [tʃ:], in which the obstruence maximum occurs simultaneously with the resonance maximum. In the first case, the resonance and obstruence envelopes (i.e. contours) are out of phase, whereas in the second case they are in phase. The difference between the two exponents is thus a distinction of phasing, which is part of the relation which mediates between phonological and phonetic representations (Coleman and Local 1987 forthcoming, Kelly and Local 1989). Deletion is not, and need not be, invoked.

Certain features of the stricture and resonance feature subsets will be specified for the entire mora. In most Japanese moras, some of the resonance features in particular, fall into this class (cf. 19). In order to capture generalizations that are pertinent both to the stricture and resonance phases of a mora, the features used here are adopted from Jakobson, Fant and Halle (1952). In the main, the customary articulatory and acoustic interpretations of these features have been retained, although the presumption of their segmental nature has not. Furthermore, the greater structural richness of the current phonological framework obviates the need for some of the traditional features.

By way of example, I shall now present and discuss the representation of the mora with exponents (variously) [tʃi]~[tʃ:].

The stricture feature [*cnt*] distinguishes partial from complete closure, or in other terms a long envelope from a short envelope. Long envelopes are characterised by the possibility of being freely extended, subject to respiratory restrictions. Short envelopes, on the other hand, may not be extended. A non-continuant has a duration, albeit very brief, which has a much lower maximum upper limit than that of continuants. Although even complete closure can be

freely maintained for relatively long periods, such articulations would in this analysis be characterised as continuants i.e. syllabic stops (cf. Hoard 1978).

The analysis of fricative nuclei rests on this interpretation of continuance. In the present example, [*cnt*] is used to distinguish the stricture phase of moras such as [tʃi] and [te] from [ʃi] and [se]. The set of resonance features is held to include [+*cnt*] by default. This is represented by a feature-specification default rule, FSD.

FSD: [*voc*] ⊃ [+*cnt*]

The feature [*grv*] has been retained as it was felt to be well-motivated in a number of respects (cf. Campbell 1972):

1. It expresses a close relationship between backness and labiality that cuts across traditional primary distinctions of vowel and consonant.
2. It captures the close relationship that holds between front vowels and palatal and palatalized consonants.
3. It expresses the distributional relationships between nongrave and grave tense fricatives in Japanese.

These three points are exemplified in the discussions above, and are illustrated by the group of Japanese moras that are traditionally analysed as /ha/, /hi/, /hu/. Omitting much detail, these may be represented phonetically as:

/ha/: [ha] grave stricture, grave resonance.

/hi/: [çi] nongrave stricture, nongrave resonance.

/hu/: [Φu] grave stricture, grave resonance.

'Labial' and 'anterior' articulation is further distinguished by the [*cmp*] (compactness) feature, 'labial' articulation being [−*cmp*];

'anterior' articulation, [+*cmp*]. Compactness is also used to differentiate 'open' resonance, which is [+*cmp*], from 'nonopen' resonance, which is [−*cmp*]. [ha] is thus grave and compact throughout, whereas [Φu] is grave and noncompact throughout.

The naturalness of the compactness opposition is supported by the fact that items with noncompact resonance must be distinctively specified for the feature [*grv*] (i.e. backness vs. frontness). Gravity is not distinctive with compact resonance (i.e. /a/). Compact resonance is redundantly specified with the gravity of the associated stricture; compare grave [ha] and [ka] with nongrave [sæ] and [tæ], all of which are compact throughout.[15] Likewise, diffuseness is not distinctive in nongrave stricture (e.g. /t/, /s/), but instead the diffuseness of nongrave strictures is that of the associated resonance. This constraint can be represented by value-sharing:

$$\begin{bmatrix} cns: & \begin{bmatrix} grv: \boxed{1} \end{bmatrix} \\ voc: & \begin{bmatrix} cmp: + \\ grv: \boxed{1} \end{bmatrix} \end{bmatrix}$$

A simplified representation of the mora traditionally analysed as /ti/ is presented in (26)[16]. This representation does not include any specification for phonation or nasality, since I am only concentrating on 'palatalization' and affrication at the moment. Compactness, diffuseness and gravity are specified for the entire mora. (This will not, of course, be the case for *all* moras.) Continuance is not specified among the resonance features, since it can be predicted from the FSD.

[15]To make his analysis more symmetrical, McCawley (1967) 'hypothesises' a gravity opposition in compact vowels, and then justifies the validity of his hypothesis with a discussion about the history of the Japanese vowel system. In the present study, attention to phonetic detail obviates McCawley's hypothesis Ironically, Keating and Huffman's (1984) study is so dependent on instrumental observation that this simple fact is not noticed.

[16]From here on, each example is complemented by an extensionally equivalent [feature: value] representation. The formal properties and principles of Unification Phonology will not be described however, other than through exemplification.

