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SEGMENT SEQUENCES AND SEGMENTAL FUSION

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1. Segmental Discreteness

One of the most venerable and venerated postulates in the history of linguistics is the assertion that the speech continuum is capable of non-arbitrary division into a linearly ordered string of units, which, depending upon the topic under investigation, can be anything from phonetic segments to whole discourses. Such an approach was fundamental to American structuralism, with its strict separation of levels and its claim, since espoused also by British neo-Firthians, such as M. A. K. Halliday, that the units found at one level are comprised of sequences of units found at the next lower level. Postulating that phonological segments are linearly discrete, structuralists discussed the influence of adjacent segments upon each other, such as palatalization of velars before front vowels or labialization of consonants before rounded vowels, in terms of the distributional variants, or allophones of slightly more abstract phonemes. Only in one school was the segmental discreteness postulate, as I shall call it, challenged in any serious way. This was in the earlier work of Firth and his students, who claimed that the segment could not be described as an element by itself, but only as a part of some larger structure, such as the syllable, word, or group.[1] Firth did not hesitate to claim, for instance, that the notion of positional variant obscured the fact that the set of segments that can occur syllable-finally may be of a totally different nature from what can occur elsewhere in the syllable.

An example of this is the status of the stop found after initial s in English, which most structuralist analyses of English have regarded as an unaspirated allophone of the voiceless stop series. An equally plausible analysis would treat it as an allophone of the voiced stop series. Since English voiced stops are fully voiced only if found

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[1] The Firthian notion 'group' corresponds vaguely to the structural notion 'major constituent'.

between voiced segments and are otherwise simply lax consonants, an analysis like this could go even further and say that the important contrast between the two sets of stops is not voicing, but tenseness. What are generally regarded as voiceless stops are in fact tense stops and what are regarded as voiced stops are lax consonants which become voiced between voiced segments by assimilation. The difference between word-initial lax stops, with their very slight voicing, and post-sibilant lax stops, is certainly no greater than that between aspirated and unaspirated voiceless stops, and so the two analyses would seem equally valid. Under a Firthian analysis this problem would simply not arise, since the set of consonants found in post-sibilant position would be considered a formally distinct class of segments unrelated phonologically to the segment classes found in other canonical positions.[2]

More recently, the segmental discreteness postulate has been given formal treatment and has been made the very center of phonological and phonetic analysis in generative phonology, where even the form of phonological rules forces the linguist to think in terms of segments, rather than in terms of other, perhaps suprasegmental, units. The segmental discreteness postulate works impressively well for a large number of phonological problems, a typical case being the standard analysis of the homorganic nasal consonant assimilations found in many languages. In Yoruba, for example, the continuous aspect marker ń is prefixed to the verb stem, abutting on a consonant. The ń then becomes homorganic to the consonant, as shown below:

(1)	ń + bọ̀	→	ḿbọ̀	'coming'
	ń + fì	→	ŋ́fì	'taking'
	ń + tà	→	ńtà	'selling'
	ń + jà	→	ɲ́jà	'fighting'
	ń + ge	→	ŋ́ge	'cutting'

[2]For a further exposition of Firth's approach to phonology see Palmer [1970]. Palmer's collection includes several important papers done within the Firthian tradition, including a paper by Robins which is an excellent summary statement of prosodic theory.

The rule for this assimilation can be stated quite generally as in (2):

(2) $$\begin{bmatrix}-\text{vocalic}\\+\text{nasal}\end{bmatrix} \rightarrow \begin{bmatrix}\alpha\text{anterior}\\ \beta\text{coronal}\\ \gamma\text{high}\\ \delta\text{back}\end{bmatrix} / \_\_\_\_ \begin{bmatrix}\alpha\text{anterior}\\ \beta\text{coronal}\\ \gamma\text{high}\\ \delta\text{back}\end{bmatrix}$$

2. Non-discreteness in Accentual Phonology

The possibility that there are some phonological phenomena which do not yield to a strictly segmental treatment has rarely been raised and then only with reference to so-called supra-segmental phonology. That is, with reference to the analysis of accentual systems. Consider, for example, the data presented by Woo [1969:16-17] on Bambara accent. Woo claims that Bambara lexical items can be analyzed into two accentual classes, high-toned (3a) and low-toned (3b).

