Current Issues in Linguistic Theory

The Phonological Spectrum

Volume I: Segmental structure

EDITED BY
Jeroen van de Weijer
Vincent J. van Heuven
Harry van der Hulst

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VOLUME I: SEGMENTAL STRUCTURE

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Preface

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The two volumes of the *Phonological Spectrum* aim at giving a comprehensive overview of current developments in phonological theory, by providing a number of papers in different areas of current theorizing which reflect on particular problems from different angles. Volume I is concerned with segmental structure, and focuses on nasality, voicing and other laryngeal features, as well as segmental timing. With respect to nasality, questions such as the phonetic underpinning of a distinctive feature [nasal] and the treatment of nasal harmony are treated. As for voicing, the behaviour of voicing assimilation in Dutch is covered while its application in German is examined with an eye to its implications for the stratification of the German lexicon. In the final section of volume I, the structure of diphthongs is examined, as well as the treatment of lenition and the relation between phonetic and phonological specification in sign language.

Volume II deals with phonological structure above the segmental level, in particular with syllable structure, metrical structure and sentence-level prosodic structure. Different syllable structure theories, as well as possible relations between segment structure and syllabic structure, and evidence from language acquisition and aphasia are examined in Section 1. Metrical structure is examined in papers on foot structure, and, experimentally, on word stress in Indonesian. Finally in this volume, there are three laboratory-phonological reports on the intonation of Dutch.

December 2002

Nasality, voice and more

Vincent J. van Heuven, Harry van der Hulst, and
Jeroen van de Weijer

This volume is concerned with segmental structure, and focuses on nasality (Section 1), voicing and other laryngeal features (Section 2), as well as segmental timing (Section 3).

With respect to nasality, questions such as the phonetic underpinning of a distinctive feature [nasal] and the treatment of nasal harmony are treated. In the first article ('Nasal harmony in functional phonology') by Paul Boersma, the claim is made that processes of nasal harmony should be approached from both an articulatory as well as a perceptual point of view, unlike previous approaches to the different types of nasal harmony that occur cross-linguistically. Rachel Walker ('Reinterpreting transparency in nasal harmony') examines variation in nasal harmony, which has long been known to vary considerably cross-linguistically in terms of undergoing segments. These differences can be described as corresponding to different constraint rakings in the OT framework, and bear on the analysis of transparency and locality in feature spreading. Finally, the paper by Stefan Ploch explores the question of whether phonological 'nasality' can be derived from phonetic nasality. His conclusion is that it is not possible to predict on the basis of phonetic measurement of the nasal airstream whether a phonological unit of nasality should be postulated, and thus proposes that this element has an abstract, 'cognitive' status.

In Section 2, the behaviour of voicing assimilation in Dutch is covered while its application in German is examined with an eye to its implications for the stratification of the German lexicon. In her article 'The role of phonology and phonetics in Dutch voice assimilation', Mirjam Ernestus shows that the categorial status of the different rules for voicing in Dutch may well have to be refined giving the large range of factors that affect the phonetic outcome of certain inputs. Caroline Féry ('Final Devoicing and the stratification of the lexicon in German'), like Ernestus, deals with the well-known phenomenon of final devoicing in German and argues that an adequate analysis requires a stratification of the phonological lexicon in terms of native, foreign, loan, etc. Finally, Eon-Suk Ko ('The laryngeal effect in Korean: Phonology or phonetics?') also focuses on the laryngeal features, but here the distinctions between lenis, aspirated and tense consonants in Korean are specifically at stake. Ko argues that the phonetic segmental effects associated with these consonants belong to the phonetics, not the phonology.

In the final section of Volume I, the structure of diphthongs is examined, as well as the treatment of lenition and the relation between phonetics and phonology in sign language. Diphthongs in Swabian are the topic of Markus Hiller's paper. He discusses the question whether minute details regarding timing should be specified in underlying representation or left to the phonetic implementation. Philipp Strazny ('Depression in Zulu: Tonal effects of segmental features') examines the interaction of laryngeal quality and tone in Zulu. K. G. Vijayakrishnan examines lenition processes and claims that Optimality Theory provides a better angle on these than previous autosegmental frameworks, focusing on Tamil specifically. Finally, Onno Crasborn and Els van der Kooij ('Base joint configuration in: Phonetic variation and phonological specification') show that the status of the base joints in the hand does not have to be specified in the underlying representation of signs in Sign Language of the Netherlands: the phonetic output of these joints can in all cases be derived from other factors.

Nasality

Nasal harmony in functional phonology*

Paul Boersma
University of Amsterdam

This paper will show that a theory of phonology that distinguishes between articulatory and perceptual representations and processes (Boersma 1998) accounts for the typological facts of nasal harmony more succinctly and with fewer assumptions for innate substantive devices, than theories that maintain a single kind of phonological features and a single phonological grammar, like the theories applied to nasal harmony by Piggott (1992), Piggott and Van der Hulst (1997), and Walker (1998).

1. Representations: The case of the nasal glottal stop

Nasal harmony is one of the areas of phonology in which articulatory and perceptual representations bear no one-to-one relationship, so that a failure to distinguish between them is bound to lead to confusion and controversy. The single issue discussed most often in the literature is the representation of the sequence [ãʔ̃ã], which can arise from the rightward spreading of nasality from a nasal consonant through a glottal stop, as in Sundanese [nũʔ̃ũs] 'to dry' (Cohn 1990: 52). All writers agree that the velum, which must be down during the two instances of [ũ], is also down throughout the glottal stop, but that no nasality is present acoustically during the glottal closure because this closure causes the nasal airflow to fall to zero (Piggott 1992: 39; Cohn 1993: 347; Walker & Pullum 1999: 766). This section will address the articulatory and perceptual representations of the nasal glottal stop, and show why both of these representations are needed in a phonological account of spreading of nasality through glottal stops.

1.1 Articulatory representations

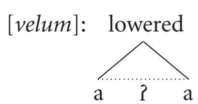
The articulations of [ãʔ̃ã] are shown in (1).

(1) *Articulatory score for* [ãʔ̃ã]

glottis:	adducted	constricted	adducted
velum:	lowered		
lips:	open		
pharynx:	narrow		

In this articulatory score, time runs from left to right, and the tiers are time-aligned with each other. The only two articulatory ***contours*** in this score are the closing and opening of the glottis. These can be regarded as the results of separate closing and opening gestures, or as the results of a composite closing-and-opening gesture. All the other articulators are stationary. The velum stays down, so that the velopharyngeal port stays open, and the supralaryngeal cavities stay in a shape appropriate for [a] (lips open, pharynx narrowed, jaw lowered). The expiratory actions of the lungs are not shown. For practical reasons we can abbreviate articulatory representations as a sequence of IPA symbols within square brackets, thus writing (1) simply as [ãʔ̃ã], with a nasalization symbol above the glottal stop in order to express velum lowering. With an intermediate degree of abbreviation, we could depict this articulation as a tree with links from the feature value [lowered velum] to the three segments involved:

(2) *Articulatory tree for* [ãʔ̃ã]



The dotted line expresses the fact that articulator positions like [lowered velum] must be defined on a continuous stretch in time without any intervening gaps.

1.2 Acoustic representations

The main uncategorized perceptual results of the articulation (1) are summarized in (3).

(3) *Acoustic events as a result of* [ãʔ̃ã]

silence:		+	
place:			gl.bu.
voice:	+		+
F1:	open		open
nasal:	+		+
	ã	_	ˀ ã

Again, time runs from left to right on each tier, and all of these perceptual tiers are time-aligned with each other and with the articulatory score in (1). On the perceptual place tier, we see the abbreviation "gl.bu.", which stands for a glottal release burst; we can note that [glottal] is a value on the perceptual place tier, just as bilabial, apico-dental, pharyngeal, etc., since all of these are associated with their own acoustic spectral characteristics. "F1" stands for the first formant, which is the acoustic cue that we perceive as vowel height. The feature /nasal/ refers to audible resonances in the nasal tract and is present only during the vowels, not during glottal closure. Below the perceptual tiers, we see an IPA notation of the auditory states and events, where "_" denotes silence and "ˀ" the glottal release burst. The acoustics of (2), then, can be abbreviated with the ***microscopic transcription*** [[ã _ˀã]] (Boersma 1998: 30).

1.3 Perceptual representations

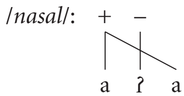
What the listener perceives in [[ã _ˀã]] is not just this sequence of acoustic states and events. She assigns hidden structures to it, like segments, syllables, and feet, in a language-specific way, thus retrieving from the raw acoustic signal a discrete phonological code that allows her to compare the utterance with the entries in her lexicon. One of these abstractions may be the *segmental* level, and we could write the utterance on this level as /ãʔã/, without a nasalization symbol above the glottal stop in order to express the absence of the main cue for nasality there. As a representation of perceived nasality, however, the shorthand between the slashes is ambiguous: do the two nasalization symbols refer to the same feature value, or to two separate feature values? As an example of the former, the tree in (3) shows a truly 'linear' segmental representation:

(4) *Segmental nasality*

/nasal/: + – +
| | |
a ʔ a

But nothing in what we know about human perception tells us that perceived entities should be continuous: if we look at a car behind a lamp-post, we perceive a single car, not two halves. Likewise, the two nasality cues in [[ã_ˀã]] may well be perceived as a single nasal feature value:

(5) *Suprasegmental nasality*



Which of the two representations (4) or (5) applies in the language at hand, depends on the domain on which nasality tends to be specified. In a language like French, where every vowel can be nasal or non-nasal more or less regardless of the nasality of the adjacent segments, (4) is likely to be the best choice for the listener. In a language like Guaraní, where words have either only nasal or only non-nasal vowels, (5) is more appropriate, because it creates a shorter code.

1.4 Hybrid representations

I think we should stop here and regard (1), (4), and (5) as the representations relevant for phonology. However, generative theories of phonological representations have not stopped here, and have always advocated the existence of a single cognitive feature [nasal], which is supposed to have articulatory as well as perceptual correlates. However, this position becomes problematic in cases where one of these two correlates is absent, as in the case of [ãʔ̃ã] /ãʔã/. An amusing controversy arises in the discussion about whether the glottal stop in [ãʔ̃ã] /ãʔã/ is phonologically nasal or not. Cohn (1993: 349) considers this glottal stop *phonetically nasal*, because the velum is lowered, but *phonologically non-nasal*, since it is *transparent* to nasal spreading, lacking a supralaryngeal node and therefore a nasality node. Piggott (1992: 39), by contrast, calls this glottal stop *phonetically non-nasal*, because there is no nasal airflow, but *phonologically nasal*, because it must be considered a *target* (undergoer) of nasal spreading. Cohn appears to have an articulatory view of phonetics and a perceptual view of phonology, whereas Piggott seems to have a perceptual view of phonetics and an articulatory view of phonology. The cause of this confusion is that Cohn and Piggott share the standpoint that there must be a single phonological feature [nasal]. As soon as we accept that both the articulatory feature [lowered velum] and the perceptual feature /nasal/ are phonologically active, the controversy vanishes: the glottal stop under discussion is articulatorily ‘nasal’, perceptually ‘non-nasal’, and it is articulatorily an undergoer of ‘nasal’ spreading and perceptually transparent to it. A formal theory about how phonology revolves around these two kinds of representations, is presented in Boersma (1998), and I will presently describe how it works out for the case of nasal harmony.

2. Processes

2.1 The grammar model of functional phonology

Since Cohn and Piggott share the view that phonetic implementation follows the phonology, their opposing views of phonological and phonetic representation return in their views on the derivation of the phonetic form:

(6) *Generative views of spreading nasality through a glottal stop*

	Underlying form:		Phonological form:		Phonetic form:
Cohn:	|naʔa|	→	/nãʔã/	→	[nãʔ̃ã]
Piggott:	|naʔa|	→	/nãʔ̃ã/	→	[nãʔã]

In both of these conflicting derivations, the first arrow denotes the phonological process of nasal spreading, and the second arrow denotes phonetic implementation. If we distinguish between articulation and perception, the derivation becomes very different, the most important difference being the reversal of the order of the phonological and phonetic surface forms:

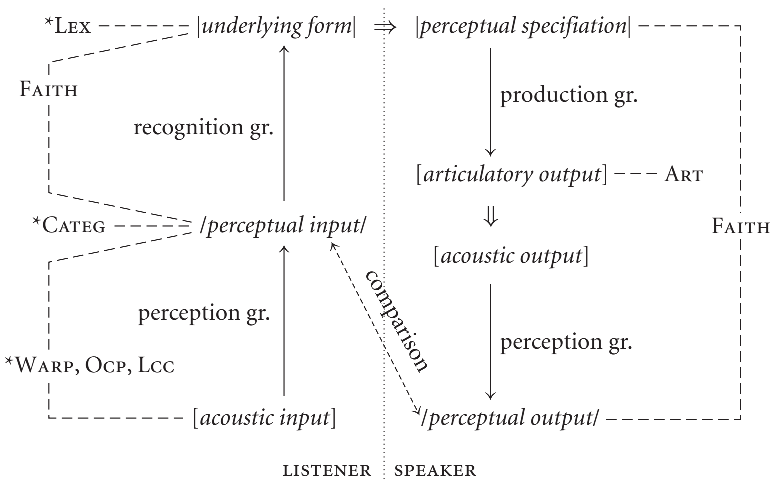
(7) *Functional view of spreading nasality through a glottal stop*

Underlying form:		Articulatory form:		Perceptual form:
|naʔa|	→	[nãʔ̃ã]	→	/nãʔã/

The first arrow denotes the phonology and phonetic implementation, which are not seen as separate modules, and the second arrow denotes the speaker’s perception process, whose task it is to convert a raw articulatory (acoustic, ‘phonetic’) form into a more discrete perceptual (‘phonological’) form. In this ***specification-articulation-perception triad*** (Boersma 1998: Ch. 1), the underlying form is a perceptual specification (Saussure 1916), and it is the task of the grammar to choose an implementation that strikes the best balance between the functional principles of ***minimization of articulatory effort***, which favours easy articulatory forms, and ***minimization of perceptual confusion***, which favours perceptual similarity between the underlying specification and the perceptual surface form. The order in (7) expresses the idea that the speech production process, which will have to choose an articulatory implementation, is ultimately perception-oriented, in the way Powers (1973) has claimed for *all* human behaviour.

Figure (8), taken from Boersma (1998: Ch. 6), shows that the theory of functional phonology incorporates the specification-articulation-perception triad as the production part of a more complete grammar model that also includes comprehension.

(8) *The grammar model of functional phonology*



The production grammar can be identified with what we know as 'the' grammar from most theories of phonology, but its formalization is quite different (§2.2). The perception grammar occurs twice in (8); its task is to turn raw acoustic forms, which are the automatic results of the articulations of the speaker or others, into more discrete perceptual representations, and it performs sequential abstraction (§2.3). The recognition grammar handles the interaction between phonology and semantics in the process of lexical access (Boersma 2001).

2.2 The production grammar and its local rankings

The production grammar shown in Figure (8) is modelled as an Optimality-Theoretic grammar consisting of acquired articulatory (ART) and faithfulness (FAITH) constraints. Its input is the perceptual specification; its candidates are articulatory implementations paired with perceptual results:

(9) *Evaluation of articulatory candidates and their perceptual results*

	|*spec*|	A	B
☞	[art_1] →/$perc_1$/		*
	[art_2] →/$perc_2$/	*!	

Note the intertwining of the production and perception grammars: the arrows in each candidate cell denote the workings of the perception grammar, on which the evaluation procedure in the production grammar can have no influence. The faithfulness constraints, which compare the output of the perception grammar with the underlying specification, are elements of the production grammar.