26) $$\begin{bmatrix} -grv \\ -cmp \\ +dif \end{bmatrix}_{|\iota|}$$

$$\begin{bmatrix} cns : \boxed{\iota} \\ -cnt \end{bmatrix} \qquad |voc|$$

Compactness, diffuseness and gravity are closely associated, and in some sense codependent, since they all relate articulatorily to the displacement of the tongue and lower jaw. Vocalicity and continuance, however, are of a different order, since they relate to articulatory envelope in a way that gravity, compactness and diffuseness do not.

I shall not discuss the interdependence of gravity, compactness and diffuseness, but I will state that both stricture and resonance are dependent on their common features. This is represented by their whole-mora status in (26). $|voc|$ and $|cns|$ are not temporally ordered: (27a) is exactly equivalent to (27b).

27a) b)

These graphs are equivalent representations of the feature-structure:

$$\begin{bmatrix} m : & \begin{bmatrix} cns \\ voc \end{bmatrix} \end{bmatrix}$$

In a phonetically interpreted theory of phonology however, not only must constituent structure be modelled, but so also must the

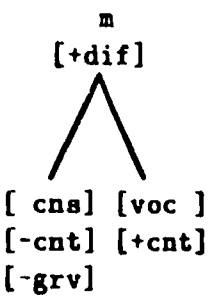
process by which unordered representations are 'given' temporal arrangement. This process can be seen to have a twofold aspect: rather than being simply the preparation of items for transmission along a single data stream, there are a number of parallel data streams. Ordering signals within individual streams is known as sequencing. The second aspect of queueing concerns the temporal relations, termed 'phasing relations', between signals in independent streams. Phasing relations determine coordination of the speech organs, and many disorders of speech production can be attributed to incorrectly acquired phasing. Unilinear catenative phonetics and phonology, which do not properly recognise phasing relations, are thus at a serious disadvantage regarding the diagnosis and rectification of such speech disorders.

Examples of ordering statements are (28) and (30). These include all that is needed to specify that a) in moras with both stricture and resonance phases, the stricture maximum never follows the resonance maximum, although it may precede and/or coincide with (i.e. co-start with) the resonance peak; and b) $\begin{bmatrix} -cnt \\ -grv \end{bmatrix}$ stricture is 'affricated' in $[+dif]$ moras.

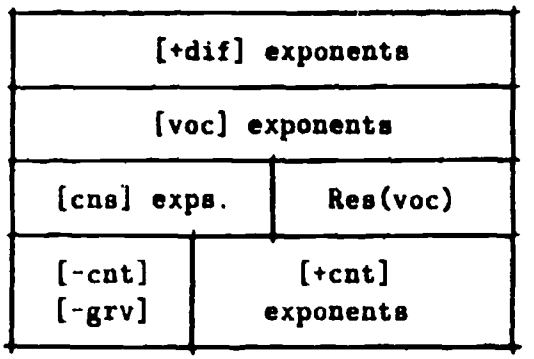
28) $[cns] \mathrel{|\!\!<} [voc]$ ($\mathrel{|\!\!<}$: 'co-starts with')

The temporal arrangement of the phonetic exponents of (29a), according to (28), is illustrated in (29b).

29a)



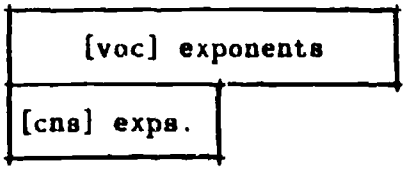
b)



Note that the nodes in (29a) are not linearly sequenced. This may seem odd, considering it is intended as a representation of a mora containing 'affrication'. But representing affrication in an unsequenced structure allows an explanation of the relationship between fricative-nucleus and vocalic-nucleus affricate-onset moras as a difference in phasing of the stricture and resonance envelopes. In vocalic nuclei, $[cns]$ costarts with $[voc]$ (i.e. $[cns] \rfloor\!\!< [voc]$), whereas for fricative nuclei $\begin{bmatrix} cns \\ -cnt \end{bmatrix}$ is coterminous (i.e. completely coincides) with $[voc]$ (30):

30) Phasing of stricture and resonance envelopes in affricated mora-onsets:

a) Vocalic nuclei: $[cns] \rfloor\!\!< [voc]$



b) Fricative nuclei: $[cns] \rightleftharpoons [voc]$ ('is coterminous with')

[voc] exponents
[cns] exponents

8 Concluding Remarks

Few of the components of the above analysis are new. For instance, in a short pedagogical exposition of Japanese pronunciation, Daniels (1958) made the following interesting observation:

> "consonants are said to be 'prefixed to' the vowels rather than to 'precede' them because ...in Japanese it is necessary to put the speech organs into the position for the vowel ...before producing the consonant — so far, that is to say, as it is possible to do this and still produce 'the consonant'. There is therefore more or less difference in almost all cases between the ways in which 'the same' consonant is produced when prefixed to different vowels."