(3)

a. High-toned class		b. Low-toned class	
yɾɾ	'tree'	mùsò	'woman'
mángòró	'mango'	nyɪ̀màn	'good'
fɪnmán	'black'		

Phrases consisting of a noun and one or more adjectives have high tone on all syllables of the last word. All other words take the tone of the noun, the first word, on all syllables. This generalization also applies to the low tone found on the second syllable of mángòró. The following examples illustrate this:

(4)

mángòró nyɪ̀màn →	mángóró nyɪmán	'good mango'
mùsò nyɪ̀màn →	mùsò nyɪmán	'good woman'
mùsò fɪnmán nyɪ̀màn →	mùsò fɪ̀nmàn nyɪmán	'good black woman'
yɾɾ fɪnmán nyɪ̀màn →	yɾɾ fɪnmán nyɪmán	'good black tree'

The evidence from Japanese is similar. A lexical item in Japanese is specified in the lexicon as having accent on any one mora or as being unaccented. According to Woo [1969:5-6], whose discussion is based on McCawley [1968], pitch is assigned to a word on the basis of accent. Her generalization is that "excepting the first syllable, which is low-toned unless accented, all syllables preceding and including the accented syllable are high-toned, and all syllables following the accented

syllable are low toned" [Woo 1969:6]. This is illustrated below, where accent is indicated by a double apostrophe over the vowel of the accented syllable:

(5)	mɪyako	→	mɪ̀yákó	'city'	(Japanese)
	atamä̋	→	àtámá	'head'	
	kokö̋ro	→	kòkórò	'heart'	
	kä̋buto	→	kábùtò	'helmet'	

In certain types of phrase, as illustrated in (6), the tone pattern does not correlate directly with lexical accent, because all accents in the phrase except the first are deleted.

(6)	mɪyako dö̋su	→	mɪ̀yákó désù	'It's a city.'
	atamä̋ dö̋su	→	àtámá dèsù	'It's a head.'
	atamä̋ dä̋r tä̋ru	→	àtámá dàttàrù	'If it were a head...'

Thus in Japanese and Bambara there are rules which effect the entire accentual pattern of the word. These rules can be written segmentally, using one of several possible conventions for indicating that all phonological material except accent is to be ignored, or they can be written in terms of lexical items, deleting or neutralizing accentual features of whole morphemes.

That these are not segmental, but rather morphological or string processes is illustrated by data from Mende [Spears 1967]. Mende has six possible tone sequences or contours on the lexical item, regardless of the length of the item. Thus a falling contour can have the following realizations:

(7)	bâ	'price'
	fóò	'year'
	kálɪ̀	'hoe'
	fólāmà	'junction'

In certain noun compounds and noun-adjective constructions, the second element loses its tone pattern entirely, becoming non-high throughout. If the first element has a final high tone, the first syllable or noun

of the second element assimilates to it. Final rising and falling tones on the first element are then simplified to low and high tones, respectively:

(8)	bɛ̀lɛ̀ nǐná	'new pants'	→	bɛ̀lɛ̀ nǐnà
	pùndʃǐ nyámú	'ugly mosquito'	→	pùndʃ nyàmù
	ndòmàá nyàndèé	'beautiful shirt'	→	ndòmà nyándèè
	pɛ́lɛ́ pàndà	'good house'	→	pɛ́lɛ́ pándà

The assimilation of the first low-toned mora of the second element is a segmental process, but to describe the tone-pattern neutralization, which has syntactic rather than phonological conditioning, as a segmental process misses the atomic nature of the tone pattern. The pattern functions as a unit, not as a sequence of tone-bearing segments.

3. Non-discreteness in Segmental Phonology

Accentual phenomena such as those discussed above do not constitute clear difficulties for current theories of phonology.[3] Discussions of segmental phonology have noted similar phenomena in vowel harmony. Lightner [1965] treats Classical Mongolian vowel harmony as a morpheme feature. Prosodic phonologists have treated such disparate phenomena as nasalization and retroflexion as functions of units ranging from the syllable to the word group, but in every one of these cases the long component, to use Harris' [1944] term, is coterminus with some structural unit. A number of formalisms exist for handling features of such structural units, and they will not be discussed here. The relevant cases are those in which segments which are a part of some formative or adjacent parts of distinct formatives behave in a way which requires a 'false step' analysis [Zwicky 1973]. Such a case is French vowel nasalization. The standard analyses of French nasalization require something like the following two rules [Schane 1973]:

(9) a. $V \rightarrow [+\text{nasal}] \; / \; \underline{\quad} \begin{bmatrix} C \\ +\text{nasal} \end{bmatrix} ([-\text{segment}]) \begin{Bmatrix} C \\ \# \end{Bmatrix}$

[3] See Leben [1973] for extensive discussion of the representation of tone.

