Why Comaltepec Chinantec is not different

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1. Introduction

In Comaltepec Chinantec, high tones spread to a following syllable when immediately preceded by a tautosyllabic low tone (Pace 1990, Anderson, Martinez, and Pace 1990, Silverman 1997). The alternation is almost always allophonic, i.e., non-neutralizing. Comaltepec is but one of many languages that spread (or displace) high tones rightward, especially in the context of immediately preceding lower pitch. In this paper, I offer a phonetic and functional account of the Comaltepec convention of high tone spread. Through a combination of factors—(1) variability in speech production, (2) the consequences of ambiguity and misunderstanding, and (3) the tendency for speakers to copy the variability they perceive—high tones which are immediately preceded by low tones may come to "spread" to a following vowel, which renders them more distinct from other tone patterns. Quite simply, those pronunciations of words which sound less like other, similar words, are more likely to be *perceived* correctly by listeners, and so are more likely to be *produced* as these listeners become speakers. The small variations in which speech sounds naturally engage are a means by which they take on new properties.

After considering the pattern from Comaltepec, I investigate other systems with similar patterns, focusing especially on Zulu, but also mentioning Beijing Mandarin, Zagreb Croatian, Peninsular and Mexican Spanish, Quiotepec Chinantec, and Mbui Bamileke.

2. Comaltepec Chinantec tone sandhi (Pace 1990, Anderson, Martinez, and Pace 1990, Silverman 1997)

Some examples of Comaltepec tone sandhi are provided in (1).

1.	non-sand	hi context:	sandhi context:	gloss:
	kwa/ ,	toː]	kwa/ to:\	'give a banana'
	kwa/ ,	ŋɨh]	kwa/ ŋɨh\	'give a chayote'
	kwa/ ,	kuː-	kwa/ ku:Y	'give money'
	kwa/ ,	ⁿ dʒuː-	kwa/ ⁿ dʒu:Y	'give a jug'

In (1), we see that L tones become HL tones in the context of a preceding LH tone. Also, M tones become HM contours in this same context. In Silverman 1997, I suggest that the phonetic underpinnings of this pattern are likely to lie in the fact that pitch rises take longer to implement than do pitch falls. Simada and Hirose (1970), Gårding (1970), Gårding Fujimura, Hirose, and Simada (1975), and Fujimura (1977) all observe a lag between peak laryngeal muscle activation and peak F0 in rising domains. Both Ohala and Ewan (1973), and Sundberg (1979)

experimentally document that pitch rises take longer to implement than pitch falls of the same acoustic distance. This is portrayed schematically in (2).



Given the sluggishness of pitch rises in comparison to pitch falls, the oral articulators may already have achieved the proper configuration for a following consonant *before* the pitch rise is fully achieved: upon the release of this subsequent consonant, finally, maximum pitch height is achieved. As suggested by Ohala (1978:31), "...[S]ince falling tones can be produced faster than rising tones...they might be less likely to 'spill over' onto the next syllable." This "spill over" effect is schematically portrayed in (3), in which consonant and vowel gestures are superimposed on the pitch-change pattern from (2).



When applying Sundberg's and Ohala and Ewan's experimental finding to phonological patterning, two problems come to the fore. First, just because speakers' physiological limits might be encountered in an experimental context does not mean that these limits will play a role in natural linguistic contexts. Indeed, only if it can be shown that speech patterns *exactly match* experimentally-determined physical limitations can we establish a direct link between phonetics and phonology. In fact, as far as I know, an *exact* match between physiological constraints and linguistic conventions has *never* been established in linguistic research. For example, Sundberg finds that women can increase their rate of pitch rise more quickly than can men, but no language is sensitive to such sex-based differences. But nonetheless, physiological constraints might come to constrain phonological patterning at a historic distance. That is, sound systems might not push the absolute limits of physiology, but might nonetheless come to be shaped by them.

Second, speakers exhibit exquisite control of their articulatory apparatus, and might modify their productions to accommodate to any raw, physical, ceiling- or floor-effects. For example, some

languages accommodate to the sluggishness of the laryngeal apparatus when pitch increases are implemented by lengthening the vowel (for example, Thai [Gandour 1978]), or by reducing the absolute pitch rise in comparison to a corresponding pitch fall (for example, Zapotec [Arellanes, *this volume*]). So again, a purely automatic phonetics is not capable of accounting for the different directions languages might take to accommodate to identical physical constraints, but nonetheless might serve to constrain the direction of sound change.