The production grammar contains a number of ***articulatory constraints*** (depicted as Art in the figure), which evaluate aspects of the innate functional principle of ***minimization of effort***, and work directly on each articulatory output candidate (Boersma 1998: Ch. 7). Such a constraint enters the production grammar (initially high-ranked) as soon as the learner discovers the relation between an articulatory gesture and its perceptual result. The most typical example is:

(10) *Gesture (*articulator*: *gesture* / *distance*, *duration*, *precision*, *velocity*):
"Do not perform a certain *gesture* with a certain *articulator*, along a certain *distance*, for a certain *duration*, and with a certain *precision* and *velocity*."

Other articulatory constraints militate against the synchronization of two gestures or against the coordination of two simultaneous or sequential gestures.

The ***local-ranking principle*** (Boersma 1998) restricts the typologically possible languages by assuming that pairs of constraints can be ranked in a universal manner if they differ in a single argument or condition, and that they can be ranked in a language-specific manner otherwise. Thus, articulatory constraints can be locally ranked according to articulatory effort, e.g. (10) is ranked higher if the *distance*, *duration*, *precision*, or *velocity* is greater, and everything else stays equal. Otherwise, the rankings are largely language-specific: a *global* measure of articulatory effort (e.g. Boersma 1998: Eq. 7.4) can only account for cross-linguistic statistical tendencies.

The production grammar also contains a number of ***faithfulness constraints*** (depicted as Faith in the figure), which evaluate aspects of the innate functional principle of ***minimization of confusion*** indirectly in an evaluation of aspects of the similarity between the perceptual result of each candidate and the underlying perceptual specification (Boersma 1998: Ch. 9). Such a constraint enters the production grammar (initially low-ranked) as soon as the learner's perception grammar has supplied her with a perceptual category. The most typical example is:

(11) *Replace (*feature*: *value*$_1$, *value*$_2$ / *condition* / *left-env_right-env*):
"Do not replace a specified value (*value*$_1$) on a perceptual tier (*feature*) with a different value (*value*$_2$), under a certain *condition* and in the environment between *left-env* and *right-env*."

Other faithfulness constraints militate against insertion of surface material (*Insert) and deletion of underlying material (*Delete), or against the loss of specified simultaneous and sequential relations between features (*DeletePath, *Shift).

Faithfulness constraints can be locally ranked according to perceptual confusion, e.g. (11) is ranked higher if *value*$_1$ and *value*$_2$ are further apart or if the condition or the environment contribute to a smaller amount of confusion, and everything else stays equal. Otherwise, the rankings are largely language-specific: a *global* measure of perceptual confusion (e.g. Boersma 1998: Eq. 4.24) can only account for cross-linguistic statistical tendencies.

The attested language-specific variation of speech processes results in this model from the cross-linguistically free, language-specific ranking of the various articulatory constraints and the various faithfulness constraints, in the way generally proposed by Optimality theorists, when not constrained by the local-ranking principle; Boersma (1998) presents many examples.

As an example of the articulation-perception distinction in OT, Tableau (12) tells us why the 'linear' segmental specification |ãʔ̃ã| will probably be implemented as [ãʔ̃ã], which the speaker will perceive as the unfaithful form /ãʔã/

(12) *Realization of an underlying nasal glottal stop*

|ãʔ̃ã|	*Replace (nasal: +, –)	*Gesture (velum: up & down)
☞ [ãʔ̃ã]→/ãʔã/	*	
[ãʔã]→/ãʔã/	*	*!
[aʔa]→/aʔa/	**!*	

In this tableau, we see that both kinds of surface representations are needed in phonology: the faithfulness constraint evaluates the perceptual representations between the slashes (by comparing them to the perceptual specification between the pipes), and the articulatory constraint evaluates the articulatory representations between the square brackets. The second candidate, with a velum raising during the glottal closure, will always lose to the first candidate, regardless of the constraint ranking: we can see that if multiple articulatory candidates yield the same perceptual result, their patterns of faithfulness violations will be identical and their relative harmonicity will be determined solely by the articulatory constraints. The third candidate, with a raised velum throughout, will also lose to the first regardless of the constraint ranking.

Tableau (12) contains an underlying representation that is unlikely (though not impossible) from the point of view of phonological acquisition. Since the learner will hear only the surface form /ãʔã/, she will probable store it in her lexicon as |ãʔã|, at least if nasality is segmental in her language. This is an automatic result of the minimization of faithfulness violations in the recognition grammar (Boersma 2001), and corresponds to Prince and Smolensky's (1993) idea of Lexicon Optimization. A more common tableau would therefore be (13).

(13) *Realization of an underlyingly non-nasal glottal stop in a nasal environment*

|ãʔã|	*Replace (nasal: +, –)	*Gesture (velum: up & down)
[ãʔã]→/ãʔã/		*!
☞ [ãʔ̃ã]→/ãʔã/		
[aʔa]→/aʔa/	*!*	

This articulatorily perfect result is perfectly faithful to the specification as well.

In many languages, nasality will be autosegmental, so that an underlying representation like (5) is more appropriate than |ãʔã|. In such a case, the tableaus become more complicated (§ 4).

It is illustrative to compare Tableau (12) with how generative phonology would have to handle the underlying form |ãʔ̃ã| if it chooses [ãʔã] as the surface form:

(14) *Generative account of the realization of an underlying nasal glottal stop*

|ãʔ̃ã|	*NasGlottalStop	Ident-IO (nasal)
ãʔ̃ã	*!	
☞ ãʔã		*

The faithfulness constraint Ident-IO (nasal) is the 'hybrid' counterpart of *Replace (nasal). The problem with tableau (14) is that it needs the markedness constraint *NasGlottalStop, which has to rule out nasal glottal stops in the surface form. Functionally, it expresses quite indirectly an interaction between articulation and perception ("it is difficult to find an articulation that will lead to a simultaneous perception of nasality and a glottal stop"), whereas in (12) the perceptual and articulatory drives have been separated out. The largest difference for a theory of UG is that the generative approach has to propose large numbers of innate substantive constraints such as *NasGlottalStop, whereas the functional approach only proposes a few innate templatic constraint families like *Replace and *Gesture, whose substantive content (e.g. the features /nasal/ and [velum]) can be filled in during the acquisition process (Boersma 1998: Ch. 14; 2000). In the case under discussion, *NasGlottalStop could become superfluous if the 'hybrid' surface form is taken as [ãʔ̃ã], as in Walker (1998), but that severs the connection between faithfulness and perception, since IDENT-IO (nasal) will now be satisfied if the velum is lowered.

2.3 The perception grammar and its local and global rankings

In (8), we see that the perception grammar performs several functions (Boersma 1999): for the speaker, it produces a representation from which she can evaluate faithfulness; for the listener, it produces a perceptual representation of the speech of another person, as an input to the recognition system that will ultimately lead to comprehension; for the learner, it produces perceptual representations of her own speech and of the speech of others, so that the learner can gradually learn to speak in the same way as others do.

The perception grammar is implemented as an Optimality-Theoretic grammar consisting of acquired categorization constraints. Its input is a continuous acoustic signal; its candidates are discrete perceptual representations:

(15) *Evaluation of perceptual candidates*

[[acoustics]]	A	B
☞ /$perc_1$/		*
/$perc_2$/	*!	

The perception grammar generates covert structure: it contains a number of templatic constraint families that help to reduce the raw acoustic material in a language-specific way to a more discrete abstract representation that can be related to the necessarily discrete phonological representations in the lexicon. The lowest-level action of the perception grammar is the conversion of continuous acoustic cues into discrete perceptual feature values with the help of categorization constraints (the *CATEG and *WARP families shown in the figure, see Boersma 1998: Ch. 8). For instance, [[m]] will in most languages be mapped on the value /labial/ on the perceptual place tier and on the value /+/ on the perceptual nasality tier. The perception grammar will also generate a ***link of simultaneity*** or ***path*** (in the terminology of Archangeli & Pulleyblank 1994) between these two values, i.e. the value /labial & +/ on the place & nasal tier. Other constraints in the perception grammar control the abstraction of simultaneous and sequential cooccurrence. For instance, [[m]] may be perceived as the single 'segmental' percept /labial nasal/, if the two feature values frequently occur simultaneously in the language at hand. For the subject of nasal harmony, the concept of *sequential* abstraction is more important, and I will spell out its formalization.

A pair of constraint families in the perception grammar together determine the abstraction of sequential acoustic cues into a single percept:

(16) Ocp (f: x; cue_1 | m | cue_2)
"A sequence of acoustic cues cue_1 and cue_2 with intervening material m is heard as a single value x on the perceptual tier f."

(17) Lcc (f: x; cue_1 | m | cue_2)
"A sequence of acoustic cues cue_1 and cue_2 with intervening material m is not heard as a single value x on the perceptual tier f."

These names are abbreviations of the terms Obligatory Contour Principle and Line Crossing Constraint known from generative phonology as inviolable constraints on representations. In functional phonology, they are violable constraints on the perceptual representation that is derived from an acoustic signal by the perception grammar. For instance, (4) violates Ocp (nasal: +; Ṽ | ʔ | Ṽ), and (5) violates Lcc (nasal: +; Ṽ | ʔ | Ṽ). The existence of these constraints is a result of general properties of human perception: if we see an object partly obscured by other objects, we can still sometimes perceive the various visible parts together as a single object. Thus, Ocp and Lcc control the construction of higher-level sequential units such as segments, autosegments and syllables (Boersma 1998: Chs. 12, 17; Boersma 1999).

We can identify some universal local rankings of Ocp and Lcc:

(18) *Local rankings of* Ocp
a. Higher if the sequential combination of cue_1 and cue_2 is more common.
b. Lower if there is more intervening material.

(19) *Local rankings of* Lcc
a. Lower if the sequential combination of cue_1 and cue_2 is more common.
b. Higher if there is more intervening material.

Consider the Portuguese articulation [sɐβɐ̃ũ], which stands for a sequence of contracting lungs, tongue grooving, half-open jaw, lip approximation & opening, a velum lowering gesture, and lip rounding. The acoustic result will be [[sɐβɐ̃ũ]], which stands for sibilant noise, mid-high F1, bilabial place, nasal mid-high F1, nasal low F1. The nasal mid-high F1 and the nasal low F1 tend to cooccur in sequence very often in Portuguese, which, together with the very small amount of intervening material between [[ɐ̃]] and [[ũ]] (namely, none), will probably lead to the perception of [[ɐ̃ũ]] with a single /+/ value on the nasality tier. We can formalize this as in (20).

(20) *A near-universal example of abstraction: Nasal diphthongs*

acoustics: [[ɐ̃ũ]]	Ocp (nasal: +; Ṽ | | Ṽ)	Lcc (nasal: +; Ṽ | | Ṽ)
/nasal/: + + ; ɐ u (each vowel linked to its own +)	*!	
☞ */nasal/*: + ; ɐ u (one + linked to both vowels)		*

Thus, /ɐ̃ũ/ will be considered a single nasal unit, and this is why we can say that Portuguese 'has' a nasal diphthong. The advantage for the speaker of Portuguese is that she can store the word |sɐβɐ̃ũ| 'soap' in her lexicon with a single /+nasal/ value instead of with two.

With slightly more intervening material, perhaps a syllable boundary (which itself is covert structure created by the perception grammar) or a short silence, the result may already be more language-specific, but in the case of rightward spreading of velum lowering through a glottal stop, as in Sundanese, we still expect that the result is perceived with a single /+nasal/ value:

(21) *Perceptual integration of nasality in Sundanese*

acoustics: [[ã_ˀã]]	Ocp (nasal: +; Ṽ | _ˀ | Ṽ)	Lcc (nasal: +; Ṽ | _ˀ | Ṽ)
/nasal/: + – + ; a ʔ a (each segment linked to its own value)	*!	
☞ */nasal/*: + – ; a ʔ a (+ linked to both a's, – linked to ʔ, lines crossing)		*

Unlike the situation in (20), where the name of the Lcc constraint feels a little inappropriate, the winning candidate in (21) indeed shows crossing association lines: the non-nasal silence that intervenes between the two nasal cues must be regarded as a /–/ value on the nasal tier.

Sequences with more material between the nasal cues will be less likely to be perceived with single nasality. Articulations that produce a longer non-nasal stretch will be heard either as two separate nasal vowels, or as a single nasal autosegment, mainly depending on whether the language 'has' autosegmental nasal harmony or not. For instance, French has nasal and non-nasal vowels in every syllable independently: next to the harmonic |ʃɑ̃sɔ̃| 'song' and |pate| 'pâté', it has the equally well-formed disharmonic |lapɛ̃| 'rabbit' and |mɑ̃to| 'coat'. As far as the lexicon is concerned, there would be no advantage in storing |ʃɑ̃sɔ̃| with a single /+nasal/, because we would still have to specify whether this feature value applies to the first syllable, or to the second syllable, or to both. On the contrary, perceiving a bimorphemic |mɔ̃+ʃjɛ̃| 'my dog' as /mɔ̃ʃjɛ̃/ with a single /+nasal/ value would constitute a faithfulness violation in the production grammar, since one of the two underlying /+nasal/ values would be lost in the perceptual output (see the next paragraph). So in French Lcc (nasal) will outrank Ocp (nasal) for any intervening consonant (or syllable boundary). In Guaraní, by contrast, which has the harmonic morphemes |tupa| 'bed' and |tũpã| 'god', but no disharmonic *[tupã] or *[tũpa] (Piggott 1992), it is advantageous for listeners to lexicalize nasality on the morpheme level (or linked only to the final vowel, if there is evidence for leftward spreading), because this economizes on specifying the underlying paths (links) between the nasal values and each syllable. So in Guaraní Lcc (nasal) will outrank Ocp (nasal) for any intervening consonant, and [tũpã] will be perceived with a single /+nasal/, although it must be implemented with three velar gestures.

The perceptual integration of nasality across syllable boundaries comes at a cost. Consider the concatenation of two underlying morphemes |tãkã| and |tũkã| in a Guaraní-type language. If the result is pronounced [tãkãtũkã], this will necessarily be perceived with a single /+nasal/:

(22) *Necessary perceptual integration across a morpheme boundary*

acoustics: [tãkãtũkã]	Ocp (nasal: +; Ṽ | C | Ṽ)	Lcc (nasal: +; Ṽ | C | Ṽ)
/nasal/: – + – + – + – + t a k a t u k a	*!**	
☞ /nasal/: – – + – – t a k a t u k a		***
/nasal/: – – + – + – t a k a t u k a	*!	**

Note that there is no ranking of the constraints that will lead to a perception of the third candidate, which would have been optimal for purposes of lexical access. The perception in (22) leads to a faithfulness violation in the production grammar: the underlying form contains two /+nasal/ specifications, the perceptual candidate contains a single /+nasal/ value, so that it violates *Delete (+nasal). We must expect, then, that a high ranking of *Delete (+nasal) should be able to force satisfaction of faithfulness at the cost of something else, perhaps the surfacing of an underlying path (link of simultaneity) between [+nas] and a vowel, as in Tableau (23).

(23) *Faithfulness violation forces epenthesis*

underlying: |+nas| taka + |+nas| tuka	*Delete (+nasal)	*DeletePath (+nasal)
[tãkãtũkã] → /+nas/ takatuka	*!	
☞ [tãkatũkã] → /+nas/ /+nas/ takatuka		*

The first candidate, which has to follow the perception process in (22), merges the two underlying [+nas] specifications in the output, thus violating featural faithfulness once. The second candidate has two separate [+nas] values, which equals the specified number, but has dropped the underlying path between [+nas] and the second vowel. This epenthesis of a [–nas] vowel is not well attested in nasal harmony, but must be expected to be possible, since effects like these are abundant in the case of tone.

The epenthesis in (23) is one of the many possible 'OCP effects' in functional phonology (Boersma 1998: Ch. 18). It is due to a combination of a high-ranked Ocp in the perception grammar, and a resulting violation of a high-ranked faithfulness constraint in the production grammar. Note that if Ocp were a constraint in a 'hybrid' production grammar, a low ranking of this constraint could have the undesirable result that faithfulness constraints control the creation of covert structure:

(24) *Generative approach to hidden structure*

|+nas| taka + |+nas| tuka	Max (nas)	MaxLink (nas)	Ocp
[+nas] takatuka	*!		
[+nas] [+nas] takatuka		*	
☞ |+nas| |+nas| takatuka			*

In this example, where consecutive nasal vowels must perhaps be considered adjacent on the level of the syllable head (Piggott & Van der Hulst 1997), high-ranked faithfulness can influence the speaker's interpretation of the surface form. In functional phonology, by contrast, the production grammar has no influence on the mapping from acoustic to perceptual form (Boersma 1999).