The careful distinction which I have attempted to observe between the *order* of phonological units, their placement in structure, and physical *time* and *temporal sequence* in the phonetic interpretation of phonological representations derives directly from Firthian Prosodic Analysis. Carnochan (1957:158) spells out this distinction with particular clarity:

> It is perhaps appropriate to emphasize here that order and place in structure do not correlate with sequence in

> time, with reference to the experience of the text. The symbols with which a phonological structure is written appear on the page in a sequence; in $^{v}DE^{vh}B\partial^{g}ry$ (Example 1, Masculine), structure of *jefaffe*, the symbol h precedes the symbol B, but one must guard against the assumption that the exponent of the element of structure h precedes the exponent of the element of structure B, in time in the pronunciation of *jefaffe*. There is no time in structure, there is no sequence in structure; time and sequence are with reference to the utterance, order and place are with reference to structure.

In the same volume, Firth (1957:5) reminds us that

> In these structures, one recognizes the place and order of the categories. This, however, is very different from the successivity of bits and pieces in a unidirectional time sequence

and a footnote directs us, in Firth's characteristically erudite manner, to Aristotle's *Organon*, Chapter VI! Firth (1948) makes a similar observation about the prosodies of Chinese monosyllables, and the nondistinctiveness of the order of C and V elements in 'apanese:

> diacritica of the monosyllable are not considered as successive fractions or segments in any linear sense, or as distributed in separate measures of time.

A footnote to this statement refers to a paragraph from Joos (1948), which must have been published just before Firth's paper:

> In Japanese, if we neglect the geminates and the syllabic nasal, there is no structural significance in the order of

> phones in the typical syllable[17] *ka*. The typical syllable consists of a consonant (or zero) and a vowel, and these are always uttered in the order CV, but this order is of no consequence above the phonetic level. Correspondingly, the kana syllabary has a symbol which means *k* and also means *a*, but can be said to mean *ka* rather than *ak* only in consequence of the articulatory habit. ...And when a syllabary-keyboard Morse sender for radio telegraphy was designed for the Japanese armed forces, it is not surprising that it was built so as to send out the *a* signal of *ka* before the *k* signal: the order having no linguistic significance ...

Abstraction of features that pertain to complete phonological domains, rather than their distribution into individual segments, is a common principle of Firthian prosodic analysis (cf. Palmer 1970). The use of feature structures in prosodic analysis is novel, however, as is their interpretation.

Traditional Firthian prosodic analysis, although contributing much to the methodology of this study, suffers from a lack of uniformity in its formalism. Formulæ such as $^{\nu}\overline{TI}$, although intended to be noncatenative, still implicitly contain information about temporal order. 'T' and 'I', though not phonemic, nevertheless have catenative exponents. The same holds for structural templates of C and V units. Furthermore, 'T' and 'I' are still too obviously alphabetic for an analysis that claims to be completely abstract: they still call to mind 't' and 'i' more readily than, say, 'd' and 'u'. Most seriously, prosodic analysis offers no ready basis on which related and unrelated languages may be compared. And while it correctly recognizes the value of careful and detailed phonetic study, and only the utilitarian value of actual phonetic records, it largely failed to concern itself with the interface of phonology and speech production.

[17] Joos means the unit which I call "mora", of course

The relationship of transformational phonology to the psychological model of which it is supposedly a part has been similarly ambivalent. On the one hand, phonologists have concerned themselves with details of 'naturalness', 'formal expressive power', and so on, without much consideration of the physical phenomena which phonology attempts to model. So although in intent transformational phonology is a model of something that goes on in the brain, in most work there has been little or no mention of what mental processes or physical structures phonological theory models. Imagining surface phonetic representations to be not of physical events but of cognitive states — supposedly what a person 'knows' about the form of their speech — is highly pernicious, for in all works of transformational phonology, simple segmental phonetic 'records' of events are used to represent surface structure. This step has no justification; it's just that two meanings of 'surface' have been conveniently and systematically confused. On the one hand, 'surface' refers to cognitive states; on the other, to physical events. Although transformational phonologists rightly tackle the problem of characterising what speakers do and do not know about their language, it must also try to evaluate the status of phonologist's observational records in its methodology.

Unification phonology, on the other hand, has a number of distinct advantages. It has a relatively restrictive view of morphophonological organization: namely, there are two qualitatively different levels of representation, phonological and phonetic, related by an arbitrary mapping (denotation, or exponency). Phonological representations are structured, but unordered. The data discussed in this paper suggests that this position at least is exactly right. And formally-inclined phonologists can draw some comfort from the fact that the Unification formalism is computationaly tractable, mathematically elegant and extremely well-understood.

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