(|| = pause boundary)

b. $\begin{bmatrix} C \\ +nas \end{bmatrix}$ $\quad \emptyset \; / \; \_\_\_ \; ([-segment]) \; \begin{Bmatrix} C \\ \|\| \end{Bmatrix}$

These rules are functionally coupled in a way which has not been formalized, but (9b), a supposedly independently motivated rule, applies only to the output of (9a), since all nasalized vowels in French arise from (9a). Thus (9a) creates a form which is not possible in French, a nasalized vowel followed by a nasal consonant. (9b) is needed to correct this false step. In effect (9) represents a special type of global rule application: (9a) can apply only if (9b) also applies. What actually obtains in French is an alternation between nasalized vowels and oral vowel + nasal consonant sequences. There is no evidence either for nasal assimilation or for nasal consonant deletion. Rather, two adjacent segments fuse into one segment sharing some properties of both. Such an alternation cannot be captured with existing phonological apparatus without a false step analysis.

3.1 Root-final palatals in Tswana. Another such case is the analysis of root-final palatals in Tswana, a Southern Bantu language.[4] Tswana forms the passive and causative verb stems by adding the suffix, or extension, -ǀwa (passive) and -ǀsa or -ya (causative) to the root, as in (10):

(10)	-aga	'build'	-agǀwa	'be built'
	-bôntsha	'show'	-bôntshǀwa	'be shown'
	-ôkêtsa	'add to'	-ôkêdǀwa	'be added to'
	-bua	'speak'	-buǀwa	'be spoken'

In many cases two forms are possible: a form in which the full suffix is present, as in (10), and also a form in which the ǀ has been deleted, as in (11):

[4] The data for this discussion are from Cole [1955]. The problem was brought to my attention by Gerard Dalgish, a graduate student at the University of Illinois.

(11) -bôniwa/-bônwa 'be seen'
-ratiwa/-ratwa 'be loved'
-rokiwa/-rokwa 'be sewn'
-agiwa/-agwa 'be built'

Stems which have final labials also permit the two forms, but in addition, the labial becomes a palatal if the i deletes:

(12)

-bopa	'mould'	-bopiwa/-botšwa	'be moulded'
-gapa	'plunder'	-gapiwa/-gatšwa	'be plundered'
-tihaba	'stab'	-tihabiwa/-tihajwa	'be stabbed'
-rôba	'break'	-rôbiwa/-rôjwa	'be broken'
-bôfa	'bind'	-bôfiwa/-bôšwa	'be bound'
-iefa	'pay'	-iefiwa/-ešwa	'be paid'

The alternation in (12) could be described by an analysis which palatalizes labials and then deletes the i. Thus we would have derivations like the following:

(13) bop + iwa
botš + iwa palatalization
botš + wa i deletion

Such an analysis would seem to make use of the i-deletion rule which the grammar must have anyway, to account for the forms in (11).

There are, however, some uncomfortable consequences associated with this sort of analysis. First of all, the palatalization rule is about as unnatural a rule as can be imagined. Not only can it not involve assimilation, since there is no articulatory resemblance between labial consonants and palatal vowels, but in just those cases where we would most expect to find articulatory assimilation, that is, with alveolars and velars, there is no palatalization. Thus the palatalization rule is exactly the inverse of what one would expect a palatalization rule to be, palatalizing labials but not palatalizing articulatorily adjacent segments. A further problem with the analysis represented by (13) is

that l-deletion, normally an optional rule,[5] is obligatory just if palatalization has applied. It cannot be made obligatory just after labials, because as shown in (12), pl, bl, and fl sequences are all possible. The rules of palatalization and l-deletion must, then, be coupled in some way. This can be done by noting in the grammar that they are conjunctively ordered, even though they are not collapsible, or by writing a single transformational rule which would handle the two processes simultaneously, as in (14):

(14)

$$\text{SD: } X \begin{bmatrix} +\text{obstruent} \\ +\text{anterior} \\ -\text{coronal} \end{bmatrix} + \begin{bmatrix} -\text{obstruent} \\ +\text{high} \\ -\text{back} \end{bmatrix} Y$$

$$\qquad 1 \qquad\quad 2 \qquad\quad 3 \qquad\quad 4 \qquad\quad 5$$

$$\text{SC: } 1 \begin{bmatrix} +\text{obstruent} \\ -\text{anterior} \\ +\text{coronal} \\ +\text{high} \end{bmatrix} 5$$

But (14), on the other hand, is redundant in that it incorporates the independently motivated rule of l-deletion.