We have started with the perception of nasal diphthongs, and proceeded with the perception of nasality across glottal stops and consonants in general. The question arises whether /–nasal/ gaps in /+nasal/ stretches can be even larger than this, perhaps spanning a syllable, i.e. whether sequences like [pãtikã] are ever perceived with a single /+nasal/. I know of no such instances in nasal harmony, but analogous examples may exist in tongue-root-harmony systems, as in Wolof, where high vowels are transparent to spreading of RTR (Archangeli & Pulleyblank 1994):

(25) *Perception of feature values across syllables*

3. Nasal harmony, type A

In this section, I will show that one type of nasal harmony is due to articulatory spreading. Piggott (1992) distinguishes two kinds of nasal-harmony systems, which he calls type A and type B. In type-A nasal harmony, nasality spreads from a nasal segment until the spreading is blocked by a segment that is apparently not compatible with nasality. In Malay, for example, nasality may spread rightward through [j] but not through [k]:

(26) *Nasal spreading in Malay (from the initial consonant to the right)*
[mã̃j̃ãn] 'stalk'
[mãkan] 'eat'

Thus, /j/ is a ***target*** for nasalization (it's ***nasalizable***), whereas /k/ is a ***blocker*** (it's ***opaque***). The following typology summarizes the possible targets in type-A languages:

(27) *Nasalizable segments (Piggott 1992)*

laryngeals	*glides*	*liquids*	*fricatives*	*plosives*	*language example*
+	–	–	–	–	Sundanese
+	+	–	–	–	Malay, Warao
+	+	+	–	–	Ijo, Urhobo
+	+	+	+	–	Applecross Gaelic

This typology corresponds to the following implicational universals:

(28) *Universals of nasal spreading*

a. If glides can be nasalized, so can vowels and laryngeals.
b. If liquids can be nasalized, so can glides.
c. If fricatives can be nasalized, so can liquids.
d. Plosives cannot be nasalized.

3.1 A segmental functional analysis of type-A nasal harmony

Functionally, the generalization is straightforward. Suppose first that the constraint that is honoured by spreading nasality to the right is *Move (velum), i.e. a constraint that aims at postponing the raising gesture of the velum, as an indirect way to minimize the number of raising and lowering gestures of the velum. This gestural definition immediately accounts for the Malay type:

(29) *Glides undergo nasal spreading in Malay*

|maja|	*Replace (nas: –, + / liquid)	*Move	*Replace (nas: –, + / glide)
[mãja]→/mãja/		*!*	
☞ [mãj̃ã]→/mãj̃ã/			*

This account is entirely segmental: the underlying form |maja| has a single |+nasal| segment and, crucially, three segments separately specified for |–nasal|. The result /mãj̃ã/ has four adjacent /+nasal/ values. Only with this segmental approach can we use constraints that refer to complete features, like *Replace (nasal: –, +). For a more autosegmental approach, see §3.2. We see, then, that the segment |j|, which is specified as non-nasal, undergoes 'nasal' spreading, i.e., is implemented with a longer velar lowering, which happens to lead to a perception of a nasal glide.

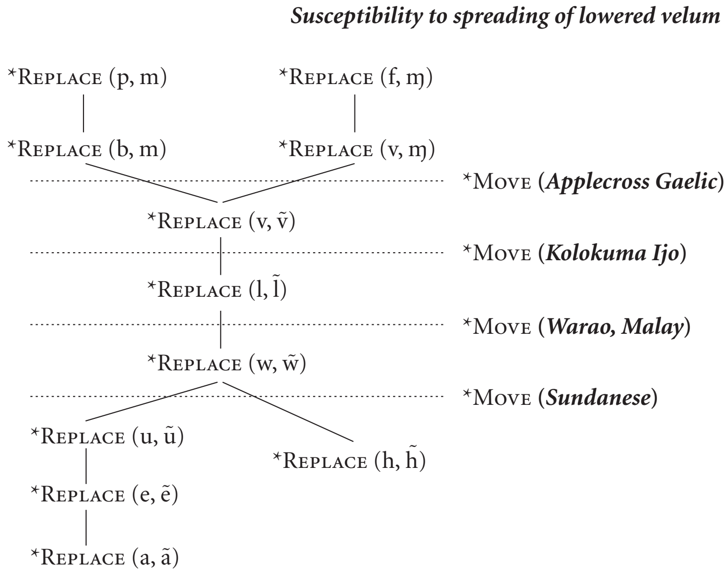
The two *Replace constraints in (29) are ranked according to the local-ranking principle, since the closer an oral constriction is, the more its perceptual result is modified by adding a nasal side branch (Schourup 1972: 533). Thus, Malay liquids block nasal spreading:

(30) *Liquids block nasal spreading in Malay*

|mara|	*Replace (nas: –, + / liquid)	*Move	*Replace (nas: –, + / glide)
☞ [mãra]→/mãra/		**	
[mãr̃ã]→/mãr̃ã/	*!		

For purposes of readability, I will abbreviate the two faithfulness constraints in (30) as *Replace (l, l̃) and *Replace (w, w̃), respectively. The entire fixed confusion-based hierarchy of nasalizability is shown as the *Replace constraints connected with solid lines in (31):

(31) *Fixed hierarchy of anti-nasalization faithfulness*



The cases of the obstruents need some comment. If the velum is lowered during a gesture that would otherwise produce a labial plosive, a nasal stop will automatically result. So honouring *Move would violate some probably highly ranked faithfulness constraints against deletion of the perception of plosiveness and insertion of the perception of sonorancy:

(32) *Plosives block nasal spreading in Malay*

|maka|	*Replace (k, ŋ)	*Move
☞ [high velum etc.]→/mãka/		*
[low velum etc.]→/mãŋã/	*!	

The fact that these faithfulness (correspondence) constraints are ranked so high, can be attributed to the strong perceptual repercussions of their violation, according to any reasonable global measure of perceptual distance. For instance, *Replace (k, ŋ) can be seen as a shorthand for the conjunction of *Delete (plosive) & *Insert (sonorant).[1] For fricatives, a tableau analogous to (32) can be drawn for most languages:

(33) *Fricatives block nasal spreading in most languages*

|masa|		*Replace (s, n)	*Move
☞	[high velum etc.]→/mãsa/		*
	[low velum etc.]→/mãnã/	*!	

Since we have no way of telling whether the deletion of frication is worse than the deletion of plosiveness, the top pairs of constraints are not universally ranked with respect to each other. Note that the candidate set in (33) is restricted in such a way that a nasalized fricative cannot occur as a perceptual output. This is because speakers of most languages would not know how to produce such a sound, so that the relevant articulation does not show up as a candidate at all. In Applecross Gaelic, people are reported to be able to produce it, so their tableau is like:

(34) *Nasalized fricatives reported for Applecross Gaelic*

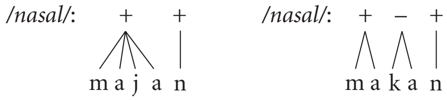
|masa|	*Replace (s, n)	*Move	*Replace (s, s̃)	*Gesture (special trick)
[high velum etc.]→/mãsa/		*!		
[low velum etc.]→/mãŋã/	*!			
☞ [special trick]→/mãs̃ã/			*	*

So (31) shows a four-way typology, based on the ranking of *Move with respect to the fixed hierarchy. The typology also seems to predict the existence of languages that show nasalization of plosives and/or fricatives (as nasal stops), though the number of these languages may be very low because of considerations of global measures of distinctivity, which may force the language-specific rankings of *Replace (p, m) and *Move (velum) to be drawn from distributions ("windows") that hardly overlap. Nevertheless, final plosives in Sanskrit become nasal when followed by a nasal consonant, and in Lewis Gaelic (e.g. Ladefoged, Ladefoged, Turk, Hind, & Skilton 1997), plosives but not fricatives nasalize after the masculine article |ən|: |ən+palə| 'the town' → /əmalə/; |ən+kʰaːr| 'the car' → /əŋhaːr/; |ən+fɛr| 'the man' → /əɱfɛr/.

3.2 An autosegmental functional analysis of type-A nasal harmony

An autosegmental approach might be more realistic than the segmental approach of §3.1. The two Malay forms in (26) are probably perceived as in (35):

(35) *Autosegmental perception of nasals in Malay*



The /mãj̃ãn/ form is particularly interesting (for a similar type, see Piggott 1992: 59). Since the nasalization of /ãj̃ã/ is a result of rightward spreading from /m/, and not of a leftward spreading from /n/, it is plausible that /ãj̃ã/ is perceived in the same nasal stretch as its left neighbour, but in a different stretch from its right neighbour. The Malay perception grammar can achieve this by having a high-ranked Ocp (+nas), but an even higher ranked Lcc (+nas; V | | nasal stop). This move ensures that both underlying |+nasal| specifications in |majan| surface faithfully, thus satisfying *Delete (+nasal). We see here another case of the difference between articulation and perception: /mãj̃ãn/ has two perceptual /+nasal/ values, although it is implemented with a lowered velum throughout; this is the reverse case of /tũpã/ in Guaraní, which has a single perceptual /+nasal/ value but is implemented with two separate velum lowering gestures.

Tableau (29) now becomes:

(36) *Glides undergo nasal spreading in Malay*

underlying: |*nasal*|: + – (m a j a)	*Delete (+nas)	*InsertPath (+nas/ liquid)	*Move	*InsertPath (+nas/ glide)
[mãja]→ /*nasal*/: + – (m a j a)			*!*	
☞ [mãj̃ã]→ /*nasal*/: + (m a j a)				*
[baja]→ /*nasal*/: – (b a j a)	*!			

This analysis tacitly assumes a general low ranking of faithfulness for the negative value of /nasal/, i.e. for the constraints *Delete (–nasal) and *DeletePath (–nasal). This low ranking means that we could have removed all occurrences of /–nasal/ from (36), thus essentially obtaining an analysis in terms of a privative feature /nasal/. In either case, the autosegmental approach leads to an analysis equivalent to the segmental analysis of § 3.1.

The conclusion, then, must be that any account of type-A nasal harmony expressed into functionally rankable directly functional constraints, is observationally, descriptively, and explanatorily adequate, since it accounts for the data, predicts the typology, and needs no assumptions and principles except those rooted in general properties of motor behaviour and perception. I will now look at four alternative analyses.

3.3 Perception-based spreading in type-A languages?

As an alternative functional analysis of type-A nasal harmony, we might propose that the rightward nasal spreading is not caused by postponing an articulatory gesture, but by honouring a faithfulness constraint, say MAXIMUM (nas), which aims at maximizing the duration of the perception of nasality. But we will have to rule out spreading through plosives in Malay. A discontinuous sequence such as [mãkã] can be ruled out in either of two ways: first, by a strong constraint *INSERT (nas) against the insertion of nasality; second, by an articulatory constraint *GESTURE (velum) against velum movement.

The first solution, with *INSERT (nas), only works if [mãkã] is perceived with two separate instances of nasality:

(37) *Faithfulness-only account of Malay*

|nas| — m a k a	*INSERT (nas)	*DELETE (plosive)	MAXIMUM (nas)
☞ [mãka] → /nas/ m a k a			**
[mãŋã] → /nas/ m a ŋ a		*!	
[mãkã] → /nas/ /nas/ m a k a	*!		*

But this solution is problematic, since perceptually the glottal stop is as much of a plosive as /k/ is, so that if [mãkã] is perceived with two nasals, [mãʔã] should also be perceived with two nasals, but then the correct candidate [mãʔ̃ã] /mãʔã/ would violate *INSERT (nas) and lose.

The second solution, with *GESTURE (velum), also works if [mãkã] is perceived with a single instance of nasality:

(38) *Malay with non-directional articulatory constraints*

|nas| — maka	*DELETE (plosive)	*GESTURE (velum)	MAXIMUM (nas)
☞ [mãka] → /nas/ (m a) k a			**
[mãŋã] → /nas/ (m a ŋ a)	*!		
[mãkã] → /nas/ (m a k a)		*!	*

But this solution is problematic, too. For an underlying form |makan|, it predicts [mãkãn] rather than the correct [mãkan]:

(39) *Malay with non-directional articulatory constraints*

|nas| |nas| — makan	*DELETE (plosive)	*GESTURE (velum)	MAXIMUM (nas)
[mãkan] → /nas/ (m a) k a /nas/ (n)		*	**!
[mãŋãn] → /nas/ (m a ŋ a n)	*!		
*☞ *[mãkãn] → /nas/ (m a k a) /nas/ (n)		*	*

The problem here is that the final [n] forces velum lowering in the first, correct, candidate, too, giving the final vowel of [mãkãn] an articulatorily free ride. Since this articulatory licensing of perceptual nasalization does not seem to occur in this example, the conclusion must be that the spreading in type-A languages must be due to a spreading of the velum lowering gesture in the leftward or rightward direction, or both.

3.4 Walker's (1998) approach to type A

Walker (1998) proposed a family of SPREAD constraints (analogously to *MOVE), with an explicit definition in terms of the number of nasal association lines. Walker expresses the nasalizability hierarchy with cooccurrence constraints for 'hybrid' features:

(40) *Walker's hierarchy of nasalizability*
*NasObsStop >> *NasFricative >> *NasLiquid >>
>> *NasGlide >> *NasVowel >> *NasSonStop

These are constraints in the style of the ***grounding conditions*** of Archangeli and Pulleyblank (1994). Such a constraint is thought to have become an innate element of Universal Grammar during the course of evolution, as a result of the selection pressure associated with the interaction between functional principles. In a functional theory of phonology, which expresses function directly, these indirectly functional constraints should be superfluous.

And indeed, some of Walker's constraints have no correlate in a functional account. Walker needs the structural constraint *NasObsStop, which is a filter against the cooccurrence of [+nas], [–cont], and [–son] (Walker 1998: 36), in order to rule out the unpronounceable nasalized labial plosives, which would otherwise be the winner:

(41) *The need for superfluous cooccurrence constraints*

maka	Ident-IO (±sonorant)	*NasObsStop	Spread (nasal)	*NasVowel
maka			***!	
☞ mãka			**	*
mãk̃ã		*!		**
mãŋã	*!			**

In the functional account of (32), a candidate perceived as /mãk̃ã/ can never occur, simply because no articulation can produce it. This means that if we distinguish between articulation and perception in the production grammar, several phonetically impossible combinations do not have to be stated as inviolable constraints in the grammar, as they have to in a grammar with hybrid representations.

The second problem is that the hierarchy of structural constraints (40) does not generate the typology by itself. To rule out [mãŋã] for |maka|, Walker (1998: 113) still needs faithfulness constraints like Ident-IO (±sonorant) and Ident-❀O (±voiced), which are comparable to *Replace (k, ŋ). Thus, Walker's approach needs a hierarchy of structural constraints as well as a hierarchy of faithfulness constraints (i.e. other Ident constraints are ranked lower), whereas the functional approach needs nothing more than a confusion-based hierarchy of faithfulness.

3.5 Sonority hierarchy and type A

The hierarchies in (31) and (40) are reminiscent of the ***sonority hierarchy***, and indeed the sonority scale has come up in at least one account of nasalizability (Gnanadesikan 1995). This is natural from a generative point of view, since the sonority hierarchy is a very good candidate for an innate phonological device, since nearly all languages will then use it for syllabification. However, the position of /h/ in the hierarchy is problematic, as Gnanadesikan notes. In the nasalizability hierarchy, faithfulness for /h/ is ranked on a height comparable to that of vowels, because nasalizing this sound will not strongly change its main perceptual features (noise and spectrum). In hierarchies for syllabification, on the other hand, /h/ will pattern with the other fricatives /f/ and /s/ in its preference for the syllable margin, which is again only natural since the sound is voiceless (Boersma 1998: 455). Gnanadesikan gives an example of a two-year-old child, who pronounces |bil'ou| 'below' as [fib'ou], copying the initial obstruent to replace the sonorant onset of the stressed syllable, but pronounces |bih'ajnd| 'behind' as [fih'ajn], *not* copying the initial obstruent to replace the apparently non-sonorant onset of the stressed syllable.

