VOICELESS NASALS IN AUDITORY PHONOLOGY

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Löfqvist (1980) suggests that for each supralaryngeal configuration there is, more or less, a corresponding laryngeal target. And since the larynx and the supralaryngeal articulators are largely independent of each other, we may assume that any given laryngeal target has a particular functional goal, and isn't merely an automatic consequence of the supralaryngeal configuration. For example, plain intervocalic voiceless stops are often accompanied by a laryngeal abduction. Far from being an automatic consequence of an stop, a spread glottis here serves the functional role of inhibiting the voicing that might otherwise occur upon a sufficiently brief oral closure, thus potentially salvaging a contrast between voiceless and voiced stops.

However, laryngeal gestures may also possess contrastive status in and of themselves, and similarly, are often associated with particular supraglottal configurations. In this paper, I discuss how spreading the glottis during a nasal stop contributes to the achievement of a potentially contrastive acoustic state. In particular I investigate the timing of this laryngeal gesture with respect to the nasal stop--these are so-called "voiceless" and "breathy" nasals--and how certain particular timings here serve to better encode the relevant acoustic information at the level of the peripheral auditory system.

My claims, then, are that different timings of articulatory gestures with respect to one another culminate in better or worse percepts. The better the percept, the less marked the pattern, and the worse the percept, the more marked the pattern. Optimal timing patterns correlate with degree of auditory nerve response: the greater the auditory nerve response, the less marked the pattern, and the lesser the auditory nerve response, the more marked the pattern. A functional link may thus be established between recoverability and markedness.

Consider first how place of articulation is cued in a plain nasal. Pooling the results of several studies (Fant 1960, Fujimura 1962, Recasens 1983, Dantsuji 1984,86,87, Kurowski and Blumstein 1984, Bhaskararao and Ladefoged 1991), it seems that CV formant transitions primary in conveying place information, VC formant transitions secondary, and nasal murmur formants tertiary. Here, the steady state portion of the nasal, often called the nasal murmur, contains place cues primarily in the form of a nasal zero, or anti-resonance; a frequency range of dampened energy. In Burmese and Catalan, for example, studies show that the murmur itself can help to cue place of articulation. The farther back in the oral cavity the constriction, the higher in frequency is this reduction in energy. Moreover, nasality as a class may be cued by both a low frequency formant, as well as a mid-range energy plateau. So intervocalic nasals, for example, ama, ana, aŋa, enjoy an abundance of cues, and not coincidentally, are never subject to neutralization due to lack of cues.

Now, if a spread glottis is implemented simultaneously with a nasal stop (an̥a, am̥a, aŋ̥a) what are the acoustic consequences? Again, pooling the results of several researchers (Ladefoged 1971, Ohala 1975, Dantsuji 1984, 1986, 1987, Ladefoged and Maddieson 1995), CV formant transitions would be obscured, VC formant transitions would be obscured, and nasal murmur formants would be obscured. This, of course, is a most undesirable result, because the functional gain of adding the aspiration is lost by losing oral place contrasts.

Instead, the spread glottis is normally timed to the early portion of the nasal stop. In this fashion, a partial nasal murmur survives, and most importantly, CV transitions survive as well, and so all place information is recoverable. So, in Burmese for example, we find aN̥ma, aN̥na, and aN̥ŋa. The typology of voiceless nasals can be accounted for by the salience of contrastive cues. Henderson (1985), for example, reports that voiceless nasals of the Burmese form are cross-linguistically more common than others.

But why should this be the canonical realization of voiceless nasals? Relatedly, why are CV transitions especially important? The answer I would like to suggest derives from certain neurological facts about the peripheral auditory system. Briefly, Bladon discusses some of the major principles of what he terms "auditory phonetics." For present purposes, the two principles in (1) are most relevant.

(1) On/off response asymmetry: spectral changes whose response in the auditory nerve is predominantly an onset of firing are much more perceptually salient than those producing an offset (Tyler, Summerfield, Wood, and Fernandes 1982).
Short-term adaptation: after a rapid onset of auditory nerve discharge at a particular frequency, there is a decay to a moderate level of discharge, even though the same speech sound is continuing to be produced (Delgutte 1982).

The generalization here is that acoustic signals that involve abrupt increases in acoustic energy trigger maximal auditory nerve response, and presumably result in better percepts.

So in (2), I provide a schematic of the articulatory and acoustic properties of the canonical voiceless nasal, and most importantly, the distorting effect imparted by the auditory nerve. Observe that sudden increases in energy--from voiceless nasal flow, to nasal murmur, to vowel--results in a heightened neural response, which, again, presumably results in a better percept.

So let's look at Burmese in some detail. In (3) are pairs which minimally contrast for voicelessness.