This is where functional forces on the system become relevant, which may, over generations of speakers, crucially interact with phonetic constraints. If high tones did not spread In Comaltepec, then they might be misperceived by the listener as belonging to the low tone category, due to the only limited temporal domain in which the pitch rise is implemented. In (4), the pitch rise is cut off as the second consonant is beginning, and does not achieve nearly as high a value.



Of course, synchronic neutralizations and diachronic mergers are commonplace. However, the overwhelming tendency is for contrasts to neutralize in contexts with insufficient opportunity for the salient expression of acoustic cues. For example, in coda position consonants typically lack their all-important release cues, and contrasts which depend release (for example, laryngeal contrasts) are often neutralized or suspended here. But when the opportunity for cue expression is greater, neutralization is much less common. As pitch increases can be effected after the following the consonant, and since there is a natural tendency for pitch rises to "spill over" anyway, the pitch rise may be better cued when it spreads. Also, since the tone alternation is allophonic in Comaltepec, and only rarely neutralizing (neither HL nor HM is lexically contrastive), tone spread better conveys the high tone value without obliterating other contrastive values. So, I'm suggesting that there is a phonetic influence on high tone spread in Comaltepec, and exactly because the high tone spread has functional value—meaning that contrastive values are more readily conveyed to listeners—this tone value has been conventionalized in its present form.

How might such a sound change come about? One possible answer comes two important observations about the nature of speech communication. First, there is INHERENT VARIABILITY in speech production. In the case at hand, some tokens of low-high tones will engage in the natural "spill-over" effect, while others will not. Second, listeners employ a form of PROBABILITY MATCHING when engaging in speech communication (Gallistel 1990, Labov 1994). That is, speakers' own productions largely match the sorts of variability that they perceive to be present in their speech community.

As there is inherent variability in speech production, in the history of Comaltepec both spread and non-spread tokens were among the possible variants. Learners come to largely reproduce the nuances of variation they perceive their elders engaging in, despite the fact that variants with spread tones are more successful at keeping contrastive elements distinct. Some tokens *without* spread will be ambiguous to listeners. These ambiguous tokens will sometimes be impossible to categorize as either high or low, and hence will not be added to the pool of tokens over which variability is calculated. Due to the greater likelihood of unambiguous perception of spread variants, and the greater likelihood of ambiguous perception of non-spread variants, learners' calculated variability may differ slightly from their elders', in that the variants which contrast more sharply with oppositions will more often be perceived correctly, hence, in turn, be more likely produced. The variability inherent in speech production may be the fodder for these sorts of sounds changes: the more distinct a variant is from an acoustically similar contrastive value, the more likely the system will wend towards this variant.

To summarize the argument, there is a natural tendency for high tones to "spill over" into the next syllable when immediately preceded by low tones. These high tones will be rendered more perceptually prominent to listeners upon their spreading. As listeners match their production probabilities to the patterns which they perceive, these perceptually more prominent variants are more likely to take hold in the system, and the sound change toward high-tone spread is set in motion.

In (5) I present a hypothetical diachronic scenario which incorporates the forces argued to be at work on the proposed sound change in Comaltepec. We might enter the sound change at a point in time when 75% of the tokens involve no high tone spreading, and 25% of the tokens involve spread. Let's assume that all (100%) spread tokens are conveyed correctly to listeners, but only 95% of the non-spread tokens are conveyed effectively; 5% of the non-spread tokens are not perceived by children as intended LH contours. Given this 5% loss, these listeners will perceive a slightly different distribution than their elders actually produced: 74% of the tokens will be perceived as lacking spread, and 26% of the tokens will be perceived as involving spread. Since variability in production derives from the variability that is *perceived* by listeners, not the variability that is *produced* by speakers, this generation's productions should differ slightly from their elders'. Moreover, given the natural phonetic tendency to spread high tones rightward, we may further allow for a natural 3% increase in the number of spread high tones. This increase does not derive from probability matching, but instead derives from natural phonetic tendencies. If phonological theorists wish to maintain a distinction between phonetics and phonology, they may say that this 3% of the total is phonetic in origin, while the remaining 97%—with all its variability-is phonological.