We must conclude that the plausibly innate device of the sonority hierarchy has an exception in the direction of immediate functionality, and is not an arbitrary universal. This is a strong argument against substantive innateness in phonology, especially if the exception does not play a role in many languages, since this would leave only a small number of generations to have selected the presumably innate exception.

3.6 Piggott's (1992) account of type A

Piggott's (1992) account for the nasal-spreading typology (38) proposes some problem-specific innate principles for UG:

(42) *Piggott's principles of nasal harmony (simplified)*

a. "The class of blockers must constitute a natural class with the nasal consonants."

Nasals are ***stops***, so one of those classes must be the class of stops: /m/, /n/, /p/, /t/, which accounts for the blockers in Applecross Gaelic.

Nasals are also ***consonantal***, so depending on whether glides are consonantal, we have the classes /m/, /n/, /p/, /t/, /f/, /s/, /l/, /r/ (Warao) and /m/, /n/, /p/, /t/, /f/, /s/, /l/, /r/, /j/, /w/ (Sundanese).

And nasals are ***sonorant***, so we would expect the class /m/, /n/, /l/, /r/, /j/, /w/, i.e. a language in which obstruents are targets, but sonorants block!

b. "The class of blockers must not be limited to sonorants."
   This exception rules out the third possibility in (42a).

c. "There is a natural class called ***non-approximant consonants***."
   This class consists of /m/, /n/, /p/, /t/, /f/, /s/, accounting for Ijo.

While (42a) sounds like a general principle that could find application in other areas, the UG principles (42b) and (42c) are obviously specific to the problem of type-A nasal harmony. Since these principles are of advantage to only a very small minority of languages, they are very unlikely to have had any chance of emerging by a rich enough selection during the course of evolution (a few hundred generations).

4. Nasal harmony, type B

In this section, I will show that by contrast with type-A articulatory spreading, type-B nasal harmony is due to perceptually-based spreading. Type-B nasal-harmony languages (Piggott 1992) are characterized by morpheme-level or word-level specifications for |+nasal| or |–nasal|, and most segments surface differently in nasal and non-nasal morphemes:

(43) *Type-B nasality contrasts (Southern Barasano)*

In |–nasal| morphemes: — In |+nasal| morphemes:

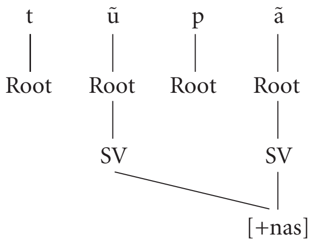
a, u	ã, ũ
w, j	w̃, j̃
l, r	l̃, r̃
$^{\mathrm{m}}$b	m
s	s
t, k	t, k

Other type-B languages have comparable systems. Tuyuca (discussed at length by Walker 1998) has /b/ instead of /$^{\mathrm{m}}$b/.

4.1 Transparency of plosives

One of the conspicuous properties of type-B nasal-harmony languages is the transparency of plosives to nasal spreading. So, in Guaraní we have [tupa] 'bed' and [tũpã] 'god', but no *[tupã] or *[tũpa] (Piggott 1992). In Piggott's analysis, nasality is spread from right to left across all segments that have a Spontaneous Voicing (SV) node, i.e. all sonorants:

(44) *Piggott's spreading along the Spontaneous Voicing tier*

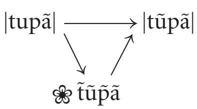


Since the two vowels are adjacent on the SV tier, Piggott's analysis has the desirable property of ***locality*** in spreading processes.[2]

Piggott and Van der Hulst (1997) reanalyse the process as spreading on the syllable level: a nasalized vowel, being the head of its syllable, makes nasalization a property of the syllable, and this then spreads to adjacent syllables, nasalizing all the sonorants in every affected syllable. This move allows Piggott and Van der Hulst to account for more facts than Piggott (1992), such as the fact that all sonorants in syllables with nasalized vowels are nasalized themselves, and the similarity with vowel-harmony processes. Again, however, the locality requirement has informed the search for a higher structure in which nasalization is continuous.

Walker (1998: 43) also explicitly wants to honour the locality requirement, invoking the line-crossing constraint as an inviolable well-formedness condition on (hybrid) phonological representations. Her analysis is stated in terms of the ***sympathy*** device introduced by McCarthy (1999):

(45) *Walker's analysis of transparency to leftward spreading*



In this view, the surface form [tũpã] is derived from the underlying form |tupã| as well as from a sympathetic (❀) form /t̃ũp̃ã/, which is itself derived from the underlying form by maximal spreading, but which contains two unpronounceable segments.

Both Piggott's and Walker's theories work. However, a theory that distinguishes between articulation and perception in phonology must maintain that feature geometries are illusions evoked in the linguist who advocates hybrid representations, and that these illusions will evaporate if the correct distinctions are made (Boersma 1998: 22, 442). I will show that if we separate articulation and perception, we do not need Piggott's feature geometry or Walker's sympathy approach.

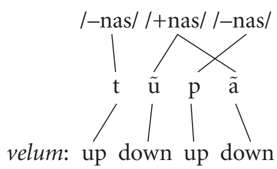
Because of the morpheme-level specification, which successfully nasalizes at least all vowels, sequences of two nasal vowels with an intervening obstruent are very common in these languages. For this reason, Ocp for nasality will outrank the line-crossing constraint:

(46) *Perceiving nasality across a plosive*

acoustics: [tũpã]	Ocp (nas: +; Ṽ | plosive | Ṽ)	Lcc (nas: +; Ṽ | plosive | Ṽ)
perception: /–nas/ /+nas/ /–nas/ /+nas/ t ũ p ã	*!	
☞ perception: /–nas/ /+nas/ /–nas/ t ũ p ã		*

Thus, the two nasalized vowels are perceived with a single value [+nasal] on the perceptual nasality tier, despite the intervening plosive. The articulation, on the other hand, cannot be regarded as continuous, since the velum has to go up and down for the labial plosive. This combination of discontinuous articulation and perceptual unity can be pictured as:

(47) *Asymmetry between articulation and perception*



Note that (47) does not imply that /+nas/ precedes the second /–nas/: if we see a car standing behind a lamppost, do we see it to the left or to the right of the lamppost? Obviously both. Likewise, /+nas/ in (47) both precedes and follows the second /–nas/, contra Archangeli and Pulleyblank (1994: 37), who invoke the assumption of strict precedence of feature values within tiers in an attempt to derive the inviolability of the line-crossing constraint (more precisely, 'gapped' configurations) from more basic principles. The universality of the locality condition is an illusion brought about by the ubiquity of articulation-based spreading, which is never discontinuous (because that would violate its very purpose of gesture reduction), and by the rarity of a high Ocp across salient intervening material. However, a high rate of cooccurrence of nasality in adjacent syllables, as in type-B nasal harmony languages, will shift the balance in the direction of perceptual unity. At least if speech perception is like other kinds of perception.

4.2 Why all sonorants are nasalizable in type-B languages

Another conspicuous property of type-B nasal-harmony languages is that they all nasalize their glides and liquids. A hierarchy of nasalizability, similar to the one for type-A languages, does not appear to exist. I will discuss one possible cause.

Type-A languages seem to be like most languages in that they have to deal with constraints against the replacement of the trill |r| with a nasalized trill /r̃/. If the constraint refers to the difference between the two, and the difference is in the nasality, we must conclude that the underlying form contains a |–nasal| specification (or, equivalently, lacks a |nasal| specification).

This will be different in type-B languages, which make a point of applying nasality to the morpheme or word level. If nasality is suprasegmental, segments are less likely to be specified for nasality themselves. So the perceptual specification of the segment will not contain any specification for |–nasal|. The only relevant specification for |r| is |trill|, and both /r/ and /r̃/ honour *Delete (trill). So the relevant specifications for all segments are:

(48) *Type-B nasality contrasts (Southern Barasano)*

In |–nasal| morphemes:	In |+nasal| morphemes:	
a, u	ã, ũ	|low/high vowel, +son|
w, j	w̃, j̃	|back/front glide, +son|
l, r	l̃, r̃	|lat/trill, +son|
^{m}b	m	|stop, +son|[3] (following Piggott 1992)
s	s	|fricative, –son|
t, k	t, k	|plosive, –son|

This means that the surface forms reflect the faithfulness constraints in the following way:

(49) *Faithfulness handling*

a. All the specified features surface faithfully in oral as well as in nasal words.

b. In a nasal context, the obstruents violate *DeletePath (nasal). Since there is a partially nasal segment (/^{m}b/), I'll speak of *DeletePath (half a nasal) instead, and assign two violations for entirely non-nasal obstruents in a nasal environment.

c. In a non-nasal context, the sonorant stops introduce partial nasality, so they violate *Insert (half a nasal). Any entirely nasal segment would violate it twice.

Here are the tableaus for all segments:

(50) *Nasalizing a liquid (or vowel or glide)*

|ara + *nasal*|	*Delete (*any feature*)	*DeletePath (half a nasal)	*Insert (half a nasal)	*Gesture (velum)
☞ [ãr̃ã]→/ãr̃ã/				
[ãrã]→/ãrã/		*!*		**

(51) *Nasalizing a sonorant stop*

|a[+son,stop]a + *nasal*|	*Delete (*any feature*)	*DeletePath (half a nasal)	*Insert (half a nasal)	*Gesture (velum)
☞ [ãmã]→/ãmã/				
[ã^{m}bã]→/ã^{m}bã/		*!		**
[ãbã]→/ãbã/	*!	**		**

(52) *Oralizing a sonorant stop*

|a[+son,stop]a|	*Delete (*any feature*)	*DeletePath (half a nasal)	*Insert (half a nasal)	*Gesture (velum)
[ama]→/ama/			**!	**
☞ [a^{m}ba]→/a^{m}ba/			*	**
[aba]→/aba/	*!			

(53) *Nasalizing a plosive (or fricative)*

|a[–son,plos]a + *nasal*|	*Delete (*any feature*)	*DeletePath (half a nasal)	*Insert (half a nasal)	*Gesture (velum)
☞ [apa]→/apa/		**		
[ama]→/ama/	*!*			**

The ranking can be summarized as *Delete (segmental feature) >> Faith (nasal) >> *Gesture (velum). The first ranking seems quite natural, because nasality will always be realized on the vowels, so that it is not very important to have it realized on the consonants as well. The second ranking expresses the idea that velar gestures do not play any role in the phonology. In this respect, type-B languages differ completely from type-A languages.

To sum up: in type-A languages, glides, liquids, fricatives, and plosives *don't* want to be nasalized, but sometimes they are forced to be (by articulatory spreading); in type-B languages, these segments *do* want to be nasalized, but sometimes they cannot be (because of fricativity and plosivity faithfulness). For the liquids, which are in the middle of the hierarchy, these opposing desires must lead to nasalization being much more common in type-B than in type-A languages. This is borne out: liquids show blocking behaviour in many type-A languages, because a nasalized liquid sounds differently from a non-nasalized liquid, and they are nasalized in all type-B languages, because a nasalized liquid is still a liquid.

4.3 Walker's generalization

The functional approach appears to have missed a possible unification of type-A and type-B languages, discovered by Walker (1998), who observed that the typology of type-A languages lacks a type with nasalized plosives, and that type-B languages actually fill this gap by allowing nasalized plosives in their sympathetic candidates. The problem with this approach becomes apparent when we consider the only point in which the two overlap: the case of the fricatives. In those few type-A languages where nasality spreads through fricatives, these fricatives are *undergoers*, i.e. they are nasalized themselves. In type-B languages, fricatives are *transparent*. This difference corresponds exactly with the basic difference that we found between the two types: type-A languages have articulatory spreading, i.e. spreading of a lowered velum, and type-B languages have perceptual spreading, i.e. spreading of perceptual nasality even if it involves additional velum effort.

4.4 An independent need for nasal cooccurrence constraints?

It might be argued that constraints like *NasLiquid, which were used by Walker (1998) but which were shown to be superfluous in a functional approach, are independently needed in phonological descriptions, because they express the fact that most languages tend to have non-nasal liquids like /r/ but not nasalized liquids like /r̃/. With the axiom of Richness of the Base (Prince & Smolensky 1993), any underlying |r̃| should be converted to [r] by the grammar, presumably with the help of a markedness constraint like *NasLiquid. But in functional phonology, segmental restrictions are not a task of the production grammar. In a language without surfacing nasalized liquids, the learner will never perceive a nasalized liquid, so that she will rarely be forced to construct a nasalized liquid in a lexical form. This poorness of the base is one of the three automatic restrictions in the functional grammar model (§4.5). If a language does have surface nasalized fricatives, the perception grammar will be happen to handle them, and their cross-linguistic markedness will be irrelevant during production.

I still have to explain why languages tend not to have nasalized liquids. If the grammar does not handle this, what does? Suppose that a language has nasalized liquids but no non-nasalized liquids, and that it also has plain nasal stops. If there is a little variation in the nasality of the liquids in this language, the nasalized liquids will tend to become replaced by non-nasal liquids, because this would improve the perceptual distinctivity within the phoneme inventory (Boersma 1998: Ch. 17). Also, the large confusion probability between the nasalized liquids and the nasal stops will cause many learners to merge some of the nasal and nasalized phonemes into larger, easier to distinguish, categories. Gradually, the language will come to be built around an average balance between perceptual confusion and articulatory effort.

4.5 Three indirect restrictions on perceptual surface forms

The functional grammar model leads to three automatic restrictions not known in generative phonology.

First, the acoustics is an automatic result of the articulation, so that the perception tends not to contain any features that nobody can produce. Hence, the functional approach has no need for *NasObsStop.

Second, all candidates are learned articulations. For instance, we do not usually generate candidates with nasal fricatives, so that *NasFricative is not needed to rule them out.

Third, the lexical forms have restrictions approximately identical to those of perception. So we do not have to account for what would happen to an underlying |tũpa| in Guaraní, since the lexicalization process will have led to morpheme-level nasality in all lexical items. This levies our responsibilities with respect to Richness of the Base. The main case in which the workings of Richness of the Base become apparent, is the borrowing of foreign words. For example, Desano borrowed the Portuguese word [sɐβɐ̃ũ] 'soap' as [sabo], and [ʒoɐ̃ũ] 'John' as [ɲũ] (Kaye 1971). An OT approach along the lines of Prince and Smolensky (1993) would assume that the underlying forms are the disharmonic |sɐβɐ̃ũ| and |ʒoɐ̃ũ|, and have the grammar convert these to the harmonic [sabo] and [ɲũ]. However, there is no reason not to assume that these words were actually perceived harmonically and that they were therefore lexicalized as |sabo| and |ɲũ|.

4.6 Acquisition

Some of this reasoning may give the impression of circularity. Type-B languages are characterized by a high nasality Ocp, caused by a high correlation of nasality in consecutive syllables, and this high correlation of nasality again stems from the specification of nasality in the lexicon, which is on the level of the morpheme or linked to a fixed single vowel for every morpheme. And this morpheme-level lexical specification has again been caused by the unified perception of nasals across consonants, caused by a high nasality Ocp.

