Studies in the Linguistic Sciences
Volume 27, Number 1 (Spring 1997)

A PHONOLOGY-PHONETICS MISMATCH: [VOICE] IN CONSONANT-TONE INTERACTION*

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Consonant-tone interaction is a phonological effect in which voiced obstruents trigger the insertion of L or block the spread of H. Phonetically, both voiceless obstruents and voiced obstruents have an effect on the fundamental frequency of the following vowel. Voiceless obstruents cause a fall in pitch from a high frequency, while voiced obstruents cause a rise in pitch from a low frequency. It would be expected, based on the phonetic findings, that voiceless obstruent effects are phonologized to the same extent or to a greater extent than voiced obstruent effects. This is, in fact, not the case. Instead voiced obstruent effects are phonologized exclusively. This is attributed to the presence of a privative feature [voice] for which voiceless obstruents are not specified. Thus, a phonological entity precludes the realization of a phonetic phenomenon in this case. This mismatch between the phonetics and the phonology suggests that there is a significant degree of independence between the two components.

1. Introduction

There is a mismatch between predictions based on phonetic studies and those based on phonological theory in the case of consonant-tone interaction. Because of the existence of the privative feature [voice], the consonant-tone interaction that is phonologized crosslinguistically involves only voiced obstruents. However, phonetic studies of the effects of consonants on pitch lead to the incorrect prediction that other consonants besides voiced obstruents will also be involved in consonant-tone interaction.

The patterning of the interaction between consonant and pitch at the phonetic level is different from the patterning of consonant and tone at the phonological level. Extrapolating from observations at the phonetic level, there are at least 2 phonetically driven predictions that can be made about what will occur at the phonological level. The weak phonetic prediction is that voiceless obstruents should have an effect equal to that of voiced obstruents in the phonology. The strong phonetic prediction is that voiceless obstruents should have a greater effect than voiced obstruents. Observations of consonant-tone alternations at the phonological level, however, can be generalized in at least two ways, both of which are incompatible with the phonetic predictions. One possible generalization from the phonological data is that consonant-tone interactions involve voiced obstruents much more frequently than voiceless obstruents. Another, which will be argued for here, is that consonant-tone interactions involve only voiced obstruents, and never voiceless obstruents.

2. Phonetic effects of obstruents on vowel pitch

Phonetically, voiced obstruents are correlated with lowered pitch and voiceless obstruents are correlated with raised pitch. The phonetic effects of obstruents on pitch suggest that voiced and voiceless obstruents should behave equivalently in the phonology. Early studies indicate that vowels after voiced obstruents have a lower average frequency than vowels after voiceless obstruents. The results of three studies in which the average fundamental frequency of vowels was measured after voiced and voiceless consonants are given in (1). In these studies, the values of the vowel F_0 are consistently found to be lower after voiced obstruents and higher after voiceless obstruents.

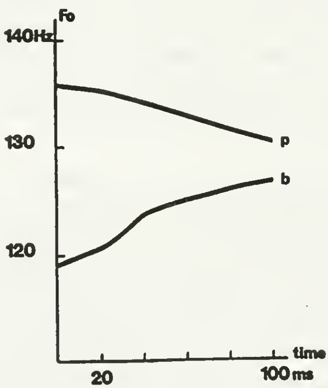
(1) Fundamental Frequencies (in Hz) of Vowels as a Function of the Preceding Consonant as Determined by Three Studies

	p	*t*	*k*	*b*	*d*	*g*	*v*	*z*	*f*	*s*
a.	127.9	127.1	127.2	120.9	120.6	122.8	122.2	122.6	124.3	126.1
b.	175	176	176	165	163	163	155	169	173	175
c.	130.7	129.8	131.1	125.1	124.8	125				

(Supplemented version to chart in Hombert 1978:
a = House & Fairbanks 1953; b = Lehiste & Peterson 1961; c = Mohr 1968)

Later studies found that the pitch effects of obstruents are concentrated at the onset of the vowel. The classic study is Hombert 1978 and his charts of average fundamental frequency after voiced and voiceless obstruents are seen in (2) and (3).