We may now see, given the small tendency to misperceive non-displaced tokens, coupled with the small phonetic tendency toward an increased number of displaced tokens, how, over the course of time, the conventions of the system may undergo change.

There are complications, however. M-final tones on syllables which lack post-vocalic laryngeals $(V^M, V^M and V^{HM})$ are tone sandhi triggers as well; observe that both long and short vowels may bear sandhi triggers. In (6) we see that L tones become HL, and M tones become HM, when preceded by M tones on syllables that lack post-vocalic laryngeals.

6.	M trigger	M triggers:					
	non-sand	hi context:	sandhi context:	gloss:			
	mir-j ,	hij	mi:⊣ hi∖	'I ask for a book'			

mir-	,	moh?]	miː⊣ moh?∖	'I ask for squash'
miː-	,	ku:-	mi:- ku:\	'I ask for money'
miː-	,	?o:-	mi:- ?o:\	'I ask for papaya'
miː-	,	ŋi႔	mɨːɨ ŋi ႑	'I ask for salt'
miː-	,	loh႔	mɨːɨ loh ႑	'I ask for a cactus'

Clearly, the proposed scenario cannot offer an immediate account of this pattern. However, in my 1997 paper, I report that sandhi-triggering M tones historically derive from Proto-Chinantec *H tones (7).

7.	Comaltepec:	Proto-Chinantec:	Proto-Chinantec:		
	ku:-	*kuː]	'money'		
	ndzœr-	*dʒuː]	'earthen jar/jug'		
	?wi:ŋ-	*?wir]	'Ojitlán' (a large Chinantec village)		

In that paper I proposed that these *H tones became analogically associated with LH triggers. In particular, H syllables that lacked post-vocalic laryngeals might become susceptible to high-tone spread. As these high tones lowered to mid, the "spreading" process remained. The reader is referred to my 1997 paper for an in-depth discussion of this and other complications.

3. High tone displacement in Zulu (Russell 2000, Silverman 2000)

It turns out that rightward H tone spreading from LH syllables is a rather common crosslinguistic pattern. Zulu, for example, displays a similar pattern in the context of an immediately preceding "depressor" consonant. "Depressor" consonants have been characterized as phonetically and/or historically breathy-voiced. These consonants get their name from the significant pitch-lowering that accompanies them upon consonantal release. Following depressor consonants, high-tones on short vowels are displaced from their vowel of origin to a following vowel: $DV_{\uparrow}CV_{\downarrow} \rightarrow DV_{\downarrow}CV_{\downarrow}$. Tone displacement is blocked if a depressor immediately follows: $DV_{\uparrow}DV_{\downarrow} \rightarrow DV_{\downarrow}DV_{\downarrow}$. Also, it does not take place from long vowels. Instead, the pitch rise is implemented exclusively on the first vowel itself: $DV_{!/}XV_{!}$. Again, as in Comaltepec, tone displacement in Zulu is usually allophonic, and may only rarely be neutralizing (Silverman 2000).

In (8) are some examples of high tone displacement (from Cope 1966; depressors are <u>underlined</u>; displaced tones are **bold**; depressor effects are *italicized*.)

8.	isiła:lo LH LL	chair	i <u>z</u> iła:10 ∧ L <i>L</i> HL L	chairs
	i↓ n s i: <u>z</u> w a H↓ L L	young man	$\begin{array}{c} \underline{j} \ \underline{i} \ \underline{n} \ \underline{s} \ \underline{i}: \underline{z} \ \underline{w} \ \underline{a} \\ \overline{-} \ \qquad \land \qquad \\ L \mathbf{HL} L \end{array}$	by a young man

i n o: n i	bird	<u>n</u> e n o: n i	with a bird
		$ \land $	
H L L		L HL L	

In (9) I exemplify the remainder of the pattern.