Having to choose between these analyses would be neither easy nor pleasant, but fortunately there are further data which render such a choice unnecessary. The causative stem is formed by adding the suffix -ya or -lsa to the verb root:

(15)	-tshêga	'laugh'	-tshêglsa	'cause to laugh'
	-loga	'knit'	-logisa	'cause to knit'
	-fêna	'succumb'	-fênya	'overcome'
	-lekana	'be equal'	-lekanya	'make equal'

Stems ending in -f may also take either ending, but if the ending is -ya, the resulting forms are as shown in (16):

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[5] In fact, Cole [1955:192] claims that normally the deleted form is preferred. Only in two-syllable, vowel-initial roots is the l normally not deleted.

(16)	-lêofa	'sin'	-lêotšhwa	'cause to sin'[6]
	-tlhalefa	'become wise'	-tlhaletšhwa	'make wise'
	-natefa	'be nice'	-natetšhwa	'make nice'

These forms, which have labialization in the causative although the causative suffix does not contain a labial, raise the question of what the source is of the labialization in palatalized root-final labial consonants. The only possible source in (16) is the f itself, which fuses completely with the y to produce the segment tšhw[7] with the features [-obstruent, +coronal, +anterior, +round, +tense, +strident, -continuant]. Such segments represent a compromise between the articulatory properties[8] of the two segments which have fused, as illustrated below:

(17)						
	a.	p	+	l	=	tšw
		voiceless labial unaspirated stop		high palatal vowel		voiceless labialized palatal affricate
	b.	ph	+	l	=	tšhw
		voiceless labial aspirated stop		high palatal vowel		voiceless labialized aspirated palatal affricate

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[6] Cole [1955:205] notes that in many cases the w seems to be disappearing, but he argues that the forms with the w are definitely older than those without.

[7] I don't know why fy produces the affricate tšhw and fl the fricative šw. It could be due to the greater closure of y over against that of l, but this is only a guess.

[8] I have avoided the use of distinctive features of any variety for fairly obvious reasons. Basically they involve the facts that no current feature framework allows labials and rounded segments or aspirated consonants and fricatives to be treated as a natural class. As the data and discussion show, both claims are necessary. To avoid having to revise a feature framework on the spot, I have opted for the use of more traditional articulatory description.

c.	b	+	ɪ	=	dž^w
	voiced labial stop		high palatal vowel		voiced labialized palatal affricate
d.	f	+	ɪ	=	š^w
	voiceless labial fricative		high palatal vowel		voiceless labialized palatal fricative
e.	f	+	y	=	tšh^w
	voiceless labial fricative		palatal semi-vowel		voiceless aspirated labialized palatal affricate

The fusion in (17e) is what is found in the causative forms, where, in the absence of any w, labialization occurs and can only be attributed to f maintaining its labiality even after fusion produces a palatal. The analogous fusions in (17a-d) represent the processes involved in the passive verb forms. The fused form will, of course, have the w of the wa suffix following the p + ɪ fusion at some point in the derivation, but it cannot be claimed that the w of botšwa must represent the suffix. Just as strong a case exists for attributing it to the p, just as the causative fusion in natetšhwa gets its w from the f. The w of wa, may then be deleted after a labialized consonant. In fact, Cole [1955:34] notes that "...labialization of labial consonants is not permissible in the sound structure of Tswana." This would block sequences of labialized consonant plus w too.

(17b) and (17e) are an interesting pair in the way that aspiration is treated. In both cases the fused form is tšhwa, arising in (17b) from phiwa and in (17e) from fya. The source of aspiration in (17b) is obvious. The form contrasts with an unaspirated piwa in that the latter fuses to unaspirated tšwa, and so the aspiration must be due to the fact that phiwa is aspirated. In (17e) the only possible source for the aspiration is the fact that the unfused form contains an f, and

the aspiration is a reflection of that. The occurrence of aspiration in fusions involving a fricative will be discussed further below.

The palatalizations illustrated in (17) are also found in the diminutive forms of nouns, formed by adding the suffix -ana/-ane to the noun stem. Historically this suffix began with a palatal glide y or a palatalized velar fricative γ^{y}, and the historical palatal remains evident in the alternations of labials and palatals illustrated in (18). These alternations are identical to those represented in (17), including the alternation of fy with tšhw:

(18)	kolobê	'pig'	kolojwane	'piglet'
	tsêbê	'ear'	tsêjwana	'sm. ear'
	kobô	'cloak'	kojwana	'sm. cloak'
	tshipi	'iron'	tshitšwana	'sm. piece of iron'
	mogopô	'bowl'	mogotšwana	'sm. bowl'
	lesapô	'bone'	lesatšwana	'sm. bone'
	tsêphê	'springbok'	tshetšhwana	'springbok kid'
	marôphi	'blisters'	marôtšhwana	'sm. blisters'
	gaufi	'nearby'	gautšhwane	'fairly nearby'
	sefêfu	'blind person'	sefôtšhwana	'lt. blind person'
	phôfu	'eland'	phôtšhwana	'young eland'

As in the causative (16) there is no labial glide present anywhere in the environment, and so the labialization must again be attributed to the original labial obstruent.