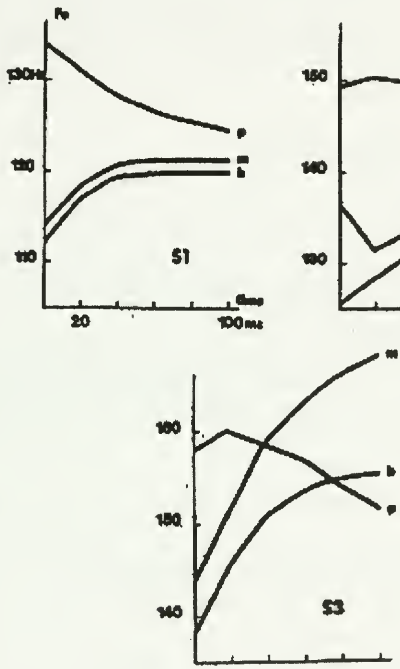
(2) Pitch traces: Averages for 3 speakers (Hombert 1978)



In these charts, ***p*** represents all voiceless obstruents, ***b*** represents all voiced obstruents and ***m*** represents all sonorants. In all cases, there is a significant rise from a low frequency after voiced obstruents and a significant fall from a high frequency after voiceless obstruents. In a separate experiment, also reported in

Hombert 1978, a Yoruba speaker was asked to say words with different tones and differing onset consonants. The results once again showed a fall after voiceless obstruents, regardless of vowel tone, and a rise after voiced obstruents. Lea 1973 also reports the same results for English: rises after voiced obstruents and falls after voiceless obstruents.

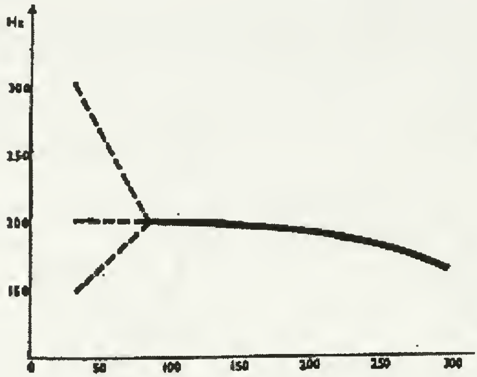
(3) Individual pitch traces: Averages by speaker (Hombert 1978)



Another study, undertaken by Haggard, Ambler, & Callow 1970, provides evidence that the pitch effects that have been consistently found are actually perceived by the language user. As illustrated in (4), three pitch traces with the same vowel frequency but with different onsets were synthesized. One onset was rising, another falling and the other level. The synthesized syllable was ambiguous between ***bi*** and ***pi***. The researchers found that the pitch tracing with a falling onset was more often identified as ***pi***, the pitch tracing with the rising onset was more often identified as ***bi*** and the pitch tracing with the level onset was identified inconsistently. This indicates that onset pitch following an obstruent is a significant cue in identifying its voicing.

To summarize, voiced and voiceless obstruents are both characterized by consistent pitch effects, realized on the following vowel, which are cues to the voicing of the obstruents. These studies lead to the weak phonetic prediction that voiced and voiceless obstruents will be equally involved in phonological consonant-tone interaction. But, as mentioned, a stronger prediction, discussed in section 3, is also possible.

(4) Pitch salience in a perceptual study (Haggard, Ambler & Callow 1970)



3. Markedness of rising tones

The strong phonetic prediction is that voiceless obstruents will have a greater effect on tone in the phonology than voiced obstruents. The reasons for expecting this involve considerations of the markedness of the effects that accompany voiced obstruents, ie., rising tones or pitch.

There are a number of indications (5) that rising tones are systematically disfavored.

(5) RISING TONES ARE MARKED IN THE FOLLOWING WAYS:

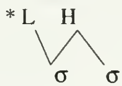
- A. FALLING TONES ARE MORE NUMEROUS IN TONAL INVENTORIES OF LANGUAGES.
- B. IMPLICATIONAL HIERARCHY: THE PRESENCE OF RISING TONES ENTAILS FALLING TONES.
- C. CONSTRAINTS HAVE BEEN PROPOSED AGAINST CONTOUR TONES AND AGAINST RISING TONES, BUT NOT SPECIFICALLY AGAINST FALLING TONES.

