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0. Introduction

Phonological systems do not always possess contrasts that lend themselves to maximal perceptual salience. One component of a segment is potentially perceptually obscured by another component of that same segment. This paper is an investigation into this conflict, and strategies for its resolution, exploring the "ballistic accent" phenomenon in the Chinantec language of Oaxaca, Mexico.

Laryngeal features and (suprapharyngeal) stricture features may be simultaneous, i.e., may coexist on a single segment. However, their phonetic realization does not always mirror this simultaneity. For example, in phonological terms, an aspirated stop involves a combination of stricture and place features which corresponds to an oral occlusion, in addition to a feature which corresponds to a laryngeal abduction. In terms of phonological representation, the features representing the oral cavity configuration are unordered with respect to the feature representing the laryngeal configuration. Were the phonetic realization of this segment to mirror its phonological representation, the laryngeal abduction would not be perceived by the listener. A laryngeal abduction has no acoustic consequences if implemented simultaneously with an oral occlusion. Stated simply, a full closure reduces the acoustic output to zero. With zero acoustic energy, no contrast, laryngeal or otherwise, is perceivable. I refer to this phenomenon as ACOUSTIC OPACITY.

However, the phonetic component possesses a remedy for the obscuring effects of Acoustic Opacity. Through a process of temporal sequencing, otherwise obscured features may be revealed. In the case at hand, maximal laryngeal abduction is realized at the release of the oral occlusion. As the maximally abducted larynx is phonetically coextensive with the following, more sonorous segment, sufficient acoustic energy is present to encode this contrastive information. Although derived from a single segment with no internal duration, the resulting phonetic string consists of two perceptually salient elements ordered in time. This results in ACOUSTIC TRANSPARENCY.

In general, the lesser the sonority, the more pronounced this temporal sequencing becomes. Acoustically speaking, the lesser the sonority, the less energy exists to bear the burden of encoding laryngeal contrasts. If a contrastive feature possesses insufficient acoustic cues, its perceptual salience is obviously reduced. Thus stops, with minimal sonority, are likely to realize their oral and laryngeal components with the greatest degree of temporal sequencing, again, to maximize salience. Indeed, Kingston 1985, echoing the electromyographic studies of Hirose, Lee, and Ushijima 1974, Lõfqvist 1980, Lõfqvist and Yoshioka 1980, and Yoshioka, Lõfqvist, and Hirose 1981, 1982, posits that laryngeal features are more tightly "bound" to the release of a stop than to the release of a continuant.

Contrastively phonated nasals, with a greater degree of sonority, are predicted to sequence their contrastive laryngeal features to a lesser extent than stops. Finally, non-modally phonated vocoids, with maximum sonority, contain sufficient acoustic energy so that phonologically simultaneous laryngeal features may be phonetically simultaneous as well. Thus we observe breathy and creaky vowels (Dhall 1966, Smith 1968, Fischer-Jorgensen 1970).

Now consider that certain languages sequence contrastive phonation features of vowels, resulting in a sequential part-modal, part-non-modal realization (for example, Chinantec, Mazatec, and Trique (Silverman *in prep.*). This seems to directly contradict the predictions of the present theory, as the acoustic energy of vowels, with their maximal sonority, would seem sufficient to encode both oral and phonatory contrasts. However, this sequencing is by and large limited to tonal languages. As tone is most reliably produced and most reliably perceived during modal phonation (Plomp 1967, Ritsma 1967, Bickley 1982, Remez and Rubin 1984, Ladefoged, Maddieson, and Jackson 1988, Cao and Maddieson 1992, Silverman *in prep.*), observed sequencing in this case thus turns out to exemplify Acoustic Transparency: as tone would be obscured if phonetically co-occurring with non-modal phonation. Upon phonetic sequencing, Acoustic Transparency is achieved: tone is revealed. The Otomanguean language of Chinantec is herein shown to exemplify this effect.

Chinantec possesses a phonemic and morphemic contrast traditionally referred to as "ballistic accent". Ballistically accented syllables are articulated more forcefully than "controlled" syllables, affecting pitch, amplitude and phonation. Some examples are in (1).