To summarize this discussion of the data from Tswana, I will stress the following points. Certain palatals arise in ways which do not suggest natural assimilation rules. That is, labials palatalize, but neither coronal nor back consonants do so. Palatalization always involves the deletion of the vowel or glide which conditions it. In all cases the palatal consonant which results is labialized, but this labialization is not always attributable to a following w, as it is in the passive. In some cases it is the labial itself which must be posited as the source for the labialization. Finally, the resulting palatal may also

be aspirated if it is a non-continuant and derived from an aspirated or fricative consonant. This then suggests that the palatalization does not represent an assimilatory process, but rather the merger or fusion of two segments so that certain distinctive articulatory properties of both original segments are still present.

3.2 Voiceless nasals in Yatye. Another synchronic alternation can be found in the contraction phenomena of Yatye.[9] When a CV verb is followed by a consonant initial noun or adverb, the final vowel of the verb deletes, resulting in a consonant cluster. If the initial consonant of the verb is a voiceless non-strident fricative and the initial consonant of the noun or adverb is a nasal, the two merge into a voiceless nasal with the same point of articulation as the original nasal. Otherwise the nasal assimilates in voicing to the initial consonant of the verb.

(19)

agù mònà	→	agmònà	ahyẹ̀ me	→	àm̥e
akpá mòsì	→	akpm̥ósì	apú mànyì	→	am̥wáànyì
ahyẹ̀ nâ	→	àn̥â			

The first two examples in (19) suggest that Yatye has an independently motivated rule of nasal voicing assimilation. The data would then lend themselves to an analysis in which voicing assimilation would be followed by consonant deletion. However, there is no independent evidence of such consonant deletion, and that rule would apply only to the output of voicing assimilation. The last form in (19) disconfirms such a solution, since the labiality of p is preserved as labialization of the fused segment. The labialization cannot be derived from the u, since labialization would then be expected in agmònà as well.

3.3 Vowel coalescence in Ọwọn Afa. Ọwọn Afa is a dialect of Yoruba in which verb-nominal sequences contract according to regular phonological rules [Awobuluyi 1972], unlike the highly irregular contractions of Standard Yoruba. In some cases the final vowel of the verb deletes, and

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[9] Yatye is a Kwa language spoken by about 20,000 people in the Benue-Plateau and Southeast States of Nigeria. The data are from my own field work in 1965-1967.

in others the vowel of the verb assimilates to the initial vowel of the noun. The cases relevant to the problem of fusion are those in which the final vowel of the verb is non-high, e, ɛ, a, ɔ, or o, and the initial vowel of the noun is non-covered, ɪ, e, o or u. The following fusions occur:

(20)

a.	a + ɪ	→	ɛ	
	dà ɪwé	→	dɛ̀wé́	'buy book'
b.	a + e	→	ɛ	
	dà ehwe	→	dɛhwe	'buy house'
c.	a + u	→	ɔ	
	dà ùʃù	→	dɔ̀ʃù	'buy pounded yam'
d.	a + o	→	ɔ	
	dà ópú	→	dɔ̀ɔ́pú[10]	'buy dog'
e.	ɛ + u	→	ɔ	
	tɛ̀ ùʃù	→	tɔʃù	'step on pounded yam'
f.	ɛ + o	→	ɔ	
	tɛ̀ ópú	→	tɔ̀ɔ́pú[10]	'step on dog'
g.	ɔ + ɪ	→	ɛ	
	dɔ̀ ɪwé	→	dɛ̀wé́	'burn books'
h.	ɔ + e	→	ɛ	
	dɔ̀ ehwe	→	dɛhwe	'burn houses
i.	e + u	→	o	
	bè ùʃù	→	bòʃù	'look for pounded yam'
j.	o + ɪ	→	e	
	gò ɪwé	→	gèwé́	'look at book'

These fusions can be captured by the following transformational rule:

(21)

$$\begin{bmatrix} V \\ -high \\ \alpha covered \end{bmatrix} \begin{bmatrix} V \\ -covered \\ \beta back \\ \gamma round \end{bmatrix} \rightarrow \begin{bmatrix} V \\ -high \\ -low \\ \alpha covered \\ \beta back \\ \gamma round \end{bmatrix}$$

[10] The vowel length is from the LH tone sequence and is not the result of simple assimilation. Awobuluyi does not comment on his use of two segments here to show a rising tone.

That is, the segment resulting from the fusion is a mid vowel with the coveredness of the first vowel and the backness and roundness of the second vowel. It is a compromise between the two original vowels.