One indication that rising tones are disfavored is that falling tones are more numerous in tonal inventories of languages. Cheng 1973 compares 737 Chinese dialect locations with a total of 3433 individual tones. He finds that falling tones are the most common type of tone, followed by level tones which are followed by rising tones. There are 1-1/2 times more falling tones than rising tones (1125 compared to 790).

There is also an implicational relationship between rising tones and falling tones, such that the presence of rising tones entails the presence of falling tones. In other words, if a language has rising tones, it will always have falling tones. The converse is not necessarily true. If a language has falling tones, it need not have rising tones. So there are languages with falls but no rises, such as Hausa, Kikamba, Holoholo, Chichopi, Gitonga, Bukusu, and Efik, but there appear to be no languages with rises but no falls.

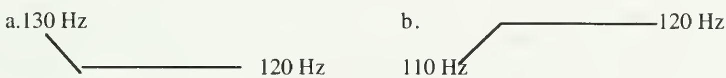
Within a language, rising tones are typically more limited or restricted in their use than falling tones. This combined with the other evidence for the markedness of rising tones results in a linguistic situation in which constraints are proposed against contour tones or against rising tones, but not against falling tones. One constraint against rising tones, proposed by Odden (forthcoming) for Chiyao, is given in (6). In this language, rises are possible as long as the next syllable is not H.

(6) No Rise



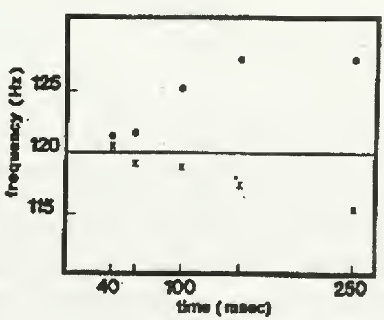
Phonetic studies that have something to contribute to our understanding of why rises may be marked include both perceptual and articulatory studies. Hombert 1978 reports on an experiment in which perception of falling tones is concluded to be better than the perception of rising tones. In this experiment, illustrated in (7), pitch traces were synthesized that had a steady state of 120 Hz. but which differed in onset frequency. One pitch trace fell at the onset from 130 Hz. (7a), and the other rose from 110 Hz. (7b).

(1)



The duration of these onsets was manipulated so that they included durations of 40, 60, 100, 150 and 250 ms. Subjects were asked to match the beginning pitch of the sound. Their relative success is illustrated in (8).

(8)



Although the subjects were never able to correctly identify the beginning pitch of the sound, the perceived pitch was always closer to the actual pitch when the onset had a falling contour rather than a rising contour. Subjects also performed better when the contoured portion was longer, but this need not concern us here. Hombert concludes that rising pitch tends to be perceived more in terms of its end point than in terms of its beginning. In other words, rising pitch is more difficult to perceive.

What Hombert's experiment did in terms of perception, other experiments did in terms of production. Ohala & Ewan 1973 and Sundberg 1973 demonstrate that a falling pitch can be produced much faster than a rising pitch over the same pitch interval.

Based on studies such as the ones cited here, Ohala 1978 concludes that falling tones are probably perceptually more salient than rising tones. Thus, this section has provided reasons why the effect of voiceless obstruents on pitch is more likely to be phonologized than that of voiced obstruents. In a nutshell, the voiceless obstruent effect is more salient because it consists of a falling tone rather than a rising tone.

4. Phonetic effects of sonorants on vowel pitch

There is still another reason why voiceless obstruents are more salient than voiced obstruents. Sonorants are phonologically neutral to voice-tone interactions in most cases. It is also generally agreed that they are neutral phonetically, though this is not in any way obvious and there is disagreement on this point (note for instance Maddieson 1984). Whatever the case, it has been remarked that the pitch traces after sonorants and those after voiced obstruents resemble each other. Looking again at two of the same studies summarized in (1), and comparing sonorants to obstruents, we see this resemblance. In these studies (9), the fundamental frequency of vowels after sonorants fell in or near the range of fundamental frequency values after voiced obstruents, and outside the range found after voiceless obstruents.

(9) a. House & Fairbanks 1953

m	*n*	*+voice*	*-voice*
123.2	121.8	120.6-122.8 (d, g)	124.3-127.9 (f,p)

b. Lehiste & Peterson 1961

m	*n*	*r*	*l*	*y*	*w*	*+voice*	*-voice*
162	161	166	164	164	167	155-169 (v, z)	173-176 (f,t/k)

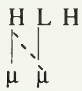
Similarly, the chart in (3) shows the resemblance of the averaged pitch trace for sonorants marked ***m*** with that of the voiced obstruents marked ***b***.