(1)

	ballistic		controlled		
	ló:^{LH}	(lime)	lo:^{H}	(skin)	(Comaltepec dialect (Anderson 1989))
	má^{1}	(food)	na^{1}	(now)	(Palantla dialect (Merrifield 1963))
	tǘ:^{2}	(blind)	tü:^{2}	(Peter)	(Quiotepec dialect (Robbins 1968))

Ballisticity has traditionally been considered a stress-based property of syllables (Merrifield 1963, Bauernschmidt 1965, Rensch 1978, Mugele 1982). Instead, I argue in Section 2 that ballisticity is laryngeally-based, involving the feature [spread glottis], with concomitant increased subglottal pressure as a phonetic enhancer. In Section 3 we will see that the distribution of aspiration in Chinantec indicates that the [spread glottis] feature is phonologically associated with the nuclear vowel. Thus ballisticity is the phonological (though not phonetic) equivalent of a "breathy vowel".

The peculiar phonetic manifestation of ballistic syllables is a result of the high functional load borne by Chinantec vowels. As these vowels possess laryngeal contrasts involving both tone and phonation, as well as contrastive nasalization, laryngeal features are sequenced in the phonetic component in order to maximize the perceptual salience of all contrastive features.

1. Segment and Surface Tonal Inventory.

In (2) is the segment inventory for the Comaltepec dialect of Chinantec (Anderson, Martinez, and Pace 1990).

(2)

p	t	c		k		i	ɨ	u
b	d	z		g		e	ʌ	o
	s		r			æ		a
m	n			ŋ				
	l							
	N	y		w				

(c = tʃ, z = dʒ, r = ʐ/ɽ, N = nasal glide)

While eight vocalic place contrasts exist, contrastive tone, length, nasality, and so-called ballisticity greatly expand the vowel inventory. The high functional load of Chinantec vowels may be seen as a result of the language's morphological structure: roots are predominantly monosyllabic, while the rather rich inflectional system is by and large subsyllabic, consisting of tone, length, ablaut, phonation, nasality, and/or consonantism. Given this dichotomy between segmental poverty and morphological richness, each segment of the Chinantec word potentially accommodates a great number of linguistically significant components. Nuclear vowels, being more sonorous than onset consonants, carry a greater burden in this respect, as their higher acoustic energy makes them more capable of encoding contrasts. Thus onset sonorants only possess a three-way contrast involving additional aspiration and laryngealization, while onset obstruents may only contrast for voicing.

The surface tonal inventory is shown in (3).

(3) L, M, H, LM, MH, HM, LH, HL, HLH, HMH

Finally, syllables are of the form C(G)V(:)(N)(?).

2. The Phonetics and Phonology of Ballisticity

Ballistic syllables are characterized by a forceful release of onset consonants, affecting pitch and duration, culminating in post-vocalic aspiration, with a loss of voicing in post-vocalic nasals. (Merrifield 1963, Westley 1971, Foris 1973, Anderson 1989). In most dialects, ballisticity may cross-classify with every other syllable type. Oral and nasal vowels, long and short vowels, and open and checked syllables, may all possess ballisticity.

2.1 Aerodynamic Considerations

Mugele (1982) presents a detailed phonetic description of the interaction of ballisticity and tone in the Lalana dialect. Among the characteristic phonetic correlates of ballisticity, Mugele highlights their so-called "intensity" or increased amplitude, indicated in spectrograms by a darker spectrographic display.