9.	a.	no displacement from	long vowels:	displacement from she	ort vowel:
		<u>z</u> i: k ^h o: n a	they being present	<u>z</u> i k ^h oː n a	they are present
		\land		$ \land $	
		<i>L</i> H L H		L H L H	
	b.	<u>no displacement from</u> (lengthened) penults:	phrase-final	displacement from she	ort vowel:
		i^{\uparrow} n d ^h u: n a	headman	e n d ^h u n e: n i	to a headman
		H LH L		H L HL L	
	c.	no displacement when	n a depressor follows:		
		$i \underline{z} i \underline{g!^{h}} o: k o$	hats		
		LLH L L			
		e [↑] m <u>b^h</u> u <u>z</u> i: n i \land	to a goat		
		H^{\perp} LH L L			

In (10) I provide spectrographic examples of both non-displaced (10a) and displaced (10b) high tones. Observe the significant difference in pitch on the relevant vowels (indicated by the arrows). In (10b) the high pitch is not in phonetic evidence on the first vowel, and instead is realized after the following consonant. Regarding (10a), in my 2000 paper I attributed the higher pitch on the initial portion of [a:] to the increased airflow immediately following the voiceless lateral. I suspect that this was a mischaracterization. Instead, the high pitch here might simply be another instance of Ohala's "spill-over" effect.



What is the origin of the pitch lowering effect of depressor consonants? Voiced stops typically induce pitch lowering upon release, whereas voiceless stops typically induce pitch raising. Some researchers (for example, Ohala 1972, Ewan and Krones, 1974, Ewan 1976, Hombert, Ohala, and Ewan 1979) implicate the tenseness versus laxness of the vocal folds at the point of stop release to account for these pitch perturbations. In certain contexts, contrastively voiced stops may be accompanied by an overall enlargement of the sealed supraglottal cavity. This cavity enlargement allows more air to cross the glottis into the sealed chamber, increasing the duration of transglottal flow, and increasing the duration of vocal fold vibration, which is likely to heighten the salience of closure voicing cues. Cavity expansion may be achieved in a number of ways, including cheek puffing, pharyngeal widening, velic raising, and larynx lowering. Larynx lowering may also involve an apparent automatic laxing of the vocal folds. It is this fold laxing which might contribute rather significantly to the observed pitch lowering observed at the release of voiced stops, as lax vocal folds are a well-attested concomitant of a lowered rate of vocal fold vibration, and lowered pitch (Hombert 1978) (11).

11.



Hombert, and also Ohala (1978), Riordan (1980) and Kingston (1985a,b) discuss certain empirical problems with the so-called "vertical tension hypothesis". However, all nonetheless concur that a positive correlation indeed exists between stop voicing and pitch lowering at release.

When we add the partial vocal fold abduction necessary for breathy voicing, further pitch lowering may be induced, as the fold laxing which accompanies abduction typically occurs with a still-lower rate of vocal fold vibration (12).



We can now see the parallels between the phonetic situation in Zulu, and that already discussed in Comaltepec. In both cases, the pattern involves a rising pitch. Again, since pitch rises take longer to implement than do pitch falls, then in the context of a depressor consonant, maximum pitch height may be achieved only *after* the following consonant has been completed, culminating in an apparent displacement of the high tone. In Zulu, unlike in Comaltepec, the system has conventionalized toward an absence of displacement in the context of long vowels. Such long vowels are apparently of sufficient duration to accommodate the pitch rise: the rise is achieved before the following consonant is implemented, and so there is no apparent displacement. (13).



As following depressors once again induce a pitch-lowering effect upon their release, there is equally little hope of the displaced high tone being realized in this context (14).

14.



Interestingly, Russell (2000) determines that short vowels flanked by depressors in Zulu are significantly longer than the other short vowels: as pitch cannot be displaced in this context due to the presence of a *following* depressor, the vowel may have evolved to be longer in order to provide a better opportunity for a pitch increase to be implemented, and consequently conveyed to listeners.

I'd like to reiterate that the contrast between lack of displacement from Zulu long vowels, and the presence of spread from Comaltepec low-high contours on long vowels, should not be viewed as an immediate and automatic consequence of phonetic constraints. Rather, the languages have responded to universal phonetic constraints by conventionalizing slightly different articulatory routines. Automatic phonetics may indeed constrain both systems, but only at a paleophonetic distance. So a phonetically-*influenced* (though not strictly phonetically-*determined*) pattern emerges in both languages.

In (15) I provide a table which summarizes the story so far.

13.