There are 2 possible interpretations of the sonorant data: either sonorants have a distinctive pitch effect, or they have no pitch effect, and the pitch traces we see are what happens when no consonant effect is present. In either case, the voiced obstruents resemble the sonorants, which makes them less distinctive than the voiceless obstruents, which stand apart from both voiced obstruents and sonorants. This leads to the conclusion that the pitch effect of voiceless obstruents must be more salient. This in turn leads to the prediction that voiceless obstruents should be more often involved in phonologized consonant-pitch interactions than voiced obstruents.

5. Phonological effects

The phonological effects of voiced obstruents on tone typically involve either the blocking of H or the insertion of L. The Chadic language Ngizim has often been cited in the literature on consonant-tone effects. In this language, there is a process of H-spread that can be depicted as in (10). Where there is a sequence of tones HLH, the initial H spreads and the site to which it has spread surfaces with a falling tone.

(10) H Spread:



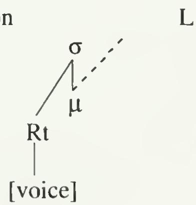
As illustrated in (11), the H spreads over a voiceless obstruent, an implosive obstruent or a sonorant. It fails to spread over a voiced oral obstruent. This effect, in which H spread is blocked by an intervening voiced obstruent is a commonly attested consonant-tone interaction.

(11) Ngizim (Schuh 1971)

/ná kà asúw/	→	[ná kâasúw]	'I swept'
/á rə̀pcí/	→	[á rə̂pcí]	'open!'
/ná bàkə́-w/	→	[ná bàkú]	'I burned (it)'
/ná ɗà nkə́-w/	→	[ná ɗânkú]	'I sewed'

Another manifestation of the interaction of voiced obstruents and tone is illustrated with the Ewe language. We can posit a process of L-insertion as in (12). Simply, L is inserted on the tone-bearing unit immediately following a voiced obstruent syllable onset.

(12) L Insertion



L-insertion invariably takes place in monosyllabic nouns in Ewe if they begin with a voiced obstruent, as in (13). That is, they always have a L or LH tone pattern. Other onset consonants, either voiceless obstruents or sonorants, are never followed by a L tone. They have either a M or MH tone pattern.

(13) Ewe (Smith 1968, cited in Stahlke 1971, Hyman 1973)

dà lá	'the snake'
ɦà lá	'the pig'
kpō lá	'the stick'
nyī lá	'the cow'

It is much rarer to find cases in which voiceless obstruents also appear to interact with tone. In fact, only two such cases have been found. In Nupe, there seems to be a process in which L spreads across a voiced obstruent (14b) or across a sonorant (14c). It does not spread over a voiceless obstruent (14a).

(14) Nupe (George 1970)

a.	/pá / 'peel' →		[èpá]	'is peeling'
b.	/bá / 'be sour'	→	[èbǎ]	'is sour'
c.	/wá / 'want'	→	[èwǎ]	'is wanting'

Similarly, the Ngizim language seems to have a process of L spread where L spreads over a voiced obstruent (15a) or over a sonorant (15b). L does not spread over a voiceless obstruent (15c). Notably, L also fails to spread over an implosive (15d).

(15) Ngizim (Schuh 1971)

a. /mùgbá bá i/	→	[mùgbà bái]	'it's not a monitor'
b. /màarə́m tə́n/	→	[màarə̀m tə́n]	'big nose'
c. /ŝì itá bái/	→	[ŝì itá bái]	'it's not pepper'
d. /kì iɗá bái/	→	[kì iɗá bái]	'he didn't eat (it)'

In order to assess the phonetic predictions, it is necessary to examine the frequency with which consonant-tone interactions involve voiced obstruents as compared to the frequency with which they involve voiceless obstruents. My survey of the literature and my own field notes on two underdescribed languages reveal at least 22 languages with demonstrable interaction between voiced obstruents and tone, similar to the effects described in (10) and (12). Specifically, in these 22 cases, the voiced obstruents are either followed by a phonological L which doesn't show up after other consonants or they block a process of H spread or H shift.