This increased intensity, argues Mugele, is due to an increase in subglottal pressure. Mugele consequently targets increased subglottal pressure as the defining articulatory correlate of ballisticity, phonologizing the phenomenon with the feature [+ballistic syllable] (henceforth [+bs]). Regarding post-vocalic aspiration, Mugele states the following: "The hypothesis that ballistic syllables are produced by an active gesture that raises subglottal air pressure...provides an explanation for the increased postvocalic aspiration. Let us assume that, in an open syllable, phonation of the vowel ceases by abducting the vocal folds. In the case of the controlled syllable, phonation ceases by abducting the vocal folds and silence follows. At the time of the abduction of the vocal folds, the flow of air is insufficient to cause any glottal friction (aspiration). In ballistic syllables, however, glottal friction is produced as air under much greater pressure rushes through the vocal folds as they are being abducted. The postvocalic aspiration begins when the vocal folds are abducted to a point where phonation is no longer possible and it continues until glottal opening reaches a point where there is insufficient stricture to maintain the friction. Thus the differences in postvocalic aspiration result from differing amounts of airflow through the glottis as the vocal folds are being abducted in order to terminate the voicing of the vowel"(pp.96-97).

It should be noted that the feature [bs] is not attested outside Chinantec (and neighboring Amuzgo). Furthermore, while enhanced subglottal pressure does appear to possess paralinguistic status in many languages as an indicator of emphasis (i.e., "emphatic stress"), it is never reported to possess true phonemic status. Maddieson (1984) makes no mention of subglottal phenomena as possessing minimal contrastive status in any of the languages he investigates.

I now argue that increased subglottal pressure is merely an enhancing concomitant of the true phonologically relevant feature [spread]. Keating (1990), drawing from Ladefoged and Lindau (1986) argues that a given phonological feature may be phonetically implemented in various ways from language to language, or speaker to speaker. She writes "...a single feature may have more than one parameter value...languages may differ in how they realize a given value. Such a difference would be related to saliency: the more parameters [that] are used for a given feature, the more robust and salient that feature's value will be"(p.332).

How may Keating's approach support the ballisticity-as-[spread] hypothesis? Is there evidence that increased subglottal pressure may be a concomitant of aspiration? Ladefoged (1958, 1968) reports that in English there are "striking increases in the [respiratory--D.S.] muscular activity immediately before a word beginning with [h]."(1968:149). Note that the respiratory musculature is involved in the manipulation of subglottal pressure during expiration: increased muscular activity during expiration results in increased subglottal pressure. Increased subglottal pressure, in turn, results in a more rapid expulsion of air from the lungs.

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(4) phonology: enhancement:
[spread] (increased glottal aperture) increased subglottal pressure
↘ ↙
increased transglottal airflow

There is evidence outside of English supporting Ladefoged's claim. Lee and Smith (1971), for example, report similar effects in Korean. In an analysis of Gujarati breathy vowels, Fischer-Jorgensen (1970) finds that the intensity of breathy vowels does not differ significantly from that of modal vowels. However, breathy vowels show increased airflow in comparison to modal vowels, most likely due to greater glottal aperture. Fischer-Jorgensen speculates that an increase in the activity of the expiratory muscles during breathy vowels compensates for the subglottal pressure reduction associated with increased glottal aperture.

It is thus reasonable to conclude that increased subglottal pressure due to increased respiratory muscular activity may be an enhancing concomitant of [spread]. This is especially true of *post-vocalic* aspiration, as there otherwise exists "a general aerodynamic weakening in final position" (Kohler 1992:209).

Let us further consider the interaction between tone and ballisticity. As we will see in Section 2.3, ballistic syllables are accompanied by a slight pitch increase toward their right edge. While F0 is primarily controlled by the laryngeal muscles, there is nonetheless evidence that increased subglottal pressure induces moderate pitch increases (Meuller 1851, Hixon, Klatt, and Mead 1971, Titze 1989, Ohala 1990). As pressure increases, flow increases, and as flow increases, rate of vocal cord vibration increases. As the rate of vocal cord vibration is the articulatory correlate of pitch, the potential relationship between glottal aperture, transglottal airflow rate, subglottal pressure, and pitch, becomes clear. The flowchart in (5) presents these interrelations.

(5) phonology: enhancement:
[spread] (increased glottal aperture) increased subglottal pressure
↘ ↙
increased transglottal airflow
↓
increased vocal cord vibration
↓
increased pitch

Pitch increases may thus be seen to correlate in part with increases in glottal aperture, which in turn correlates with increased subglottal pressure. This pressure increase is due to aspiration's presence in post-vocalic position.