15.		
	Comaltepec	Zulu
Phonetic trigger:	Lower pitch as a consequence of a lexical low tone, immediately followed by a tautosyllabic high tone	Lower pitch as a consequence of depressor consonants, immediately followed by a tautosyllabic high tone
Conventionalized consequence:	High tone spread to a following vowel	High tone displacement to a following vowel
Conventionalized Consequences for long vowels:	Spread is generalized to take place from lexical long vowels	Displacement does not take place from automatically lengthened vowels
Analogical extensions:	Level *H tones (present-day M) on syllables lacking post- vocalic laryngeals also trigger H tone spread	Level H tones may spill over onto a following vowel.

Dissimilar languages possess similar patterns

Given both the phonetic and functional forces that interact in both Comaltepec and Zulu, it should not be surprising that quite a number of other languages display similar patterns of high pitch spread/displacement.

In Beijing Mandarin, for example, rising tones typically peak only after the following consonant has been implemented; tones with low offsets show a significantly lesser effect in these same contexts (Xu 1997, Xu and Wang 2001)

In Zagreb Croatian, high pitch-accented syllables possess a rising pitch contour, pitch peaks being realized on the post-tonic syllable, rather than on the accented syllable itself (Lehiste and Ivic 1986).

In both Peninsular and Mexican Spanish, stressed syllables typically possess a pitch rise, with the pitch peak being realized on the post-stressed syllable (Navarro-Tomás 1944, Fant 1984, Prieto, van Santen, and Hirschberg 1995, Kim and Avelino *this volume*).

According to Gardner and Merrifield (1990), in the Quiotepec dialect of Chinantec, an arbitrary set of open syllables possessing M or LM tones is raised to H in the context of a preceding LH or MH contour (16).

6.	non-sandhi context:			sandhi context:	gloss:	
	k ^w ó۱	tữ-	\rightarrow	k ^w ó₁ tấ́ ๅ	give (me) two	
	cý:1	t ^j ý j	\rightarrow	cý:1t ^j ý⊺	good earthen jar	
	sir/	d ^j á-j	\rightarrow	siː/ dʲá⁊	shave down ten	
	∫ý? /	t ^j új-j	\rightarrow	∫ý?∧ t ^j új⊺	good armadillo	
	∫ý?∕	bố-	\rightarrow	∫ý?∕ bố́]	stupid armadillo	

In Mbui Bamileke high tones often shift from a leftward syllable to a rightward syllable (Hyman and Schuh 1974) (17).

11

17.	non-sandhi o	context:	sandhi context:	gloss:	
	lòó	bàsáŋ 🔶	lòò básáŋ	look for the birds	
	lòó	tiè →	lòò tiè	look for the pot	
	lòó	sáŋ 🔶	lòò sớŋ	look for the bird	

Conclusion

Physical properties of the speech mechanism—phonetic factors—may induce a delay in achieving higher pitch in the context of preceding lower pitch. But independent functional factors may induce the conventionalization of high tone spread or displacement. As tones are less likely to neutralize upon spread/displacement, displaced tokens are less often ambiguously perceived, hence more likely to be reproduced. Slowly, over generations of speakers, these phonetic and functional forces may induce a reconventionalization of the tonal system.

References

- Arellanes, Francisco (this volume) "Los tonos en el zapoteco de San Pablo Güilá: de la manifestación fonética a la opertinenica fonológica.
- Cope, A.T. (1960) "Zulu tonology," Afrika und Übersee XLIII:190-200.
- (1966) Zulu phonology, tonology and grammar. Ph.D. dissertation, University of Natal.
- Ewan, William G. (1976) Laryngeal behavior in speech. Ph.D. dissertation, University of California at Berkeley.
- _____, and Robert Krones (1974) "Measuring larynx movement using the thyroumbrometer," Journal of Phonetics 2.327-335.
- Fant, L. (1984) "Estructura informativa en español. Estudio sintáctico y entonativo," *Acta Universitatis Upsaliensis* 34, Uppsala.
- Fromkin, Victoria (1978) editor, Tone: a linguistic survey, New York : Academic Press.
- Fujimura, Osamu (1977) "Control of the larynx in speech," *Phonetica* 34:280-288.
- Gallistel, Charles R. (1990) The organization of learning. Cambridge MA, MIT Press.
- Gandour, Jack (1977) "On the interaction between tone and vowel length: Evidence from Thai dialects," *Phonetica* 34:54-65.
- Gårding, Eva (1970) "Word tones and larynx muscles," *Working Papers, Phonetics Laboratory*, Lund University 3:20-46.
- ____, Osamu Fujimura, Hajime Hirose, and Z Zyun'ichi Simada (1975) Laryngeal control of Swedish word accents," *Working Papers, Phonetics Laboratory*, Lund University 10:53-82.
- Gardner, Richard, and William R. Merrifield (1990) "Quiotepec 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, 91-106.
- Hombert Jean-Marie (1975) Towards a theory of tonogenesis: an empirical, physiologically and perceptually-based account of the development of tonal contrasts in languages. Ph.D. dissertation, University of California, Berkeley.
- (1978) "Consonant types, vowel quality, and tone," in V. Fromkin, ed., 77-111.
- ____, John J. Ohala, and William G. Ewan (1979) "Phonetic explanations for the development of tones," Language 55:37-58.
- Hyman. Larry M. and Russell G. Schuh (1974) Universals of tone rules: evidence from West Africa. Linguistic Inquiry 5:81-115.