(16) Ngizim (Schuh 1971): Chadic; Nigeria
H spread blocked by voiced obstruents
Bade (Schuh 1978): Chadic; Nigeria
H spread blocked by voiced obstruents
Suma (Bradshaw 1995): Adamawa-Ubangi; CAR
Constraint on grammatical H after voiced obstruents
Gbaya ɓokota (Bradshaw, field notes): Adamawa-Ubangi; CAR
Docking of associative H blocked by voiced obstruent
Makaa (Heath 1991): Narrow Bantu; Cameroon
In associative construction with a final voiced obstruent, a L-toned vowel is epenthesized or a downstep is triggered if other conditions are met.
Siya (Ford 1986): Central-Togo; Ghana
L monosyllabic verbs with initial voiced obstruents fail to raise before [+upper] (ie. H or raised M)
Zulu (Cope 1970): Bantu (Nguni); S. Africa
H spread blocked by voiced obstruents
(Khumalo 1987): L insertion
SiSwati (Bradshaw forthcoming): Bantu (Nguni); S. Africa & Swaziland

H spread & H shift blocked by voiced obstruents; H shift triggered by voiced obstruents; L insertion

Xhosa (Cassimjee n.d.): Bantu (Nguni); S. Africa
H shift triggered & blocked by voiced obstruents

Digo (Kisseberth 1984): Bantu (Mijikenda); Kenya, Tanzania
H spread blocked by voiced obstruents

Chonyi (Cassimjee & Kisseberth 1992): Bantu (Mijikenda); Kenya, Tanzania
Prefix H fails to shift/spread when verb has initial voiced obstruent

Duruma (Cassimjee & Kisseberth 1992): Bantu (Mijikenda); Kenya, Tanzania
Prefix H fails to shift/spread when verb has initial voiced obstruent

Dzihana(Cassimjee & Kisseberth 1992): Bantu (Mijikenda); Kenya, Tanzania
Prefix H fails to shift/spread when verb has initial voiced obstruent

Kambe (Cassimjee & Kisseberth 1992): Bantu (Mijikenda); Kenya, Tanzania
Prefix H fails to shift/spread when verb has initial voiced obstruent

Kauma (Cassimjee & Kisseberth 1992): Bantu (Mijikenda); Kenya, Tanzania
Prefix H fails to shift/spread when verb has initial voiced obstruent

Rabai (Cassimjee & Kisseberth 1992): Bantu (Mijikenda); Kenya, Tanzania
Prefix H fails to shift/spread when verb has initial voiced obstruent

Rihe (Cassimjee & Kisseberth 1992): Bantu (Mijikenda); Kenya, Tanzania
Prefix H fails to shift/spread when verb has initial voiced obstruent

Giryama (Cassimjee & Kisseberth 1992): Bantu (Mijikenda); Kenya,Tanzania
Prefix H fails to shift/spread when verb has initial voiced obstruent

Ikalanga (Hyman & Mathangwane 1994): Bantu (Shona); Botswana
H spread blocked by voiced obstruents

Ewe (Stahlke, Ansre, Smith, Welmers): Kwa; Ghana, Togo
In monosyllabic words, L occurs only after after voiced obstruents and only L occurs after voiced obstruents.

Ouldeme (de Colombel 1986): Chadic; Cameroon
'syllables with a depressor consonant [ie. voiced obstruent] take L' (Swackhamer 1991)

Mulwi (Tourneux 1982) Chadic; Chad, Cameroon
'syllables with a depressor consonant [ie. voiced obstruent] take L' (Swackhamer 1991)

Compare this with the list in (17) where only 2 languages have been found that appear to have an interaction between voiceless obstruents and tone. In both cases, the effect appears to be one of blocking the spread of L.

(17) Ngizim (Schuh 1971): Chadic; Nigeria
L spread blocked by voiceless obstruents & implosives
Nupe (George 1970): Kwa; Nigeria
L spread blocked by voiceless obstruents

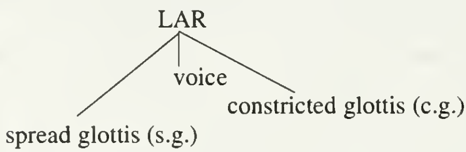
It is also worth noting that only one language, Ngizim, has both voiced and voiceless obstruent effects. This means that 21 languages have voiced obstruent effects without voiceless obstruent effects, while only one language can be said to have voiceless obstruent effects without voiced obstruent effects.