2.2 Comaltepec Phonology

While most morphologically complex forms in Chinantec are monosyllabic, there is a limited process of syllabic cliticization involving reduced forms of personal pronouns. Anderson, Martinez, and Pace (1990) report that in first person cliticization, a copy of the root vowel is suffixed to the base. Open ballistic syllables which undergo this process are characterized by a particularly prominent breathiness in the transition from root to suffix. Thus /ka^L nó^{M}R/-> [ka^L nó^{M}Oo^L] ([ka^L no^{M}ho^L]) (*I got it*) ("R" stands for "reduplicant", the suffixal morpheme).

Thus [spread], which will be argued to be underlyingly associated with the root vowel, surfaces in the onset to the following syllable. Under the present analysis, the behavior of [spread] in Comaltepec clitic phonology is consistent both with the cross-linguistic tendency to provide onsets for onsetless syllables (Ito 1989), and with the tendency for aspiration to be more salient in syllable onset position than syllable coda position (Kohler 1992).

Under Mugele's analysis, no explanation is forthcoming regarding the behavior of aspiration in this context. Mugele, who offers a nonlinguistic aerodynamic account of ballistic aspiration would seem at a loss to explain its enhancement in this context.

Note additionally that Mugele offers no explanation for observed nasal devoicing in ballistic syllables. Surely, when a phonologically plain nasal follows a vowel, the vocal cords do not abduct; voicing continues throughout the supralaryngeal adjustment from vowel to nasal. Yet ballistic syllables are reported to possess devoicing of their post-nuclear nasals. If instead ballisticity involves a [spread] feature, nasal devoicing is a natural phonetic analog.

2.3 Comaltepec Spectrographic Evidence

In figure (1) are waveforms (window A), energy contours (window B), and wideband and narrowband spectrograms (windows C and D, respectively), for a form pair which near-minimally contrasts in ballisticity, *kwé:*^{21} (arm) and *kwe:*^{2} (long (inan.)).

Wideband spectrograms (window C) indicate that ballistic syllables differ from controlled syllables in possessing significant postvocalic, aperiodic noise, characteristic of aspiration. This is indicated by the faint markings toward these syllables' right edges, after the cessation of a defined formant structure. Note that this energy is aperiodic, indicated by the lack of vertical striations toward the right edge of the syllable. In contrast, controlled