- Kim, Sahyang, and Heriberto Avelino (this volume) "An intonational study of focus and word order variation in Mexican Spanish.
- Kingston, John (1985a) *The phonetics and phonology of the timing of oral and glottal events*. Ph.D. dissertation, University of California, Berkeley.
- ____, (1985b) "The linguistic use of vertical larynx movement," manuscript, University of Texas at Austin.
- ___, and Randy L. Diehl, (1994). Phonetic knowledge. Language 70:419-454.
- Khumalo, J.S.M. (1981) "Zulu tonology, part 1," African Studies 40:53-130.
- Labov, William S. (1994) Principles of linguistic change. Oxford, Blackwell.
- Lehiste, Ilse, and P. Ivic (1986) *Word and sentence prosody in Serbocroation*. Cambridge: MIT Press.
- Maddieson, Ian (1978) "Universals of tone," In J.H. Greenberg, ed., *Universals of human language*. Stanford University Press, 335-365.
- (1997) "Phonetic universals," in William J. Hardcastle and John Laver *The handbook of phonetic sciences*. Oxford : Blackwell, 619-639.
- Navarro-Tomás, Tomás (1944) *Manuel de entonación española*. New York: Hispanic Institute in the United States.
- Ohala, John J. (1978) "Production of tone," In V. Fromkin, ed., 5-39.
- ____, and William G. Ewan (1973) "Speed of Pitch Change," Abstract, *Journal of the Acoustical Society of America* 53:345.
- Pace, Wanda Jane (1990) "Comaltepec Chinantee Verb Inflection," in W.R. Merrifield and C.R. Rensch, eds., *Syllables, Tone, and Verb Paradigms.* Studies in Chinantee Languages v.4. Summer Institute of Linguistics, 21-62.
- Prieto, Pilar, Jan van Santen, and Julia Hirschberg (1995) "Tonal alignment patterns in Spanish," *Journal of Phonetics* 23:429-451.
- Riordan, C.J. (1980) "Larynx height during English stop consonants," *Journal of Phonetics* 8:353-360.
- Russell, Margaret (2000) "Phonetic aspects of tone displacement in Zulu," in Arika Okrent, and John Boyle, eds., *The Proceedings of the Chicago Linguistic Society* 36.1:427-439. Chicago: Chicago Linguistic Society.
- Silverman, Daniel (1997) "Tone sandhi in Comaltepec Chinantec," Language 73.3:473-492.
- ____, (2000) "Hypotheses concerning the phonetic and functional origins of tone displacement in Zulu," *Studies in African Linguistics* 29.2.
- Simada, Zyun'ichi and Hajime Hirose (1970) "The function of the laryngeal muscles in respect to word accent distinction.," *Annual Bulletin, Research Institute for Logopedics and Phoniatrics*, University of Tokyo 4:27-40.
- Sundberg, Johan (1979) "Maximum speed of pitch changes in singers and untrained subjects," *Journal of Phonetics* 7.2:71-79.
- Xu, Yi (1997) "Contextual tonal variation in Mandarin" Journal of Phonetics 25:61-83.
- ____, and Q. Emily Wang (2001) "Pitch targets and their realization: evidence from Mandarin Chinese," *Speech Communication* 33:319-337.