But this circularity was to be expected, since the high Ocp and the nasality correlation strengthen and feed each other. Imagine a language like French, with nasality specified for every vowel separately. Now, some cause (perhaps type-A spreading), introduced in this language, may raise the correlation between the nasality values of the vowels in consecutive syllables. If this correlation exceeds a certain threshold, a new learner is likely to introduce a high nasality Ocp in her perception grammar. This will have a large effect on her lexicon: while the previous generation had nasality specifications for every vowel separately, the new generation will have morpheme-level nasality specifications for harmonic morphemes and have to mark the disharmonic morphemes as lexical exceptions. If the learner regularizes some of the exceptions, she will produce more harmonic morphemes than she had heard in her environment. As each new generation reduces the number of exceptions, as is common in language change, the disharmonic forms will gradually die out. While this is happening, every next generation will have more reason to posit a high Ocp. The result is a stable type-B nasal harmony language.

Conclusion

A functional account of multisegmental nasality leads us to identify two types: the articulatory spreading of velum lowering, which occurs in Piggott's type-A languages, and the perceptual harmony of nasality on the morpheme or word level, which occurs in Piggott's type-B languages.

Generative accounts of nasal harmony have to take recourse to ad-hoc natural classes, exceptions to exceptions, grammaticization of constraints against unproducable perceptual output, functional exceptions to innate hierarchies, feature geometry, and multi-level OT. If all these things were really needed, UG would be full of substantive phonological detail. However, the functional approach to phonology can account for the facts of nasal harmony without assuming anything but general properties of human motor behaviour and perception. This is compatible with the view that the phonological part of the innate language device does not contain much more than: the cognitive abilities of categorization, abstraction, wild generalization, and extrapolation; the storage, retrieval, and access of arbitrary symbols; a stochastic constraint grammar; a gradual learning algorithm; laziness; the desire to understand others; and the desire to make oneself understood.

Notes

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1. By virtue of enabling additive ranking, a phonological theory that allows conjunction of faithfulness constraints or of gestural constraints (but no mixes) is more directly functional than a theory without this possibility.

2. As a detail, we may note that the always recalcitrant segment /h/ has no SV node, so that Piggott's analysis would predict that it is transparent, not nasalizable.

3. For Tuyuca, with a /b/–/m/ contrast, the specification would be |stop, +voi|, which gives simpler tableaus.

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Reinterpreting transparency in nasal harmony

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1. Introduction

In this paper I examine crosslinguistic variation in nasal harmony. Three kinds of segment behavior are observed: *target segments* become nasalized in nasal harmony (/na/ → [nã̠]), *blocking or opaque segments* remain oral and block nasal spreading (/nata/ → [nãt̠a]), and *transparent segments* remain oral and do not block nasal spreading (/nata/ → [nãt̠ã]). The membership of these categories varies in limited ways across languages. The aim of the present work is to establish a unified understanding of nasal harmony, so that all patterns conform to one basic character – something that has not been achieved before. A second goal is to examine the wider implications for phonological theory, particularly the consequences for analysis of transparency and locality in feature spreading.

A central claim defended here is that all nasal harmony patterns are constrained by a hierarchy ranking segments according to their compatibility with nasalization. Previous work has suggested that a nasalization hierarchy is relevant only for defining sets of target segments versus blockers. However, this view is faced with a complementarity problem. First there appear to be no examples of a certain pattern predicted by the hierarchy, one in which all segments including obstruents are nasalized. Second, another system is isolated from the others, one where some obstruents act transparent and all remaining segments are targets. The crosslinguistic study presented here reveals that target and transparent segments pattern together with respect to the nasalization hierarchy: if a class of segments propagates nasal spreading (is targeted or behaves transparent), all higher-ranked classes also propagate nasalization. To explain this, I propose to analyze descriptively transparent segments together with targets of nasality spreading as a unitary class of permeable segments, i.e. segments that participate in nasal harmony. The possible outcomes for segments in feature spreading becomes accordingly simpler: they either undergo nasal spreading or they block. Systems with transparency emerge as instances where all segments undergo nasal spreading, achieving a unified typology of nasal harmony where the nasalization hierarchy exhaustively limits variation. Interestingly, this result finds support for a view of locality in which feature spreading occurs only between strictly adjacent segments (Gafos 1996; Ní Chiosáin & Padgett 1997, 2001), a notion that previously seemed to be denied by the nasal harmony data.

The unified typology obtains the hierarchical variation in segments permeated by nasalization versus blockers. However, segments undergoing nasalization are noted to have two possible phonetic outcomes: nasal or oral. The latter occurs only on permeable segments near the extreme of incompatibility with nasalization, typically voiceless obstruents. I argue that this transparency outcome arises as a derivational opacity effect, a phenomenon captured under Sympathy Theory (Itô & Mester 1997; McCarthy 1999). The effect arises in a correspondence mapping between a fully-nasalized but unpronounceable phonological output representation ([nãt̃ã] – unpronounceable because [t̃] cannot be phonetically realized) and a similar but phonetically-possible output ([nãtã]).

This paper is organized as follows. In Section 2 I lay out the cross-language typology of nasal harmony, drawing on generalizations established by an extensive survey of nasal harmony systems. Based on the co-patterning of target and transparent segments, I propose to merge these categories, producing a new, unified understanding of nasal harmony. In Section 3 I develop an optimality-theoretic analysis. Bearing out the predictions of the theory, the range of attested patterns is obtained by exhausting the possible rankings of a spreading constraint in relation to a fixed hierarchy of nasalized segment markedness constraints. Section 4 turns to the different realizations for permeable segments and develops an analysis of segment transparency as derivational opacity. Section 5 presents the conclusion.

2. A crosslinguistic typology of nasal harmony

As discussed in Walker (1995), a key discovery emerging from previous surveys of nasalization is that variation in the sets of supralaryngeal targets and blocking segments in nasal harmony conforms to the implicational nasal compatibility hierarchy in (1), where for each division, marked by a numeric label, all segments to the left are targets, while those to the right block (Schourup 1972; Piggott 1992; Cohn 1993a, b; note also Pulleyblank 1989).[1]

(1) ① Vowels ② Glides ③ Liquids ④ Fricatives ⑤ Obstruent Stops ⑥
← high ———— *compatibility with nasalization* ———— low →

In previous work this hierarchy of segments has been applied strictly to patterns with blocking, separating them from systems with transparency. However, I will argue that this core hierarchy governs all nasal harmony. As the basis for this study I draw on a database of nasal harmony patterns, comprising descriptions from over 75 languages – the most inclusive survey to date (Walker 1998, with foundation from Schourup 1972; Piggott 1992; Cohn 1993b; among others). Patterns included in this database are those in which nasalization spreads across syllables or targets nonvocalic segments in the syllable.[2] The crosslinguistic generalizations established in this research define the facts to be explained by the analysis.

2.1 Hierarchical variation in blocking segments

I begin by considering nasal harmony patterns dividing their segments exhaustively into sets of targets and blockers. For patterns of this kind, a focal result of the database is that it corroborates the hierarchy in (1). The study finds that if a segment blocks nasalization, all segments less compatible by the nasalization hierarchy will also block. Further, if a segment becomes nasalized, all segments more compatible will be targets in nasal harmony. The range of possible blocking patterns in nasal harmony is thus considerably restricted. I exemplify the limited variation below.

A well-known example of the most restricted nasal harmony is found in Sundanese, an Austronesian language spoken in Western Java (Robins 1957; Cohn 1990). In this language nasalization spreads rightward from a nasal stop. Only vowels become nasalized and the remaining supralaryngeal segments block spreading, including glides.

(2) Sundanese
a. ɲãĩãn 'to wet'
b. ŋãjak 'to sift'
c. mãwur 'to spread'
d. mõlohok 'to stare'
e. mãro 'to halve'
f. ɲĩsər 'to displace'
g. ŋũdag 'to pursue'
h. ŋãtur 'to arrange'

The Johore dialect of Malay, another Austronesian language, illustrates the second variant, in which glides as well as vowels undergo a rightward spreading of nasality from a nasal consonant (Onn 1980). Liquids and obstruents block spreading.

(3) Malay (Johore dialect)
a. baŋõn 'to rise'
b. mãj̃ãŋ 'stalk (palm)'
c. mə̃nãw̃ãn 'to capture' (active)
d. mə̃ratappi 'to cause to cry'
e. pəŋãw̃ãsan 'supervision'
f. pəmãndaŋãn 'scenery'
g. mãkan 'to eat'

The Kolokuma dialect of Ijo, a Niger-Congo language of Nigeria, provides an example of the next hierarchical step, where liquids are added to the set of target segments (Williamson 1965, 1987). In this language, nasality spreads leftward from a nasal consonant or nasal vowel. Nasalization of the flap is apparent in (4c–d). Williamson (1987: 401) notes that prevocalic [l] and [n] are in complementary distribution, [l] occurring before oral vowels and [n] before nasal ones. In nasal vocalic contexts she posits /l/ as nasalizing to [n].

(4) Ijo (Kolokuma dialect)
a. ʊ̃mba 'breath'
b. w̃ãĩ 'prepare sugarcane'
c. j̃ãɾ̃ĩ 'shake'
d. sɔ̃ɾ̃ɔ̃ 'five'
e. sãnlo 'gills'
f. izõŋgo 'jug'
g. abãmu 'loft'
h. otõŋgbolo 'mosquito'
i. tɔ̃nĩ 'light (a lamp)'

The next most permissive nasal harmony, where nasality carries through fricatives, is found in the Applecross dialect of Scottish Gaelic, a Celtic language (Ternes 1973; van der Hulst & Smith 1982). Nasality spreads rightward from a stressed nasal vowel (usually in the initial syllable) until checked by an obstruent stop. It also nasalizes the onset of the syllable containing the stressed vowel, provided the onset is not an obstruent stop.[3] Three vowel lengths are distinguished: [ˑ] marks half-long, [ː] marks long, and short vowels are unmarked.[4]

(5) Scottish Gaelic (Applecross dialect)

a.	/frīaˑv/	[ˈf̃r̃ī̃ãˑṽ]	'root' (pl.)
b.	/ʃɛ̃nɛˑvar/	[ˈʃ̃ɛ̃nɛ̃ˑṽãr̃]	'grandmother'
c.	/ʟãːj̨/	[ˈʟ̃ãːj̨̃]	'hand'
d.	/ãhuç/	[ˈãh̃ũç̃]	'neck'
e.	/sŋãˑnʲdʲan/	[ˈs̃ŋãˑnʲdʲan]	'thread'
f.	/tʰãhusk/	[ˈtʰãh̃ũs̃k]	'fool'
g.	/strãiˑɣ/	[ˈstr̃ãī̃ˑɣ̃]	'string'
h.	/kʰɔ̃ispaxk/	[ˈkʰɔ̃ī̃s̃paxk]	'wasp'

The above examples illustrate four hierarchical variations in the set of segments undergoing nasal harmony. In general terms, the hierarchy governing the patterns has five segmental classes: Vowel, Glides, Liquids, Fricatives, and Obstruent Stops, where each different set of participating segments corresponds to a step in the hierarchy (see (1)). Yet there is a further step at either end of the hierarchy that must also be considered. The step at the leftmost extreme (marked ①) corresponds to a variant in which all segments block nasal spreading. This describes a language with no nasal harmony, a widely attested occurrence – Standard Spanish is an example. The step at the opposite extreme (marked ⑥) characterizes a system where all segments are nasalized including all obstruents. However, there are no surface-true examples of this kind. We are thus confronted with a seeming lack of exhaustivity in the hierarchical typology: all step-wise variants are attested except for the sixth and final step. In addition to this apparent gap, there is another pattern discussed below that appears to stand apart from the others – a system in which some obstruents behave transparent and the remaining segments are targets. These two observations present a basic complementarity puzzle in the descriptive typology of nasal harmony: there is no pattern in which all segments, including obstruents, undergo nasalization, and on the other hand, obstruents are the only segments that behave transparent. Resolving this issue is the focus of the next section.

2.2 Patterns with segmental transparency

The separate pattern with transparent segments is particularly prevalent in the Amazonian family; well-known examples include Barasano (Tucanoan; Colombia) and Guaraní (Tupí; Paraguay). The language examined here is Tuyuca, a Tucanoan language of Colombia and Brazil (Barnes 1996). Its consonant inventory consists of [p, b/(m), t, d/(n), k, ɡ/(ŋ), s, r, w, j, h]. Voiced stops are obstruents in their basic character, but they are variably realized as oral or nasal in outputs, as determined by nasal harmony contexts (see Walker 1998 for evidence supporting their basic obstruent status). Morphemes in Tuyuca are descriptively characterized as nasal or oral as a whole (see (6)). In an oral morpheme, all segments are oral; in a nasal morpheme, all segments are produced with nasalization except for voiceless obstruents. In oral morphemes all voiced stops are produced as obstruent stops, and in the output of nasal morphemes they are realized as fully nasal sonorant stops. Because nasality spreads to all nasalizable segments in a nasal morpheme, it is impossible to unambiguously pinpoint the segment from which spreading originates. For ease of exposition, I will simply assume that nasality originates in the first vowel of a morpheme.[5] In Tuyuca, spreading from the source segment is bidirectional in the morpheme, and it is not blocked by any segment. Voiceless obstruents are transparent to nasal harmony in the sense that they remain oral and yet they do not prevent nasalization from spreading past them to other segments.

(6) Tuyuca

Oral			Nasal		
a.	wati	'dandruff'	k.	w̃ãtĩ	'demon'
b.	keero	'lightning bug'	l.	kẽẽr̃õ	'a dream'
c.	oso	'bat'	m.	j̃õsõ	'bird'
d.	bota	'post'	n.	ẽmõ	'howler monkey'
e.	pade	'work'	o.	w̃ĩnõ	'wind'
f.	sɨge	'to follow'	p.	tɨ̃ŋõ	'Yapara rapids'
g.	pee	'to bend'	q.	pẽẽ	'to prepare soup'
h.	bipi	'swollen'	r.	mĩpĩ	'badger'
i.	diti	'to lose'	s.	nĩtĩ	'coal'
j.	aka	'give food'	t.	ãkã	'choke on a bone'

Systems like that of Tuyuca, with a set of transparent segments, have resisted a unified account with the others forming the hierarchical typology. Their apparent differences have led previous analysts to posit them as a second type of nasal harmony. For instance, in an important paper on this subject, Piggott (1992) seeks explanation from parametrized representations, proposing that systems with transparency differ from those with blocking in the dependency of [nasal] in the segment structure. While Piggott's study represents a significant contribution in this area, two major problems confront the dual representation approach. First, variable dependency must be stipulated for [nasal] to distinguish the two nasal harmony patterns – no independent evidence has been discovered for variable feature dependency. Second, no explanation is offered for the essential complementarity noted above: *all* segments have the potential to block spreading; all segments *except* (some) obstruents have the potential to be targets in nasal harmony, and *only* obstruents ever act transparent.[6] This complementarity strongly suggests that the two kinds of patterns can be united into a whole, and that is the direction I propose to take here.

Recall that in the hierarchical typology, the final step, in which nasality carries through all segments in nasal harmony, appears to be unattested. To produce a unified typology, I propose that patterns in which no segments block and some obstruents act transparent (e.g. Tuyuca) belong to this last hierarchical slot. Accompanying this move is an analytical claim that obstruent stops can undergo nasal harmony. In Tuyuca, we see evidence of voiced obstruent stops undergoing nasal spreading in their becoming nasalized in nasal morphemes. In contrast, voiceless obstruent stops are transparent (i.e. oral) in the output of nasal morphemes; however, there is typological evidence that voiceless stops pattern with targets of nasality spreading.

The basis for the typological argument comes from generalizations concerning transparent segments in the nasal harmony database. From the database it emerges that segments acting transparent to nasal harmony pattern together with targets in relation to the nasal compatibility hierarchy: if a segment is *permeated* by nasal harmony, that is, if it is targeted or behaves transparent, then all more compatible segments are also permeated by nasal spreading. There are thus patterns in which voiced stops undergo nasalization and voiceless stops act transparent but none in which voiceless stops are transparent but other segments block. In addition, transparency is always limited to obstruents and targeting of all obstruents is precisely the pattern missing in the hierarchical variants. To explain these generalizations, I propose that transparent segments and targets be analyzed together as a single category of segment patterning, characterized as *permeable segments* (borrowing terminology from Ní Chiosáin & Padgett 1997). Grouping transparent segments in the same class as targets in relation to the typology of nasal harmony fills the gap in the expected hierarchical variation and achieves a unitary view of cross-language variation.