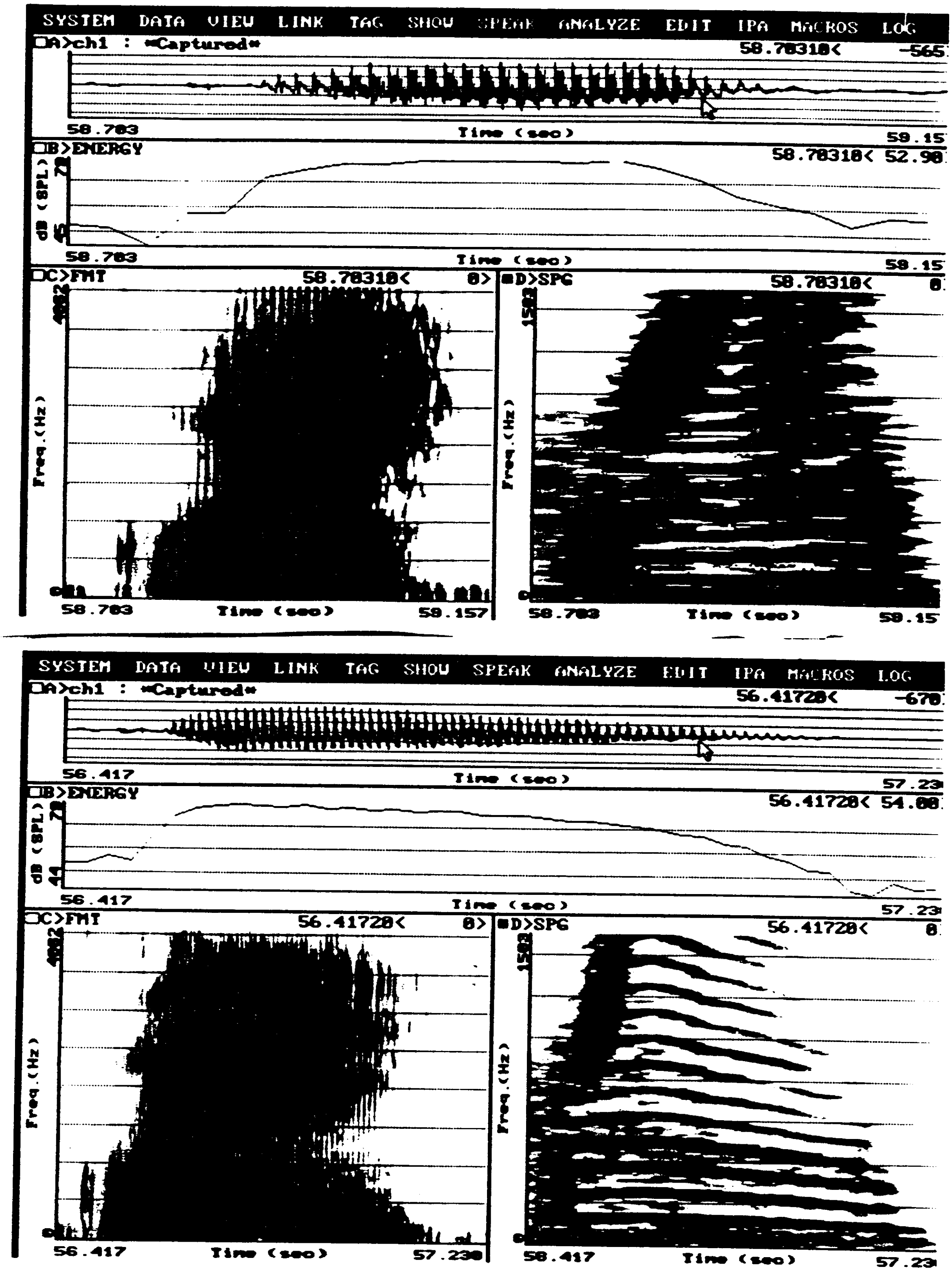

Figure (1)

(A) Waveforms, (B) energy contours, (C) wideband spectrograms, and (D) narrowband spectrograms for *kwé:*[21] (arm) and *kwe*[2] (long (inan.)).

syllables possess a periodic vibration for the duration of the vowel. This is indicated by the vertical striations, which persist for the duration of the vowel.

The narrowband spectrogram (in window D) clearly reveals several distinctions between ballistic and controlled syllables. First, in comparison to controlled syllables, the harmonic structure of ballistic syllables is much less well-defined toward the right edge of the display. This loss of definition temporally correlates with the noise present in wideband spectrograms. Moreover, the harmonic structure of ballistic syllables indicates a slight increase in frequency toward the right edge, where noise is present. This F0 hump is not present in controlled syllables. Instead, harmonic structure here indicates a gradual lowering of fundamental frequency.

Inspection of the energy contour in window B indicates a direct correlation between energy levels, F0 levels, and noise levels. Ballistic syllables possess a slight hump, or increase in energy, toward their right edge. The energy contours of controlled syllables correlate with their harmonic contours and noise levels, in possessing a gradual decline as the syllable progresses.

Recall the flowchart in (5), which considers a possible interaction between a phonological glottal abduction and a phonetic pitch increase. Wideband and narrowband spectrograms indicate the presence of aperiodic noise at the right edge of ballistic syllables. This noise, as noted, is characteristic of aspiration--glottal abduction. Energy contours indicate an increase in overall energy in this position, which presumably has its origins in the contraction of the respiratory muscles. This muscular contraction results in an increase in subglottal pressure, thus increasing transglottal airflow. Furthermore, narrowband spectrograms indicate a moderate increase in pitch in this context. Recall that increases in subglottal pressure and airflow result in moderate increases in rate of vocal cord vibration. Therefore, we may conclude that the slight increase in F0 in ballistic syllables ultimately derives from an increase in glottal aperture. Thus, although various phonetic contrasts exist between ballistic and controlled syllables, these may be reduced to a phonological contrast involving a [spread] specification.