This section has illustrated the fact that the predictions of the phonetic studies are incorrect. Voiceless obstruents do not have an equal or greater effect than that of voiced obstruents in the phonology.

6. Phonological motivation for the mismatch: The role of [voice]

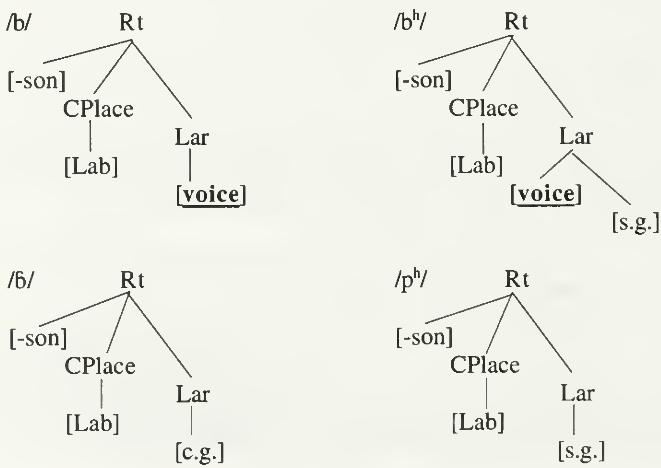
The phonetics-phonology mismatch with respect to obstruent-tone interaction can be motivated by the existence of a privative feature [voice]. The privative nature of this feature has been argued for by Mester & Ito 1989 and Lombardi 1994. The feature [voice] is one of several privative laryngeal features, which also include [constricted glottis] and [spread glottis], as in (18). (Note that this does not constitute a claim that all features are privative.)

(18) Representation of laryngeal node with privative features:

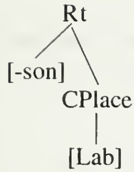


The use of these features to specify different consonant types is shown in (19). Voiced oral obstruents are exemplified by a representation of /b/, with a laryngeal specification only for [voice]. Breathy voiced obstruents are exemplified with a representation of /bh/, which is specified for both [voice] and [spread glottis] under the laryngeal node. These are the only consonants normally specified for [voice] and the only types of consonants involved in consonant-tone interactions. The other consonants illustrated include implosives, aspirated voiceless obstruents, plain voiceless obstruents and sonorants. None are specified for [voice]. The sonorants and plain voiceless obstruents normally have no laryngeal specifications. They differ in that sonorants can receive a specification for [voice], while voiceless obstruents are never so specified.

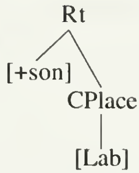
(19)



/p/



/m/



If these laryngeal specifications are assumed and since voicing is almost certainly the key factor, then it is predicted that only voiced oral obstruents and breathy voiced obstruents will participate in consistent consonant-tone interactions. This prediction is motivated by phonological factors in contrast to the earlier predictions motivated by phonetic factors.

If there is a choice between a privative and a binary voicing feature, the data on consonant-tone interaction supports the choice of a privative feature. A privative voicing feature can be used to deal with all consonant-tone interactions, while a binary feature runs into problems. With a privative feature, the restriction of the interaction to contexts with voiced obstruents falls out from the feature representation. With a binary feature, it is possible to describe the conditions under which tone is affected in terms of [+voice], but the availability of a [-voice] specification provides no advantage, and it leaves unanswered the question of why [-voice] fails to interact with tone.

The cases of Ngizim and Nupe, where voiceless obstruents seem to interact with tone, are a potential problem for a privative voicing feature. The data from these languages can, however, be reanalyzed so that voiceless obstruents are not the conditioning factor in the phonology. The Ngizim data involves a process of L-spread that appears to be blocked by voiceless obstruents and implosives. Assuming that voiceless obstruents and implosives are not specified for voicing, the process of L-spread can be described as in (20) where spreading is conditioned by the presence of a voiced consonant.