An important result of merging target and transparent segments is illustrated in (7): the nasalization hierarchy is now reinterpreted as representing possible bifurcations between blockers and permeable segments. This move obtains a unified typology that exhausts all of its expected variants. Observe that a transparency system like that of Tuyuca is now slotted in as an instance of step ⑥, where all segments are permeated by nasality spreading.

(7) Unified hierarchical variation in nasal harmony:

①Vowels___Glides___Liquids___Fricatives___Obstruent stops___*Spanish*
___Vowels②Glides___Liquids___Fricatives___Obstruent stops___*Sundanese*
___Vowels___Glides③Liquids___Fricatives___Obstruent stops___*Malay (Johore)*
___Vowels___Glides___Liquids④Fricatives___Obstruent stops___*Ijo (Kolokuma)*
___Vowels___Glides___Liquids___Fricatives⑤Obstruent stops___*Gaelic (Applecross)*
___Vowels___Glides___Liquids___Fricatives___Obstruent stops⑥*Tuyuca*
← permeable segments ———————————— blockers →

The unified typology partitions segmental behavior in nasal harmony into a simple two-way distinction: segments are either permeated by nasal harmony or they block propagation of nasality. In the following section I propose a core analysis deriving the result of the typology in (7) differentiating between just the classes of permeable segments and blockers. Beyond this, there are two possible realizations within the class of permeable segments: they are either nasalized or oral ('transparent'). Section 4 develops the account further to explain these different outcomes.

3. Analysis of the unified typology

I formalize the analysis in the constraint-based framework of Optimality Theory (OT; Prince & Smolensky 1993). I assume a basic familiarity with the underpinnings of OT and its formalisms. To characterize the basic typology of nasal harmony, two kinds of constraints will be needed: nasal markedness and spreading. I begin with the former, arguing that they are arrayed in a hierarchy according to the compatibility of certain features in combination with [+nasal], which corresponds to the property of having a lowered velum.[7] I then go on to discuss the spreading constraint that drives nasal harmony. Factorial ranking of the spreading constraint in relation to the nasal markedness hierarchy will achieve the crosslinguistic variation.

3.1 The constraints

It is the task of any cross-language account of nasal harmony to explain the hierarchical implications limiting the range of attested patterns. Building on a proposal initially made by Schourup (1972), I assume that all variation in the set of permeable segments is based on the phonetically-grounded harmony scale of nasalized segments in (8), which corresponds to the nasalization hierarchy in (1). (The notion of a harmony scale follows Prince & Smolensky 1993.) Hierarchical (in)compatibility of nasalization has also been raised in the work of Pulleyblank (1989), Piggott (1992), Cohn (1993a, b), Walker (1995, 1998), Padgett (1995b, with application to patterns of nasal place assimilation), and Boersma (1998, this volume).

(8) Nasal vowel ≻ Nasal glide ≻ Nasal liquid ≻ Nasal fricative ≻ Nasal obstruent stop

The scale in (8) is segregated by segmental class. In general, nasality spreading makes class-based distinctions in the segments it permeates; however, if it were necessary, finer distinctions could be made by scaling nasalization of individual segments. The segment categories can be expressed formally in terms of feature specifications, for example, nasalized liquids will be [+nasal, +approximant, +consonantal]. (The particular choice of features is not crucial to what follows.) Importantly, the segment classes are ranked under the condition of simply combining nasalization with the other featural properties describing a given class of sounds. The highly incompatible nasalized fricatives thus remain [+continuant] and nasalized obstruents remain [–sonorant].

Of course, the most harmonic nasal segment of all is a sonorant stop, e.g. [m, n, ŋ]. Across inventories, these are unquestionably the most widely attested nasal segments (Ferguson 1975; Maddieson 1984; Pulleyblank 1989; Cohn 1993a). Nasality is intrinsic to the harmonic nature of these segments; in fact, it is not clear that this sort of sonorant stop ever occurs without [+nasal] (but see Piggott 1992; Rice 1993 for some suggested instances).[8] Nasal sonorant stops will appear at the leftmost extreme of the harmony scale. Since nasality is essentially basic in these segments, I have not listed them above in order to maintain expositional focus on the effect of scalar compatibility in segments acquiring nasality. After nasal (sonorant) stops, vowels are the next most widely attested nasal segments in inventories and they are most susceptible to acquiring nasalization in nasal spreading. The relative harmony of nasalized segments continues to decrease gradiently moving rightward through the hierarchy. Notice that although the scale in (8) resembles the sonority hierarchy (see Blevins 1995 and citations therein), it critically differs in the treatment of nasal (sonorant) stops, which are top-ranked in nasal harmonicity but medial in terms of sonority. The two hierarchies thus cannot be fully equated.[9] Cohn (1993a) notes, however, that sonority plays a role in determining the compatibility of nasalization with continuants. I suggest that the similarity in the scales stems from the sonority and nasalization hierarchies having an overlapping basis in perceptibility. In the case of sonority, the basis of perceptibility is something akin to acoustic intensity. For the nasalization hierarchy the scale reflects nasal perceptibility (in addition to articulatory compatibility, as noted below). A nasal stop will be the best in conveying perceptible nasalization, since the acoustic properties of a nasal stop stem solely from nasal airflow. For continuants, nasal airflow is combined with oral airflow. Here it seems that perceptibility of nasalization is enhanced by greater sonority, hence the overlap in the two hierarchies.[10]

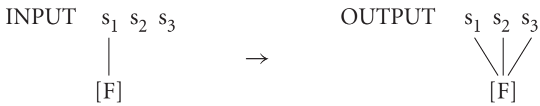
Overall, it is both articulatory/aerodynamic and acoustic/perceptual factors that contribute to the basis for the nasalization hierarchy, as noted by Cohn (1993a). For example, it is difficult to produce an audibly nasalized fricative because such a sound segment has articulatory/aerodynamic and acoustic/perceptual demands that are hard to satisfy at the same time. The nasal property requires that the segment be produced with a lowered velum, and nasal airflow undermines the build-up of pressure behind the oral constriction needed to produce frication (Cohn 1993a; Ohala & Ohala 1993; Ohala, Solé, & Ying 1998). As a consequence, perceptible achievement of either nasality or frication generally suffers in the production of nasalized fricatives. In an instrumental study of Coatzospan Mixtec, Gerfen (1996) finds that nasal airflow can be maintained during a voiceless coronal fricative with strongly audible frication, but the acoustic cues for nasalization are weak – the fricative is typically perceived as oral. On the other hand, in research on other languages it has been noted that nasalized voiced fricatives produced with clearly perceptible nasalization typically lose audible frication (Ohala 1975; Cohn 1993a; Ladefoged & Maddieson 1996).

With the harmony scale in (8), we can explain the variation in nasal harmony as variability in where languages make the cut between segments that are sufficiently compatible with [+nasal] to propagate nasalization and those that are not. Since OT is based on the notion of ranked and violable constraints, it is well-suited to capturing this insight. To implement the harmony scale in OT, it must be recast in terms of the nasalized segment constraint hierarchy in (9), where the less compatible a segment is with nasality, the higher-ranked its constraint (Walker 1995; see Prince & Smolensky 1993 for similar derivations of constraint hierarchies from harmony scales). For ease of exposition, I again refer to segment classes, rather than listing their featural description.

(9) *NasObstruentStop » *NasFricative » *NasLiquid » *NasGlide » *NasVowel

This markedness gradation represents a universal scaling of nasal feature cooccurrence constraints, and it will achieve the hierarchical implications for sets of blocking and permeable segments.

The nasalized segment constraints will conflict with the constraint driving the spread of [+nasal]. In autosegmental representations, the standard assumption is that spreading produces outcomes in which a feature is multiply-linked across a span of segments, as in (10). This modeling has a basis in understanding spreading as the extension of a gesture or property, motivated by functional/dynamic considerations discussed below.

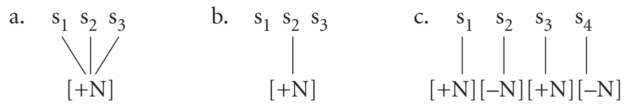
(10)


Following a proposal first made by Kirchner (1993), the multiple linking outcome can be achieved using featural alignment constraints to drive feature spreading (see also Smolensky 1993; Cole & Kisseberth 1995; Akinlabi 1996; Pulleyblank 1996; among others; see McCarthy & Prince 1993 on the general notion of alignment). A rightward [nasal] spreading constraint is given in (11). This formulation follows Zoll (1996), Walker (1998), and Ní Chiosáin and Padgett (2001) in making aspects of feature alignment more precise.

(11) Align-R([+nasal], PrWd): (henceforth Spread-R(+nasal))
Let n be a variable ranging over occurrences of the feature specification [+nasal], S be the sequence of ordered segments $s_1 \ldots s_k$ in the prosodic word domain, and $s_i\delta n$ mean that n is dominated by s_i. Then $\forall s_i, n[s_i\delta n \rightarrow \forall s_j[s_j\delta n]]$, where $s_j > s_i$.

Stated less formally, for every occurrence of a [+nasal] feature in a prosodic word, if that [+nasal] feature is dominated by some segment, it must also be dominated by every segment appearing to the right of that segment in the prosodic word. Following the analysts cited above, violation is taken as gradient; for any [+nasal] feature and the rightmost segment dominating it, a mark is accrued for each segment appearing to the right of that dominating segment in the prosodic word. Let us consider the evaluation of the structures in (12) in relation to this constraint (assuming the string of segments corresponds to a

PrWd). The structure in (12a) perfectly satisfies Spread-R(+nasal), since there is one occurrence of [+nasal] and it is linked to the rightmost segment of the string. The structure in (12b) incurs one violation for s_3 to the right of [+nasal], and (12c) accrues four violations, three for each of the segments to the right of the first [+nasal] feature specification (s_2, s_3, s_4) and one for the segment (s_4) to the right of the second [+nasal] feature.

(12)


Leftward spreading will be achieved by a parallel constraint to (11) substituting $s_j < s_i$ for the final restriction. Bidirectional spreading will result from eliminating any precedence restriction on s_j.

Nasal spreading constraints and the nasalized segment hierarchy will together derive the hierarchical effects in nasal harmony. These constraints conflict in a word containing a nasal segment. Satisfying spreading requires selection of an output containing nasalized segments. On the other hand, optimizing with respect to nasal markedness means avoiding formation of nasalized segments, which forces violation of spreading. Before exhibiting these resolutions, however, it is necessary to address the unitary analytical treatment of segments propagating nasality.

The segments that nasality carries through in spreading are the class of permeable segments, merging targets and descriptively transparent segments, as established above. Grouping these segments that propagate nasal harmony into one class is critical to achieving a unified view of variation in nasal harmony as well as a typology that exhaustively attests the possibilities predicted by the nasalization hierarchy. To achieve a unitary analysis of permeables, I posit all permeable segments as participants in nasal spreading. This claim is a conservative one; there is an unambiguous need in the theory for representations in which a spreading feature becomes the property of a permeated segment: this is the usual outcome for nasal harmony and for feature spreading in general. The crosslinguistic typology of nasal harmony provides evidence strongly suggestive of extending this view to transparent segments. It has shown us that nasality spreads from segment to segment. Importantly, apparent skipping of segments in nasal spreading does not occur as an alternative to blocking for the set of nonparticipant segments; patterns with descriptively transparent segments instead fill the slot where we expect to find all segments undergoing nasalization. This is explained if transparency is actually the outcome for a participant segment near the extreme of incompatibility with nasalization.

Analyzing all permeable segments as participants also has basis in insights stemming from the dynamic modeling of Articulatory Phonology (Browman & Goldstein 1986 et seq.), where spreading is conceptualized as the overlap of a gesture across segments. Functionally, this overlap is motivated by demands to increase perceptibility or articulatory ease, as discussed, for example, by Boersma (1998). The dynamic modeling entails that the spreading gesture is a continuous one: an overlap cannot be represented by repeating the gesture after an interruption. In the formal representation of phonological features, this attribute is instantiated by viewing each occurrence of a feature specification as a continuous and unitary entity (Scobbie 1991). In their important work on locality in spreading, Ní Chiosáin and Padgett (1997, 2001) make a formal proposal in their definition of a *convex* featural event (drawing on Bird & Klein 1990):

(13) A featural event F is convex iff it satisfies the following condition:
For all segments, α, β, γ, if α precedes β, β precedes γ, α overlaps F and γ overlaps F, then β overlaps F.

As Ní Chiosáin and Padgett point out, it is reasonable to assume that convexity holds of phonological representations without exception – it incorporates the understanding brought to phonological theory by dynamic studies. In OT, Ní Chiosáin and Padgett thus propose that convexity is a fundamental property that constrains the set of candidates that Gen produces.

An important corollary of this conception is that a gapped configuration like that in (14) is universally ill-formed under an interpretation where [F] is not a property of β.

```
(14)  *α  β  γ      where [F] is a feature and α, β, and γ are segments
        \   /
         [F]
```

This view is called *strict segmental locality*, since it enforces segmental adjacency in feature linking (Ní Chiosáin & Padgett 1993, 1997, 2001, foundation from McCarthy 1994; Flemming 1995a; Padgett 1995a; Gafos 1996; Walker & Pullum 1999). Ní Chiosáin and Padgett present detailed arguments for this position along with a review of previous supporting evidence. At the center of their discussion is an examination of Turkish vowel harmony, arguing that the spreading of vowel color features does not skip any segments and permeates consonants as well as vowels. In support of their analysis, they cite coarticulation studies which find that vocalic gestures normally overlap consonants (Öhman 1966). Placed within the context of a careful study of segment realization and contrast, Ní Chiosáin and Padgett argue that the perception of a consonant as 'transparent' to vowel harmony does not indicate that the spreading vocalic property is interrupted during the consonant; indeed, given the coarticulation research, the evidence suggests that the vocalic gesture is actually sustained during the consonant. Building on work in Dispersion Theory by Flemming (1995b), their independently-motivated explanation distinguishing contrast perception from articulation contributes to theoretical parsimony by eliminating any need for a transparency-specific representational configuration. They further argue that segmentally strict locality is needed in order to constrain the range of transparency effects found in language. A related line of research re-examines apparent transparency in coronal consonant harmonies (see especially Gafos 1996; also Ní Chiosáin & Padgett 1997; Flemming 1995a). These studies reveal that the spreading property of tongue tip shape or orientation can be maintained during so-called transparent segments – there is no need to regard them as 'skipped'.

The consequence of strict segmental locality for the analysis of nasal harmony is that spreading of [+nasal] may never skip a segment by linking across it, that is, all permeated segments must participate in nasal spreading. If nasalization of a particular segment cannot occur because of a nasal markedness constraint outranking spreading, the only possible outcome is that the segment block spreading. This agrees precisely with the analytical results driven by the typological generalizations of nasal harmony. I thus adopt convexity (from (13)) as the statement of phonological locality and take the participation of permeated segments to follow from this.

To review, two types of constraints have been established: the spreading imperative and the nasalized segment constraints. The family of nasalized segment constraints are scaled in a fixed hierarchy in relation to each other – a ranking grounded in phonetic factors. The view of spreading assumed is an elemental one: spreading simply involves the extension of a unitary and continuous featural gesture or property across segments – an understanding with a basis in functional and dynamic modelling, as well as case studies of long-distance phonological spreading. Together with the OT model, these constraints will be all that is needed to produce the core unified account of nasal harmony.

3.2 Typology from factorial constraint ranking

Prince and Smolensky (1993) hypothesize that typologies are derived by factorial constraint ranking, that is, the set of possible languages will be given by the grammars produced by all of the possible constraint rankings. The previous section motivated nasal spreading and intrinsically-ranked nasal markedness constraints. Given factorial ranking, a typology should then be derived by all possible rankings of the spreading constraint in relation to the nasal markedness hierarchy.