Note finally that narrowband spectrogram indicates that the harmonic structure of ballistic syllable vowels is affected during their aspirated portion: noise is present in the harmonic structure. Now observe that perceived pitch is determined by harmonic structure. As harmonic structure is seemingly obscured by the presence of aspiration, then aspiration best not be present in environments in which pitch possesses linguistic significance, as it does in Chinantec vowels.

I conclude that [spread] is the phonological feature defining ballisticity, and that the accompanying phonetic enhancement of increased subglottal pressure is primarily a consequence of aspiration's post-vocalic position.

3. Phonological Affiliation

According to Mugele (1982), the feature [+bs] is syllabic in its affiliation. We have already seen that the [+bs] feature does not offer a tenable explanation of the phonological and phonetic properties of ballistic syllables, and have instead implicated [spread]. We will now additionally see that the syllable is not a viable candidate for [spread]'s affiliation.

In (6) is the maximal syllable expansion in Chinantec, with [spread] associated throughout the syllable.

(6) CGV:N?
[spread]

First, a syllabic affiliation of [spread] requires that no subcomponent of the syllable may contrast in aspiration, as the phonological simultaneity of identical features results in neutralization. Yet Chinantec freely allows such contrasts (hmó:^{L}o *I do* (transitive inanimate first person singular)). Further, I follow Halle and Stevens (1971) in disallowing the phonological simultaneity of [spread] and [constricted]. This being the case, the syllabic affiliation of [spread] in ballistic syllables becomes an impossibility. Let us consider why.

Syllabic affiliation of [spread] in ballistic syllables predicts that these syllables may not contain any [constricted] specifications, as this would involve the phonological simultaneity of [spread] and [constricted], as exemplified in (7).

(7) ?ién^{L} 'child'
[spread]

In (7) we see that a syllabic affiliation of [spread] overlaps with tautosyllabic [constricted]. This impossible configuration renders the structure illicit. In fact, words of the form in (7) are perfectly acceptable.

In addition to the predicted unacceptability of [constricted] in onset position, syllabic affiliation also predicts the nonexistence of ballistic checked syllables, as these too involve the phonological simultaneity of [spread] and [constricted]. However, glottally checked ballistic syllables freely occur (ngiú?^{L} -- you vomit). For these reasons, I reject the possibility that the affiliation of [spread] in ballistic syllables is syllabic. Note that we may also eliminate the possibility that [spread] is affiliated with the rime, as rimes may contain glottal checking. Therefore, [spread] cannot be affiliated to this supposed element of prosody in ballistic syllables.

Ballistic syllables could conceivably involve [spread] associated to coda position, phonologically ordered with respect to /ʔ/. However, ordering coda /h/ with respect to coda /ʔ/ predicts that the sequencing of these two segments could be reversed. That is, we expect /hʔ/, but also /ʔh/. Note in particular that appeals to the sonority hierarchy could not preclude this ordering contrast, as /ʔ/ and /h/ do not differ along this scale. As this type of ordering contrast is unattested, it casts strong doubt on the coda /h/ hypothesis.

The affiliation of [spread] in ballistic syllables could conceivably be moraic.

(8) CGV:Nʔ
|
[spread]

In bimoraic syllables, moraic affiliation predicts that contrasts between preaspirated and postaspirated syllables should be possible. Such contrasts, of course, are unattested. Furthermore, if [spread] is moraic in affiliation, it is unclear how to capture the contrast between monomoraic and bimoraic ballistic syllables. Given the problems of moraic association, this would not seem a hypothesis worthy of further pursuit.

The segmental affiliation of [spread] in ballistic syllables will now be considered.