(20)

The alternative approach in which L-spreading is treated as a blocking phenomenon fails to explain why voiceless obstruents and implosives pattern together. An attempt to use a constraint to block L-spread using [-voice], as in (21), fails to deal with the behavior of implosives as blockers.

(21)

A reanalysis of the Nupe data is beyond the scope of this paper, but it is worth noting that George's original analysis does not posit L-spreading but instead sees this essentially as phonetic/allophonic variation of H after voiced obstruents and sonorants.

More support for the view that consonant-tone interaction is governed by the existence of a privative voicing feature, and not by phonetic factors, comes from the behavior of breathy voiced obstruents. Phonetic studies such as Ohala 1974 and Kagaya & Hirose 1975 indicate that breathy consonants depress tone more than other consonants. This suggests that breathy consonants will interact with tone more than other tone depressors (ie., voiced obstruents). In contrast, the phonological prediction is that breathy voiced obstruents will fail to pattern separately from plain voiced obstruents, given that both types of consonants are specified for [voice]. There is, in fact, no evidence that breathy voiced obstruents ever act independently of plain voiced obstruents phonologically in tone-voice interactions.[1]

7. Summary

Phonetic studies predict either (a) voiced and voiceless obstruents should have equal effects on consonant-tone interaction in the phonology, or (b) voiceless obstruents should have a greater effect. The reason is that these studies indicate that both voiced and voiceless obstruents have an effect on the pitch of the following vowel. Furthermore, in terms of salience, phonetic studies suggest that voiceless obstruent effects have an advantage because they involve a falling rather than the more-difficult-to-perceive rising tone, and because they contrast with both voiced obstruents and sonorants phonetically.

Phonologically, it is the case that (a) voiced obstruents participate much more frequently than voiceless obstruents in consonant-tone interactions, or (b) voiced obstruents participate to the exclusion of voiceless obstruents. This is supported by a survey of phonological interactions between consonant and tone, which reveals that, contrary to predictions based on the phonetic data, voiced obstruents participate in these interactions almost to the exclusion of voiceless obstruents. In fact, it's possible to exclude all cases involving voiceless obstruents.

The two cases involving voiceless obstruent effects can be reanalyzed in such a way that there is no need to refer to voiceless obstruents in the phonology. The case from Ngizim in which voiceless obstruents seem to block the spread of L can be reanalyzed as a case in which only consonants with a specification for [voice] allow the spread of L. The related case from Nupe can be reanalyzed as a case in which H is phonetically, but not phonologically, present after a voiceless obstruent. In contrast, the 22 cases of voiced-obstruent effects cannot be reanalyzed in this fashion. In these languages, the effects are clearly phonological rather than phonetic. Moreover, an attempt to handle blocking by placing conditions on the spread of H so that only voiced obstruents are excluded will not account for the fact that the segments that allow this spread do not form a natural class.

Based on the examination of the phonetic and phonological information available, it is clear that there is a phonetics-phonology mismatch. This mismatch can be explained by the existence of the feature [voice], which is the crucial element in determining consonant-tone interaction phonologically.

8. Conclusions

It has sometimes been implied that phonology is in some sense a notational variant of phonetics, as in Ohala 1979 and Ohala & Lorentz 1977. Phonology-phonetics mismatches, such as the one shown here, provide evidence that phonology is governed by principles that can act independently of the phonetics. This is not to say that phonetics cannot inform the phonology. Phonology can be seen as both related to phonetics and separate from phonetics. For example, the actual correlates of the feature [voice] may include duration, unaspirated release and vowel quality. Actual vocal-fold vibration may be lacking in voiced segments. The existence of tone effects after voiced obstruents has a phonetic motivation. But the actual manifestation of some phonetic effects in the phonology to the virtual exclusion of others argues for a real and significant difference. It also argues that, within the phonological component, phonological forces outweigh phonetic forces when the two conflict.

In addition, consonant-tone interaction lends additional support to the existence of a privative rather than a binary voicing feature.

NOTES

* I would like to thank David Odden for useful comments on this paper.

[1] Jennifer Cole (p.c.) has suggested, based on work by Simon Donnelly, that in Phuthi, breathy consonants alone trigger depressor effects. No data on Phuthi is available at present. In closely related SiSwati, it is not clear that distinctively breathy consonants exist in the language, though breathiness may be a concomitant of lower pitch.

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