The complete set of possible rankings is given in (15). These rankings match precisely with the hierarchical variation observed in the sets of permeable and blocking segments in nasal harmony (in (7)). Because of strict segmental locality, [+nasal] can never skip associating to a segment in the attempt to achieve nasal spreading. Since skipping is not an option in spreading, any nasalized segment constraint that dominates spreading will produce blocking, as it would be worse to form these nasalized segments than violate spreading. In contrast, nasalized segment constraints outranked by spreading will correspond to participating segments, as it is better to violate these constraints by forming the nasalized segments, than it is to violate spreading instead.

(15) ① *NasObsStop » *NasFric » *NasLiquid » *NasGlide » *NasV » Spread(+nas)
② *NasObsStop » *NasFric » *NasLiquid » *NasGlide » Spread(+nas) » *NasV
③ *NasObsStop » *NasFric » *NasLiquid » Spread(+nas) » *NasGlide » *NasV
④ *NasObsStop » *NasFric » Spread(+nas) » *NasLiquid » *NasGlide » *NasV
⑤ *NasObsStop » Spread(+nas) » *NasFric » *NasLiquid » *NasGlide » *NasV
⑥ Spread(+nas) » *NasObsStop » *NasFric » *NasLiquid » *NasGlide » *NasV
① *Spanish*, ② *Sundanese*, ③ *Malay*, ④ *Ijo*, ⑤ *Applecross Gaelic*, ⑥ *Tuyuca*

The overall ranking structure for the typology of nasal harmony is given in (16). A crucial feature of this pattern is that the ranking of nasalization constraints with respect to each other remains constant according to the intrinsically-ranked hierarchy in (9).

(16) Nasalized segment constraints >> Spread(+nasal) >> Nasalized segment constraints
blocking segments *spreading imperative* *participant segments*

The analysis is exemplified in (17)–(19). The tableau in (17) illustrates the ranking for Sundanese, with rightward spreading.[11] In this pattern, only vowels undergo harmony, so the spreading constraint outranks just the nasalized vowel constraint – other nasalization constraints dominate spreading. Nasalization in candidates is marked with a tilde and brackets are used to delimit spans of a [+nasal] feature, i.e. [nã] implies that one nasal feature is linked to two segments and [n][ã] signifies that there is a separate [+nasal] feature linked to each segment. In the optimal output (17a), spreading extends only as far as the adjacent vowel, since spreading further would violate a dominating nasalization constraint. In (17b), [+nasal] links to every segment, satisfying spreading, but this candidate loses since it violates the higher-ranked constraints against nasalized glides and obstruent stops. Candidate (c) shows a similar problem in spreading up to the obstruent stop. Candidate (d) nasalizes every vowel in the word, but it does not derive nasalization of the second vowel by multiple-linking of the first [+nasal] feature, rather it introduces a separate occurrence of [+nasal] into the structure. This candidate thus fails on the basis of spreading: it incurs three violations for the three segments appearing to the right of the first [+nasal] feature span and one violation for the segment to the right of the second [+nasal] feature span. In (17e), no spreading takes place, and this too loses on a spreading violation.[12]

(17) Sundanese

	ŋajak	*Nas ObsStop	*Nas Fric	*Nas Liquid	*Nas Glide	Spread-R (+nasal)	*Nas Vowel
☞	a. [ŋã]jak					***	*
	b. [ŋãj̃ãk̃]	*!			*		**
	c. [ŋãj̃ã]k				*!	*	**
	d. [ŋã]j[ã]k					****!	**
	e. [ŋ]ajak					****!	

The variations in nasal harmony will differ from Sundanese only in the ranking of the spreading constraint. The tableau in (18) illustrates the case of Ijo, where vowels, glides, and liquids undergo nasalization. For this pattern, a leftward spreading constraint is situated between the constraint against nasalized fricatives and the constraint against nasalized liquids.

(18) Ijo

	sɔɾɔ̃	*Nas ObsStop	*Nas Fric	Spread-L (+nasal)	*Nas Liquid	*Nas Glide	*Nas Vowel
☞	a. s[ɔ̃ɾ̃ɔ̃]			*	*		**
	b. [s̃ɔ̃ɾ̃ɔ̃]		*!		*		**

When spreading dominates all nasalized segment constraints, all segments will participate in nasal harmony. This is how I propose to treat Tuyuca. (Note that the directionality restriction in spreading is removed in this example.)

(19) Tuyuca

	wãti	SPREAD (+nasal)	*NAS OBSSTOP	*NAS FRIC	*NAS LIQUID	*NAS GLIDE	*NAS VOWEL
☞	a. [w̃ãt̃ĩ]		*			*	**
	b. [w̃ã]ti	*!*				*	*
	c. w[ã]ti	*!**					*
	d. [w̃ã]t[ĩ]	*!****				*	**

The optimal output selected on the basis of this ranking is (19a), in which all segments are nasalized, including the voiceless obstruent stop. This segment is actually described as oral, corresponding to a representation like that in (19d), with separate nasal feature spans on either side of the stop. However, comparing (19d) with (19b), where the stop blocks spreading, it is apparent that (19d) incurs a superset of the spreading and markedness constraint violations that (19b) does. Candidate (19d) can thus never be optimal under any ranking of these constraints. A candidate like (19a), with spreading to all segments, is the only one for which spreading can drive nasalization of the vowel following the stop. A grammar with this outcome is predicted by the factorial ranking hypothesis. Accordingly, I posit this as the basic analysis for languages with transparent segments in nasal harmony, and in the next section I explore how the optimal candidate in (19a) is mapped to the outcome in (19d) in an opaque constraint interaction.

We have now seen that exhaustive ranking of the spreading constraint in relation to the hierarchy of nasalized segment constraints derives precisely the hierarchical variation observed across languages. The unified typology is achieved through reduction to two basic kinds of constraints, spreading and nasal markedness, and two kinds of segment outcomes, permeated and blocking. A central claim underlying this typology is that descriptively transparent segments should be regarded along with targets as participants in nasal spreading. The analysis of transparent segments as participants is supported by the observations of crosslinguistic variation in nasal harmony on three fronts. First, the class of segments that may behave transparent are essentially in complementary distribution with those that may become nasalized in nasal harmony. Second, a system in which all segments including obstruents undergo nasalization is predicted under the factorial ranking hypothesis – positing transparent segments as participants fills this slot given by the hierarchy. Third, this analysis explains the generalization that whenever a segment behaves transparent to nasal spreading, all segments more compatible with nasalization are permeated by spreading – more compatible segments do not block. A more general grounding for the participation of transparent segments stems from the view that feature spreading is segmentally local. Section 4 focuses on a means of deriving the surface orality of transparent segments while maintaining the simple formulation of spreading and nasal markedness and the constrained view of strict segmental locality. In what follows I argue that transparent segments can be captured under the Sympathy approach to opaque constraint interaction (McCarthy 1999, with extensions by Itô & Mester 1997), a mechanism with independent motivation in the theory.

4. Analysis of transparency

A few different proposals have been made to preserve strict segmental locality for cases of apparent transparency, that is, where feature spreading appears to have skipped a segment. These proposals fall into two main directions. One line of research outlined above takes the position that in certain kinds of transparency, the relevant gesture is actually carried through the segment. I call this *false transparency.* This approach is taken by Ní Chiosáin and Padgett (1997, 2001) for transparent consonants in vowel harmony and by Gafos (1996) for transparency in coronal harmony (also Flemming 1995a; Ní Chiosáin & Padgett 1997). Further examples are discussed by McCarthy (1994), Padgett (1995a), and Walker and Pullum (1999). The false transparency accounts are unified by the claim that the spreading feature is compatible with the transparent segment.

A second kind of analysis addresses cases where the transparent segment seems to be realized with a feature specification truly opposing the spreading property. This type of transparency I will refer to as *antagonistic transparency* (after Archangeli & Pulleyblank 1994). Examples of this kind include certain transparent vowels in vowel harmony, for instance, nonlow front vowels transparent to [+back] harmony in Finnish (e.g. Ringen 1975; Kiparsky 1981). Transparent obstruents in nasal harmony also belong to this category – an instrumental study by Walker (1998) confirms the oral obstruent realization for voiceless stops that act transparent to nasal harmony in Guaraní. For cases of antagonistic transparency, it has been proposed that the transparent segments actually undergo spreading at some abstract level of phonological representation (see Clements 1976; Vago 1976; Piggott 1988; Walker 1996; Ní Chiosáin & Padgett 1997; among others). This abstract representation then forms the input to another level or rule, at which point the transparent segment is changed to bear the opposite feature specification to the spreading one in order to resolve an incompatibility of feature specification.[13] This approach for nasal harmony is shown in (20), formalized in an SPE-style derivation for expositional simplicity.

(20)	Underlying representation (hypothetical form)	/ãrato/
	Nasal spreading (iterative): X → [+nasal]/[+nasal]__	ãr̃ãt̃õ
	Obstruent stop denasalization: [–son, –cont] → [–nasal]	ãr̃ãtõ
	Surface representation	ãr̃ãtõ

This kind of analysis calls on what has been called *derivational opacity* by Kiparsky (1973): the outcome of an early rule is reversed in the output – here the nasalization of the obstruent stop. As a result of the derivational opacity, a valid grammatical generalization in the language, namely that nasalization spreads through a continuous string of segments, is not surface-true. This approach differs from the false transparency proposals in two important ways. First, it assumes that in the output the transparent segment actually has a specification opposite to the spreading feature, i.e. it concedes transparency, and second, it makes use of an intermediate level of representation.

The previous proposals are not incompatible with each other, rather they have shown that apparent transparency may arise under two different sets of circumstances. Our concern lies with antagonistic transparency. I will argue that it is indeed correct that antagonistically transparent segments have a feature specification opposite to the spreading one in the actual output, but we need not call on a second level of input-output mapping or intermediate derivational step to achieve this result – it can be captured in a one-level framework by utilizing Sympathy Theory.

4.1 Transparency as a (derivational) opacity effect

An important result of the derivational opacity approach to segment transparency is that it preserves the strict segmental locality of spreading – the phenomenon of spreading carries a feature through a continuous sequence of segments. The discontinuity in the output comes about not through the satisfaction of spreading, but by an operation obscuring the outcome of spreading. In this it is consonant with a central finding of the unified typology of nasal harmony: transparent segments pattern with participants in nasal spreading.

The question we face is how to obtain this kind of derivational opacity effect in OT. It cannot be achieved by a simple ranking of the nasal spreading and markedness constraints, assuming a single level of input-output mapping. The problem is illustrated in (21) for a case of bidirectional spreading. The candidate in (21a) corresponds to the real outcome of a language with transparency (signalled by "☞"); however, it is not selected by this tableau. Instead, (21b), with blocking by the obstruent stop, is the one that is optimal according to this constraint ranking. (This wrong selected outcome is marked by "☹".) Under the reverse ranking of the constraints, (21c) would be the selected winner, with nasalization of all segments. Since (21a) incurs a superset of the violations incurred by (21b), no ranking of these constraints will select (21a) as optimal.

(21) Incorrect outcome for hypothetical form /ãrato/

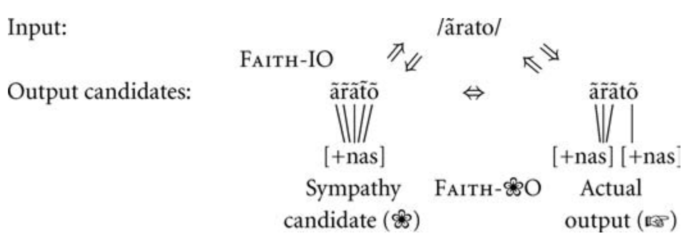
	ãrato	*NasObsStop	Spread(+nasal)
☞	a. [ãr̃ã]t[õ]		***!***
☹	b. [ãr̃ã]to		**
(❀)	c. [ãr̃ãt̃õ]	*!	

Candidates (21b) and (21c) represent more *derivationally transparent* alternatives – blocking or participation are the two basic outcomes for nasal harmony, as established in Section 3. Note the overlap in descriptive terminology: derivational transparency vs. opacity describes whether valid grammatical generalizations are apparent in the output; segmental transparency vs. opacity (or blocking) describes different kinds of segmental behavior in harmony (as outlined in Section 1).

It is of importance that derivational opacity effects exist independently in phonology and must be explained under any theory. In a study representing a significant advance in this area, McCarthy (1999) develops what is known as the 'Sympathy' approach to such phenomena in OT. In the version of Sympathy using inter-candidate faithfulness, a core proposal is that faithfulness relations may exist between one candidate and another within a single candidate set. This co-candidate faithfulness relation establishes a correspondence mapping from a designated candidate in the evaluation set to a given output (see McCarthy & Prince 1995 on the model of the Correspondence Theory approach to faithfulness). Sympathetic faithfulness promotes an output form which resembles the designated candidate, that is, it favors an output which is in *sympathy* with a particular candidate. Importantly, only a single candidate set is utilized in determining the output, and so a single level of input-output mapping is maintained.[14] McCarthy shows that this strategy is capable of capturing a range of cases of derivational opacity that were previously problematic in OT. Examples of further applications of sympathetic correspondence include Itô and Mester 1997, Davis 1997, Karvonen and Sherman 1997, Merchant 1997, Katayama 1998, de Lacy 1998, among others. (Itô & Mester also develop some extensions to McCarthy's original proposal that are discussed and utilized below.) I propose to draw on the Sympathy approach to explain antagonistic transparency, i.e. to achieve the derivational opacity in nasal harmony (and by extension to achieve antagonistic transparency in vowel harmony, though that will not be discussed here because of space limitations).

The application of sympathetic correspondence to segmental transparency is modeled in (22). The faithfulness of output candidates to the input are evaluated through Faith-IO (Input-Output) constraints. Here the input matches the underlying representation in the derivational approach in (20). Each representation produced at some stage of that derivation is included in the output candidate set. The candidate corresponding to the intermediate form with full spreading in (20) is designated as the sympathetic one in the evaluation set (marked by "❀"). Sympathetic faith constraints, abbreviated as Faith-❀O (after Itô & Mester 1997), enforce the resemblance of the actual output to this candidate. The actual output matches the surface representation in (20).

(22)



In order for the sympathy candidate not to win itself, it must lose on the basis of some high-ranked constraint. This will be the constraint banning nasal obstruent stops, which plays the role of the obstruent stop denasalization rule in (20). The actual output is the candidate most closely resembling this candidate while still respecting *NasObsStop.

It is important to note that all of the candidates being evaluated still respect locality, that is, a representation like that in (14), with gapping across a segment, is never generated or called on for comparison. The representation of the actual output has a separate [+nasal] feature specification on either side of the transparent obstruent. As observed in Section 3, the actual output structure shown in (22) cannot be obtained directly from spreading. Spreading requires that each occurrence of a feature specification be linked to all segments in the word; it is not satisfied by candidates containing separate projected copies of that feature. The actual output is instead selected on the basis of its being the best possible match to the sympathetic candidate, with full nasal spreading.

Crucially, featural correspondence between the sympathetic fully nasalized candidate and the actual output is enforced by an IDENT[Feature] constraint, which requires not that features themselves have correspondents but that the featural properties of correspondent segments are identical (McCarthy & Prince 1995).

(23) IDENT-❀O[+nasal]
Let α be a segment in the sympathetic candidate and β be any correspondent of α in the output. If α is [+nasal], then β is [+nasal].

It is the IDENT-❀O correspondence relation for [+nasal] that produces the occurrence of separate [+nasal] features on either side of the transparent segment in the optimal output, that is, the optimality of the actual output in (22) is driven by its similarity in featural properties to the fully-spread sympathy candidate, even though the optimal output itself fares poorly with respect to spreading and involves introducing an extra [+nasal] feature. This result provides support for a view of featural faith mediated through segmental identity, given by the IDENT formulation.