(9) CGV(:)Nʔ
|
[spread]

Allowing [spread] to associate directly to vowels would allow for further laryngeal contrasts in both onsets and codas. Thus onsets may possess [spread] or [constricted], and syllables may be checked, both independently of ballisticity. Further, as [constricted] does not phonologically associate with vowels (i.e., there are no creaky vowels), no feature co-occurrence violation is encountered.

Finally, segmental affiliation correctly predicts the unacceptability of moraic aspiration contrasts in bimoraic syllables.

I conclude that [spread] in ballistic syllables is phonologically associated with the nuclear vowel. Due to the phonetic requirements of tone perception, however, this aspiration is sequenced in the phonetic component, so that all laryngeal contrasts may achieve a greater degree of phonetic salience. Ballisticity is thus claimed to exemplify the phenomenon of Acoustic Transparency.

4. Conclusion

We have seen that ballistic syllables are phonologically characterized as possessing a [spread] feature. The [spread] specification in ballistic syllables phonologically associates at the segmental level. That is, the vowels of ballistic syllables are the phonological (though not phonetic) equivalent of "breathy vowels". The stricture specifications of [spread]'s associated segment would not seem to require phonetic sequencing of laryngeal features. However, vocalic modal voice is nonetheless manifested in order to enhance production and perception of tone, and thus [spread] is sequenced at the phonetic level. As aspiration in post-vocalic position is aerodynamically weakened, subglottal pressure increases in order to enhance its salience.

The phonological structure and consequent phonetic realization of Chinantec vowels may be seen as intimately tied to the language's morphological structure: a single vowel potentially accommodates several elements (place, tone, phonation, length, nasality) of distinct morphological origin. In turn, these phonologically and morphologically complex structures must be reliably encoded in the speech signal. We thus observe the phonetic sequencing of modal and breathy phonation, so that both tone and breathiness may achieve Acoustic Transparency.

References

Anderson, J.L. (1989) Comaltepec Chinantec Syntax. Studies in Chinantec Languages 3. Summer Institute of Linguistics.

Anderson, J.L., I.H. Martinez, and W. Pace (1990) "Comaltepec Chinantec Tone", in W.R. Merrifield and C.R. Rensch, eds., Syllables, Tone, and Verb Paradigms. Studies in Chinantec Languages v.4. Summer Institute of Linguistics, 3-20.

Bauernschmidt, A. (1965) "Amuzgo Syllable Dynamics," Language 41.3:471-483.

Bickley, C. (1982) Acoustic Analysis and Perception of Breathy Vowels. Working Papers, Speech Commuincation Group, MIT 1:71-81.

Cao, J. and I. Maddieson (1992) "An Exploration of Phonation Types in Wu Dialects of Chinese," Journal of Phonetics 20:77-92.

Dhall, G.B. (1966) Aspiration in Oriya. Utkal University, Bhubaneswar, Orissa.

Fischer-Jørgensen, E. (1970) Phonetic Analyses of Breathy (Murmured)

Vowels in Gujarati," Indian Linguistics 28:71-140.

Foris, D. (1973) "Sochiapan Chinantec Syllable Structure," International Journal of American Linguistics 39.4:232-235.

Halle, M., and K.N. Stevens (1971) "A Note on Laryngeal Features," Quarterly Progress Report, Research Laboratory of Electronics, MIT 101:198-212.

Hirose, H., C.Y. Lee, and T. Ushijima (1974) "Laryngeal Control in Korean Stop Production," Journal of Phonetics 2:145-152.Hixon, T.J, J.

Hixon, T.J., D.H. Klatt, and Mead (1971) "Influence of Forced Transglottal Pressure Changes on Vocal Fundamental Frequency," Journal of the Acoustical Society of America, 49:105 (A).

Ito, J. (1989) "A Prosodic Theory of Epenthesis," Natural Language and Linguistic Theory 7:217-259.

Keating, P. (1990) "Phonetic Representations in a Generative Grammar," Journal of Phonetics 18:321-334.

Kingston, J. (1985) "The Phonetics and Phonology of the Timing of Oral and Glottal Events," Ph.D. dissertation, University of California, Berkeley.