(3)	voiced nasals:		voiceless nasals:	
	mâ̰	lift up	N̥͡mâ̰	from
	na	pain	N̥͡na	nose
	ɲa	right	N̥͡ɲa	considerate
	ŋâ	fish	N̥͡ŋâ	borrow

Far more interesting are the forms in (4), taken from Okell's (1969) grammar. Voicelessness here is not only lexical, but is morphemic as well, resulting in anti-passive verbs. These are termed "h/non-h pairs" by Okell. In (4a) are plosives. Note that aspiration here is realized at stop release, after the oral occlusion which, as I've argued elsewhere (along with Kingston 1985, 1990), is the optimal realization of oral stops modified by glottal spreading. In (4b), the linear ordering of the breath morpheme is preceding the plain voiced nasal. So, whether plosive-initial or nasal-initial, the breath morpheme is optimally timed with respect to its affiliated supralaryngeal gesture.

(4) morphological aspiration (h/non-h pairs--Okell 1969):

a. obstruent-initial:

pi	be pressed	phi	press, compress
pe	break off, be chipped	phe	break off (a piece)
po	appear	pho	reveal
ceʔ	be cooked	cheʔ	cook
sowʔ	be torn, shabby	showʔ	tear
suʔ	be damp	shuʔ	moisten, make damp
kwe	be split, separated	khwe	split, separate

b. nasal-initial:

mjin	be high, tall	N̥͡mjin	raise, make higher
niʔ	be submerged, sink	N̥͡niʔ	submerge, sink
ne	be loose	N̥͡ne	loosen (in socket, etc.)
naʔ	be completely cooked	N̥͡naʔ	complete cooking

By contrast, in Sukuma (Maddieson 1991), the involved gestures are timed rather differently. Instead of early voicelessness, we see late breathiness, that is, the simultaneity of voicing and glottal spreading. m͡m̤, n͡n̤, ŋ͡ŋ̤ In (5) are some examples.

(5)

ndɪɪn͡n̤ɔ̤͡ɔ	ladle
m͡m̤a̤͡ala	gazelle
m͡m̤a̤͡ala n͡n̤a̤͡ale	small gazelle
m͡m̤a̤͡ajɔ	word

Were voicing not present here, the all important offset formant transitions would be fully obscured by voicelessness, that is, by the spread glottis. Consequently, when a language possesses this alternative timing pattern, this additional articulatory asymmetry is necessarily present, so that all contrastive information is recoverable. However, this timing configuration comes at an articulatory cost, as breathy phonation requires the larynx to be spread at one end, and simultaneously adducted at the other.

At the auditory level, the sequence of acoustic events, from nasal murmur to breathy nasal to vowel, is perhaps somewhat inferior to the incremental rise in energy found in Burmese. Nonetheless, all contrasts are fully recoverable here as well.

Finally, let's consider the case of Comaltepec Chinantec (Anderson 1989, Anderson, Martinez, and Pace 1990, Pace 1990, Silverman 1995). As in Burmese, Chinantec has voiceless nasals with early voicelessness. Some examples are provided in (12).

(12)	N̥͡mɨː˩	water
	N̥͡ɲœː˩	green beans
	N̥͡ŋaɟɲʔ˩˨	he kills

However, Chinantec also has voiceless nasals in post-vocalic position, stem-finally. Here, strangely enough, we witness the full simultaneity of all gestures, oral stop, velic lowering, and glottal spreading, with no voicing whatsoever. This pattern would seem to contradict my claims, as such a timing configuration fully obscures oral place of articulation. As it turns out, place of articulation is non-contrastive in such contexts. Anderson, Martinez, and Pace report that the post-nuclear nasal assimilates in place of articulation to a following consonant. Examples are in (13).

(13)	ka˩w̥wen̥ʔ˩˨ neʔ˩		the animal was frightened
	ʝjuːn̥˩˥la˥˧		this child
	ʝjuːn̥˩˥zeʔ˦		sick child
	pimʔ˥	(<..Nʔ + p)	he is tiny
	ʝjuːm̥˩˥piŋʔ˥		small child

ʝjuːŋ̊˩˥kʌŋʔ˧˥		big children
w̰wiŋ̊ʔ˥		black child
ʝjuːŋ̊˩˥haŋʔ˧˥		perverse child
ni˩l̥lejɲ̊˧˥	(<..N̥ + ʐ)	he will tremble
ʔʌjɲ̊˧˩	(<..N̥ + ʐ)	he pulls (him)"

So Chinantec is not contradictory at all. Instead, since place of articulation is non-contrastive here, voicelessness is free to co-occur in full parallel with velic lowering: no contrasts are jeopardized.

In summary, then, different timings of articulatory gestures with respect to one another culminate in better or worse percepts. Optimal timing patterns correlate with degree of auditory nerve response: the greater the auditory nerve response, the less marked the pattern, and the lesser the auditory nerve response, the more marked the pattern. For nasals with contrastive laryngeal abductions, pre-voicelessness is optimal, and cross-linguistically more prevalent than its sub-optimal post-breathy counterpart. So a functional link may be established between the timing of articulatory gestures and their recoverability.

This research was funded in part by NIH Training Grant T32 DC 00008.

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