Assimilatory alternatives to (21) are possible. For example one could assimilate the second vowel in tongue height and coveredness to the first vowel and then delete the first vowel.

(22) a. $\begin{bmatrix} V \\ -covered \end{bmatrix} \rightarrow \begin{bmatrix} -high \\ \alpha covered \end{bmatrix} / \begin{bmatrix} V \\ -high \\ \alpha covered \end{bmatrix} \#\ \_\_$

b. $\begin{bmatrix} V \\ -high \end{bmatrix} \rightarrow \emptyset / \_\_\ \# \begin{bmatrix} V \\ -high \\ -low \end{bmatrix}$

This analysis seems well-motivated, since Awobuluyi gives numerous other forms in which assimilation occurs, and there are also cases where a vowel is deleted. However, all other assimilations are complete, not partial, and all but a well-defined subset of cases involve the assimilation of the first vowel to the second, rather than as in (22a). If (22a) were replaced with a rule which assimilated the first vowel to the second, in keeping with the general nature of vowel assimilation in Ọwọn Afa, it would then be necessary to rewrite (22b) to delete the second vowel. This would be unnatural in Ọwọn Afa, since under no other conditions does the second vowel delete. Thus neither segmental treatment of the data is without serious difficulties. The fusion analysis is clearly superior since it avoids these difficulties.

4. Diachronic Evidence for Fusion

The Tswana and Yatye data presented above show cases of active synchronic alternations which can best be described as segmental mergers or fusions. There are also examples of diachronic fusions, typical examples of which may be the fate of the PIE labio-velars in Greek, and in Latin of the PIE aspirates.

(23)	PIE	Greek	Latin	
	*kw	hippos	equus	'horse'
		poteros	quod	'which'

*gw	baino	venio	'come'
	bos	_____	'cow' cf. Skt. gauḥ
*bh	phrator	frater	'brother'
	phero	fero	'bear'
*dh	tithemi	facio	'do'
	eruthros	rufus	'red'
*gwh	_____	formus	'warm' cf. Pers. garm
	phonos	defendo	'strike' cf. Skt. hanti

A case of diachronic fusion which is directly analogous to the Tswana data is the correspondence sets involving labialized palatals in several Yatye dialects.[11] Where Alifokpa has the labialized palatals cw, jw, and njw, Akweya has strengthened the labialization to f or v and Ijiegu has changed the labialized palatals to the palatalized py, by, and mby.

(24)

Alifokpa	Akweya	Ijiegu	
ʃcwɛndè	ʃcfɛndè	ʃpyɛndè	'pot'
ecwú	ecfú	epyú	'head'
jwú	jvú	byú	'drink'
ɪnjwʃ	ɪnjvʃ	ɪmbyʃ	'germinate'

5. Evidence From Child Language Acquisition

A third type of evidence that speakers can treat segment sequences as units comes from child language acquisition. The subject was Aaron, age 36 months. At the time he was producing some unusual substitutes for initial s + nasal clusters. After going through the stages many children seem to pass through as illustrated below in (25), Aaron then entered a stage represented in (26).

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[11]The Alifokpa and Ijiegu dialects are separated only by a river, and they are mutually intelligible. Akweya is separated from them by about sixty miles and a hundred and seventy years, dating from the Fulani jihad of 1804.

(25)

30 months	34 months	
mok	m̥mok	'smoke'
mayo	m̥mayo	'smile'
mæntʌ	m̥mæntʌ	'Samantha'
nek	n̥nek	'snake
no	n̥no	'snow'
nupi	n̥nupi	'Snoopy'

(26)

36 months	
p^hõk	'smoke'
p^hãỹõ	'smile'
p^hãntʌ	'Samantha'
t^hẽk	'snake'
t^hõ	'snow'
t^hũpi	'Snoopy'

By the age of approximately 38 months Aaron has mastered the s + nasal cluster, but what is interesting is what he was doing up to that time.

At 30 months the sm and sn clusters were produced simply as nasals. At 34 months the initial voiceless fricative began to show up as a devoicing of the first part of the nasal. At 36 months he had, in effect, mastered the cluster, but what he did, as illustrated in (26), was merge or fuse the two consonants into a single unit showing the distinctive articulatory properties of both the s and the nasal.