Kohler, K.J. (1992) "Gestural Reorganization in Connected Speech: A Functional Viewpoint on 'Articulatory Phonology'," Phonetica 49:205-211.

Ladefoged, P. (1958) "Syllables and Stress," Phonetica 3:1-14.

Ladefoged, P. (1968) "Linguistic Aspects of Respiratory Phenomena," Annals of the New York Academy of Sciences 155, Article 1:141-151.

Ladefoged, P., and M. Lindau (1986) "Variability of Feature Specifications," in Symposium on Invariance and Variability of Speech Processses, J. Perkell and D. Kaltt, eds.

Ladefoged, P., I. Maddieson, and M. Jackson (1988) "Investigating Phonation Types in Different Languages" in O. Fujimora, ed., Voice Production, Mechanisms, and Functions. Raven Press, Ltd., New York. 297-317.

Lee, C.Y. and T.S. Smith (1971) "A Study of Subglottal Air Pressure in Korean Stop Consonants," Preliminary version, presented at the 82nd meeting of the Acoustical Society of America, Denver.

Lõfqvist, A. (1980) "Interarticulator Programming in Stop Production," Journal of Phonetics 8:475-490.

Lõfqvist, A. and H. Yoshioka (1980) "Laryngeal Activity in Swedish Obstruent Clusters," Journal of the Acoustical Society of America 68-3:792-801.

Maddieson, I. (1984) Patterns of Sounds. Cambridge University Press.

Merrifield, W.R. (1963) "Palantla Chinantec Syllable Types," Anthropological Linguistics 5.5:1-16.

Meuller, J. (1851) Manuel de Physiologie (translated from German by A. J.-L. Jourdan). 2nd edition, Paris: Chez J.-B. Bailliere.

Mugele, R.L. (1982) Tone and Ballistic Syllable in Lalana Chinantec. Ph.D. dissertation, University of Texas at Austin.

Ohala, J.J. (1990) "Respiratory Activity in Speech" in W.J. Hardcastle and A. Marchal, eds., Speech Production and Speech Modeling. Kluwer Academic Publishers, Netherlands. 23-53.

Plomp, R. (1967) "Pitch of Complex Tones," Journal of the Acoustical Society of America 41.6:1526-1533.

Remez, R.E. and P.E. Rubin (1984) "On the Perception of Intonation from Sinusoidal Sentences," Perceptual Psychophysics 35:429-440.

Rensch, C.R. (1978) "Ballistic and Controlled Syllables in Otomanguean Languages," in A. Bell and J.B. Hooper, eds., Syllables and Segments. North Holland Publishing Company, Amsterdam. 85-92.

Ritsma, R.J. (1967) "Frequencies Dominant in the Perception of the Pitch of Complex Sounds," Journal of the Acoustical Society of America 42.1:191-198.

Robbins, F.E. (1968) Quiotepec Chinantec Grammar. Papeles de la Chinantla IV. Seria Cientifica 8. Museo Nacional de Antropologia, Mexico.

Silverman, D. (in prep.) Acoustic Opacity and Acoustic Transparency in Chinantec. Ph.D. dissertation, University of California, Los Angeles.

Smith, K.D. (1968) "Laryngealization and De-laryngealization in Sedang Phonemics," Linguistics 38:52-69.

Titze, I.R. (1989) "On the Relation Between Subglottal Pressure and Fundamental Frequency in Phonation," Journal of the Acoustical Society of America 85.2:901-906.

Westley, D.O. (1971) "The Tepetotutla Chinantec Stressed Syllable," International Journal of American Linguistics 37.3:160-163.

Yoshioka, H., A. Löfqvist, and H. Hirose (1981) "Laryngeal Adjustments in the Production of Consonant Clusters and Geminates in American English," Journal of the Acoustical Society of America 70.6:1615-1623.

Yoshioka, H., A. Löfqvist, and H. Hirose (1982) "Laryngeal Adjustments in Japanese Voiceless Sound Production," Journal of Phonetics 10:1-10.