(27)

a.	s	+	m	=	p^h
	voiceless fricative		labial nasal		aspirated voiceless labial stop
b.	s	+	n	=	t^h
	voiceless fricative		alveolar nasal		voiceless aspirated alveolar stop

The fusion combines the oral closure of the nasal with the voicelessness and obstruency of the s to produce a stop homorganic with the original

nasal. Just as in Tswana, the original fricative shows up as aspiration in the fusion. The nasality, as shown in (26) is moved over to the vowel. The important point is that all of the essential phonetic information is present in the 36 month forms. It has simply been restructured and redistributed. A similar merger common in child language is the fusion of initial tr to f or fw. Phonetically English tr becomes an aspirated labialized prepalatal affricate. The fw sequence treats the aspiration and friction of the original cluster as an f, retaining the original labialization.[12]

6. The Inadequacy of a Rule Ordering Solution

There appear to be certain phonological processes in natural language which cannot be stated by segmental rules without serious formal difficulties. Data of the type discussed above strongly suggest that phonological theory requires a formal notion of string operation analogous to grammatical transformations, in addition to the well-developed formalism for segmental rules. Such a formal addition defines a class of phenomena in which two adjacent segments are replaced by a single segment sharing some features of each. If described segmentally, two rules are required. One of these defines an assimilation of one segment to the other if and only if the second rule deletes the conditioning segment after the assimilation rule has applied. The synchronic alternations in Tswana, Yatye, French, and Ọwọn Afa illustrate this. In Tswana, the labial palatalization rule can apply only if the i or y is doomed to deletion. i-deletion is optional otherwise, and there is no independent motivation for y-deletion. Thus the disappearance of the i and y after palatalization is due to some other factor than i-deletion. Even if i or y deletion could be motivated here, the problem would exist that palatalization could apply only if the deletion rule would follow it. That is, palatalization would be a global, look-ahead rule. This analysis, however, fails on independent grounds since it cannot account for the labialization which is found after

[12]This fusion was the source of occasional consternation when Aaron would ask his nursery teacher for a truck.

palatalization. There simply is no source for the w, unless the labialized palatal is regarded as the fusion of a labial and a palatal. In the Yatye data, exactly the same formal situation obtains. If a voiceless non-strident fricative abuts on a nasal, the result is a voiceless nasal. Segmentally this could be handled by first devoicing the nasal and then deleting the fricative. But there is no independent motivation for the fricative deletion rule, and the devoicing rule would have to look ahead to see that the fricative does delete. Once again, the segmental analysis, which requires a forward looking global ordering, is inadequate because it fails to account for the labialization of forms like am̥wáànyì in (19). This property can be traced directly back to the bilabial fricative in the string which fused to produce the voiceless nasal, but it cannot be explained under the segmental discreteness postulate.

French nasalization has been a problem for generative phonologists precisely because of the feeding relation between nasalization and nasal deletion, and because of the relative simplicity of the data it has been difficult to motivate one or another analysis. The segmental fusion phenomena I have described show that for certain purposes natural language may treat segment sequences as units. The cases susceptible to a fusion analysis contain as a subset cases which can also take a particular type of global analysis, namely that involving look-ahead rules, but the fusion phenomenon may also involve changes, such as the labialization of the derived segment in Tswana and Yatye, which are not naturally explainable by the global analysis. Therefore if the fusion phenomenon is well motivated, then this class of look-ahead global rules must be disallowed by the metatheory. By restricting the metatheory in this way it becomes possible to choose one of the possible analyses for problems such as French nasalization as preferred, namely, the fusion analysis.

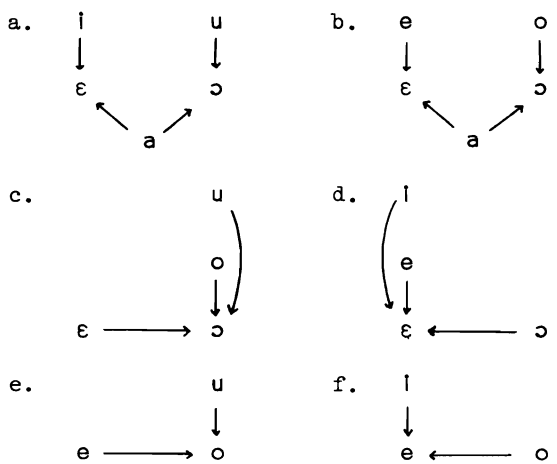
7. On the Nature of the Fused Segment

One important question remains to be dealt with: the difficult matter of predicting what features the fusion will retain from the original segments. The cases which have been examined suggest several possible

generalizations. In French a vowel and a nasal fuse to a nasalized vowel. That is, the vowel takes on what might be considered, for reasons that are difficult to state formally, the most prominent feature of the consonant--its nasality. Changes in vowel quality in French defy explanation, but the fused segment is in an obvious way a compromise between the original segments, exhibiting the major class feature of the vowel as well as the most striking feature of the consonant. In a variety of other languages it can be shown that vowel nasalization arises from a NV segment rather than from a VN sequence, as in French. Hyman [1972] argues this convincingly for Gwari and Williamson [1973] demonstrates it for Ijọ. The obvious prediction is that a vowel and a nasal will fuse to a nasalized vowel, regardless of the original order of segments.

In the Ọwọn Afa case, the original segments are both vowels. That is, they share the same major class features. The fused segment is again a compromise, but the type of compromise is clearer than in the case of nasalized vowels, as the following charts show.

(28)



Whether the fusion is described in terms of features, as in (21) or in terms of tongue position, as in the charts above, the fused segment is always that vowel in the seven vowel system of Ọwọn Afa that most nearly represents the mid point between the two original vowels. It is clear,

then, why sequences that differ by only one position do not fuse. i and u have no compromise vowel in the system. Ọwọn Afa has no ü or ɨ. Similarly a can fuse with neither ɛ nor ɔ, since it is adjacent to each. There must be at least two significant differences between the vowels for fusion to be possible.

In a sense the voiceless nasals in Yatye are a similar case. Both original segments are consonants. That is, they are both [+consonant, -vocalic]. While they differ as to [continuant] and [sonorant], they both allow an uninterrupted flow of air through the vocal tract. The compromise segment is also [+consonant, -vocalic] and shares the [-voiced] of the fricative and the point of articulation of the nasal. The child language data are similar, in this case the voicelessness and velic closure of the s changing the nasal into the corresponding voiceless stop. The continuantness of the s is preserved in the aspiration of the stop, although a feature representation would not show this clearly.

Two interesting cases are Tswana and Indo-European. In these cases the original segments differ radically. A labial consonant and a high front vowel or glide are about as distinct from each other as two segments can be, but the fused form in Tswana is still a clear compromise sharing the voicing and major class features of the consonant and the tongue position of the vowel. The Indo-European data are similar. If the labial-velars can be interpreted as segment sequences then kw → p represents a fusion nearly identical to that in Tswana palatals. The Latin f, coming from various aspirates in PIE shows the reverse of the sort of fusion Aaron employed in treating the continuantness of s as aspiration. Instead, the aspiration shows up as a voiceless continuant.

A general fusion schema apparently cannot be stated in terms of binary features. Rather, a scale of sonority is needed. At the one end of this scale are stop consonants and at the other are vowels. A partial scale would be something like the following,[13] using only the segment types exemplified in the data above:

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[13]Scales of this sort have been proposed elsewhere in the literature, for example, Sadock [no date], Zwicky [1972], and Foley [1969].

(29) stops
fricatives
nasals
glides
vowels

A fusion of two members of different classes on this scale moves in the direction of greater or less sonority, depending on which segment is closer to one of the poles. This will account for VN and NV sequences becoming nasalized vowels, since vowels are at a pole and nasals are not. It will also account for stop plus glide fusing to a stop, but it will not account for stop plus vowel fusing to a stop or for voiceless fricative plus nasal fusing to a voiceless nasal or a voiceless stop, although both are reasonable compromises.

Other factors seem to be relevant. First of all, voicelessness is a dominant feature. If one of the two segments is voiceless, the fusion is invariably voiceless. The absence of the voiceless nasal in Aaron's speech may be due to the highly marked nature of this segment in child language, as compared with the more natural voiced stop. Point of articulation is also sensitive to the sonority scale. In all cases the surviving point of articulation in the fusion is that of the more sonorous member of the pair. This generalization does not, however, account for all of the sources of Latin f. The cases in which Latin f arises from a PIE labial-velar are predicted, the f taking the point of articulation of the labial component. In all other cases it seems to be the aspiration which is maintained in the voiceless f. If one can generalize from the phonetic property of aspiration to a property of voiceless friction, then it appears that voiceless friction will be consistently maintained. The alternations reported above between aspirates and fricatives suggest that voiceless friction is a linguistically significant phonetic property, since aspirates and fricatives do appear to behave as a natural class. Interestingly enough, the one PIE aspirate which does not become f in Latin is *gwh, which becomes h.

Postscript

After the revised draft of this paper was finished, Hankamer and Aissen [1974] came to my attention. To account for certain alternations

in Pali, they propose a scale or hierarchy of sonority as follows:

stops s nasals l v y r vowels

Examination of Hungarian data leads them to suggest that fricatives generally behave like s and that the ranking of glides and liquids relative to each other is language-specific. Among the phenomena which they suggest are influenced by the sonority hierarchy are syllable structure, syllabicity, the determination of natural classes, phonological change, variability, and assimilation. On the basis of the data presented in this paper, fusion must be added to that list.

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