An overview of the constraint ranking deriving segmental transparency through Sympathy is given in (24). The candidate with full nasal spreading (24a) is designated here as the sympathy candidate. This candidate loses in the contention for the optimal output, because it incurs a fatal violation of the constraint prohibiting nasalized obstruent stops. The next highest constraint is the sympathetic faith constraint requiring identity between the sympathy candidate (24a) and a given output in the [+nasal] property of segments. The form in (24c), which matches [+nasal] identity in all but [t], is the best of the candidates respecting *NASOBSSTOP on this faith constraint. The alternative in (24b) loses, because in addition to [t], the next segment [o] is also oral. This extra IDENT-❀O faith violation is fatal, even though (24b) fares much better than (24c) on spreading.

(24) Overview of sympathy analysis of segmental transparency

	ãrato	*NASOBSSTOP	IDENT-❀O[+nasal]	SPREAD(+nasal)
❀	a. [ãr̃ãt̃õ]	*!		
	b. [ãr̃ã]to		**!	**
☞	c. [ãr̃ã]t[õ]		*	******

The tableau in (24) shows how sympathetic correspondence can achieve the effect of an opaque rule interaction of the type used to produce segmental transparency in spreading, while still maintaining a restrictive conception of locality, levels, and phonological constraints. Central to this account is the notion of a designated sympathy candidate. This will be the examined in the next section, which applies Sympathy to segmental transparency in Tuyuca.

4.2 Transparency in Tuyuca

Recall the interim result for Tuyuca from (19). SPREAD(+nasal) outranks all nasal markedness constraints to obtain permeability of all segments. The outcome of this ranking is repeated below.

(25) Tuyuca ranking from (19) (fewer candidates shown)

	wãti	SPREAD (+nasal)	*NAS OBSSTOP	*NAS FRIC	*NAS LIQUID	*NAS GLIDE	*NAS VOWEL
☞	a. [w̃ãt̃ĩ]		*			*	**
	b. [w̃ã]ti	*!*				*	*
	c. [w̃ã]t[ĩ]	*!****				*	**

The winner in (25a) is actually phonetically impossible – a nasalized obstruent stop cannot be pronounced with simultaneous implementation of all its features (see Note 13). This output is thus not one that could ever be heard and reproduced by a language learner. However, the accessibility of candidate (25a) in phonology is made evident by its influence in the selection of the actual output in (25c) – a form that cannot be selected under any transparent ranking of these constraints. The strategy of the Sympathy-based analysis is thus to designate (25a) as the sympathy candidate and select (25c) as optimal by virtue of its resemblance to (25a). Because of space limitations, I focus only on the transparency of voiceless stops here. A parallel account is capable of achieving the transparency of fricatives (Tuyuca is a language which reportedly does not tolerate nasalized fricatives in an actual output), and on the nasal outcome for voiced stops in nasal morphemes, see Walker (1998).

In designation of the sympathy candidate I follow the model of *Harmonic Sympathy* (Walker 1998), aiming to develop and explicate the *Selector-Constraint* version of McCarthy (1999) and the extensions proposed by Itô and Mester. In McCarthy's approach, he suggests that the sympathetic candidate is identified by being the most harmonic of the set of candidates satisfying some designated 'selector constraint'. Opacity effects arise when the sympathetic candidate fails as the actual output by incurring a violation of some constraint dominating the selector constraint. Under this approach it is Spread(+nasal) that would be the selector constraint in Tuyuca harmony. Spread(+nasal) screens out all but the fully spread form (25a) for sympathy status. McCarthy proposes to limit derivational opacity effects by restricting the potential for selector status to faithfulness constraints. However, this limitation turns out to be too restrictive. In their work on opacity in German truncations, Itô and Mester (1997) argue that it is necessary to allow other constraints, besides faithfulness, to serve as the selector constraint (see also de Lacy 1998). Itô and Mester find that for German truncations, an alignment constraint must be granted the selector role. They further note that since assigning selector status to a constraint amounts to inducing a separate optimization in which that constraint is top-ranked, and ranking variation is a basic element of OT, then 'the logic of OT itself compels us to expect other constraints in [the selector] role as well' (1997: 126–127, n. 12). The derivational opacity effect of segmental transparency lends support to Itô and Mester's claim, since alignment (driving spreading) again plays a selecting role in designating the sympathetic candidate. This important extension of McCarthy's original proposal is thus assumed in the analysis of segmental transparency below.

Harmonic Sympathy seeks to bring a firmer understanding to what brings about opaque constraint interactions and the privilege that the selector constraint holds. This approach focuses on the connection between derivational opacity and the resolution of constraint conflict through ranking in a hierarchy – fundamental elements of OT. The puzzle presented by many cases of derivational opacity is that in the absence of sympathetic correspondence, the appropriate outcome cannot be achieved under the normal ranking resolution of two conflicting constraints. In (21), for example, we saw that no simple ranking of Spread(+nasal) and *NasObsStop can achieve segment transparency – the dominated constraint loses absolutely. If *NasObsStop outranks Spread(+nasal), the candidate with segment blocking wins, even though it is quite different from the one that would have been selected by Spread(+nasal). The interaction between these two constraints is in fact more complex. The fully spread candidate fails because of its nasalized obstruent stop, but were Spread(+nasal) to have won the day, this would be the most harmonic form. The tableau in (24) above shows that the candidate that would have been chosen if spreading had won the conflict influences the selection of the optimal output. Under the Selector Constraint approach to Sympathy, this more complex kind of constraint interaction would be produced by designating SPREAD(+nasal) as selector; however, I propose to eliminate the need for introducing a 'selector' status as a property assigned to some constraint, and instead make this role emergent of a segmented constraint ranking structure. To achieve this, I propose that a second type of constraint conflict resolution is possible: a conflict between two constraints can be resolved by bifurcating the constraint hierarchy at the point of conflict into two ranked segments, P1 and P2, as illustrated in (26). P1 is the higher segment, and it contains the constraint that is actually respected in the optimal output, in this case *NASOBSSTOP. Within the lower segment, P2, the competing constraint, here SPREAD(+nasal), is top-ranked, and it dominates its competitor in this subhierarchy.

(26) P1 >> P2
*NASOBSSTOP SPREAD(+nasal) >> *NASOBSSTOP >> *NASFRIC >> *NASLIQ . . .

The above represents an opaque resolution of constraint conflict through *hierarchy partitioning*. As the constraint that belongs to the dominating P1 component, *NASOBSSTOP is the one that triumphs in the conflict – it is respected in actual outputs. The conflicting spreading constraint loses by virtue of its domination by the P1 segment, but it gains recognition in another respect. I propose that the candidate that is most harmonic with respect to the P2 hierarchy is the sympathy candidate via an *embedded optimization*. The high-ranking status of SPREAD(+nasal) in P2 thus allows its force to be reflected in selection of the sympathy form.

Let us examine the resulting organization of the grammar in (27). This tableau shows the partitioning of the phonological constraint hierarchy into two segments, as induced by the opaque resolution of the conflict between *NASOBSSTOP and SPREAD(+nasal). To conserve space *NASOBS collapses the individual nasalized obstruent constraints in P2 and *NASSON collapses nasalized sonorant constraints. The P1 segment is shaded here to focus on selection of the sympathy candidate in P2. Because the spreading constraint is top-ranked in this segment, the sympathy candidate will be (27a) – the one with full spreading. The result of this subhierarchical optimization is marked by the flower at the left of the P2 segment.[15]

(27) Selecting the sympathetic candidate via embedded optimization

	P1		P2		
wãti	*NasObsStop		Spread(+nas)	*NasObs	*NasSon
a. [w̃ãt̃ĩ]	*	❀		*	***
b. [w̃ã]ti			*!*		**
c. [w̃ã]t[ĩ]			*!****		***

The full tableau selecting the (derivationally) opaque optimal output is exhibited in (28). Since the sympathy candidate violates *NasObsStop, it falls out of the running for the optimal output early. Candidates (28b–c) survive *NasObsStop and fall to Ident-❀O[+nasal]. This chooses (28c) over (28b), because (28c) more closely resembles the sympathy candidate.[16]

(28) Transparency in Tuyuca:

		P1			P2		
	wãti	*NasObsStop	Ident-❀O[+nas]		Spread(+nas)	*NasObs	*NasSon
	a. [w̃ãt̃ĩ]	*!		❀		*	***
	b. [w̃ã]ti		**!		**		**
☞	c. [w̃ã]t[ĩ]		*		*****		***

Descriptively speaking, the opaque resolution of constraint conflict means that the top-ranked constraint (*NasObsStop) wins in selection of the actual output, but the losing constraint, Spread(+nasal), otherwise conditions selection such that the output resembles as closely as possible the candidate that would have been chosen if spreading were respected. The hierarchy partitioning is what enables selection of the sympathy candidate, and it is the placement of sympathetic faith between the two opaquely interacting constraints that achieves the influence of the sympathy candidate in selection of the actual output. The organization that I assume locates sympathetic faith in P1. P2 then functions as an embedded optimizer for the sympathy candidate, and the P1 and P2 segments together compose the phonological grammar. It should be noted that the preliminary tableau in (27) is shown separately for expository purposes only; the tableau in (28) represents the complete evaluation. This evaluation involves two optimizations, an embedded one with respect to P2 and one with respect to the entire hierarchy.[17] Selection of the sympathy candidate and the optimal output is performed in parallel evaluation with a single input-output level.

Observe that in a nasal morpheme containing only sonorants, the actual output will incur no Faith-❀O violations. In forms of this type, the sympathetic candidate coincides with the actual output. This is illustrated in (29) for the Tuyuca form [j̃õr̃ẽ] ‘little chicken’.

(29) Full spreading with no obstruents: Sympathetic candidate is same as actual output

		P1			P2		
	jõre	*NasObsStop	Ident-❀O[+nas]		Spread[+nas]	*NasObs	*NasSon
☞	a.[j̃õr̃ẽ]			❀			****
	b.[j̃õ]re		*!*		**		**
	c.j[õ]re		*!**		***		*
	d.[j̃õ]r[ẽ]		*!		*****		***

An important achievement of the account proposed here is that it does not make use of a transparency-specific configuration, such as gapping, to produce segmental transparency. It preserves the strict segmental locality of feature linking representations and obtains apparent skipping effects by calling on the notion of Sympathy, an approach to derivational opacity effects with extensive independent motivation in the theory. The analysis draws on the innovations of McCarthy’s sympathetic correspondence relation and Selector Constraint model of sympathy along with developments by Itô and Mester, but makes some modifications in implementation. The hierarchy partitioning in the Harmonic Sympathy model essentially serves as a spell-out of what is entailed by selector constraint status. The two approaches share the idea that selection of the sympathy candidate involves an optimization corresponding to a constraint ranking differing in some respect from that selecting the actual output. Harmonic Sympathy casts insight on the basis of the sympathy optimization by making a direct connection with the structure of the strictly ranked constraint hierarchy – the sympathetic candidate is selected through an embedded optimization with respect to a contiguous segment of the constraint hierarchy – selector status itself is obviated in the theory. It is interesting to note that the principle of *base optimization* discussed by Alderete (1999) draws on some related mechanisms to those at work in the embedded optimization for Harmonic Sympathy. Base optimization chooses as the base for output-output (OO) correspondence the word which leads to the most harmonic base-output pair with respect to the constraint hierarchy. Both the OO base optimization and embedded sympathy optimization share the notion that the constraint hierarchy alone is used to identify the base for a correspondence relation. Base optimization calls on the entire hierarchy, while the embedded optimization draws on a partitioned segment. (Note also Lexicon Optimization; Prince & Smolensky 1993.)

Interestingly, the Harmonic Sympathy structure illuminates opaque constraint interactions involving implicational constraint hierarchies. Since selector status can in principle be assigned to any constraint (following Itô & Mester 1997), it is possible to lose the effect of fixed rankings in a constraint family by designating a lower ranked constraint as selector and inducing an optimization in which it is top-ranked in selection of the sympathy candidate. This has the potential to produce undesirable results (see Walker 1998 for exemplification). On the other hand, in Harmonic Sympathy, the ranking for evaluating both the actual output and the sympathetic candidate is spelled out in the constraint hierarchy. Fixed rankings can thus be maintained if universal constraint hierarchies are interpreted as requiring that wherever a constraint is located in the hierarchy for a given grammar, it must be dominated by some occurrence of each of the constraints dominating it in a universal hierarchy. This offers a direct explanation of how the appropriate implications are to be maintained in opaque constraint interactions.

This section has established how antagonistic transparency can be captured in OT via the model of Harmonic Sympathy. Importantly, the Harmonic Sympathy approach achieves this outcome while maintaining strict segmental locality as a universal of phonological representations. The final section recapitulates the typological results established earlier and addresses the issue of limiting factors in derivational opacity effects.

5. Conclusion and further issues

Let us review the results obtained by this account of nasal harmony. First, the account proposed here achieves a unified typology of nasal harmony while at the same time maintaining a simple and constrained conception of the constraints and locality. Spreading is produced by the extension of a feature, representing a unitary and continuous property, across a sequence of segments. Blocking effects in spreading come about when a nasalized segment constraint outranks spreading, and in turn, permeation results when spreading dominates nasal markedness. An intrinsic ranking holding over the nasal markedness constraints captures the hierarchical implications across languages in the sets of segments permeated by or blocking nasal spreading. The typology of nasal harmony is achieved by factorial ranking of the spreading constraint (in P2) in relation to the fixed nasalized segment constraint hierarchy. For all but obstruent stops, evidence for the violability of the nasalized segment constraints is seen in the actual outputs of various languages with nasal harmony. In the case of obstruent stops, it is physically impossible to produce audible nasalization simultaneous with a burst; these segments thus must sacrifice some property in their output realization – they are either oral obstruents or nasal sonorant stops. As a consequence, when obstruent stops actually undergo nasal spreading, they must map to a pronounceable output – a mapping achieved through an opaque constraint interaction utilizing sympathetic correspondence. When a nasalized stop is mapped to an oral obstruent, the result is segmental transparency. This outcome is achieved through reference to a candidate where nasalization has spread to all segments, including obstruent stops. The approach thereby obviates any need for ad hoc transparency-specific representations and brings antagonistic transparency under the wing of widespread derivational opacity. Economy of analysis alone thus argues for treating true segmental transparency as a derivational opacity effect. Other considerations also support this move, such as the typological evidence of co-patterning between targets and transparent segments, the motivation from studies of other harmonies for strict segmental locality in feature linking, and a simple view of spreading as gesture extension.

At this point I turn to the matter of restricting the extent of derivational opacity effects. It is reasonable to question why transparent segments in nasal harmony are restricted to segments near the extreme of incompatibility with nasalization (i.e. obstruents). For example, what rules out a language in which only vowels are targeted and all consonants behave transparent? I suggest that acquisitional factors underlie the relatively rare outcome of segment transparency in contrast to blocking as well as the limitation of segment transparency to classes of segments near the extreme of incompatibility with nasalization. In his discussion of derivational opacity, Kiparsky (1971, 1973) proposes that opaque grammars are marked in the sense that they are harder to learn and the direction of language change will be towards derivational transparency. The sympathy account of derivational opacity sheds light on Kiparsky's claims: an opaque constraint interaction is more complex than a transparent one because it involves computing an extra optimization, namely, the embedded optimization selecting the sympathy candidate. This, in itself, predicts that segment blocking in spreading (arising from a transparent constraint interaction) will be more common than segment transparency (realized through an opaque interaction), and this generally seems to be borne out.

In addition to representing the increased complexity of derivational opacity, sympathetic faith also gives us a means for evaluating the degree of difficulty for learning a particular opacity effect. I propose that the greater the gap between the sympathetic candidate and the actual output, the harder the language will be to learn, that is, grammars with more sympathetic faith violations are more difficult to acquire than ones with fewer violations. Coming back to nasal harmony, this means that grammars with fewer transparent segments will be easier to learn. A language in which all consonants behaved transparent would be difficult to acquire because of its much greater potential for difference between the sympathetic candidate and the actual output. This view provides explanation for the tendency for opaque interactions to occur with nasalized segment constraints ranked towards the high end of the hierarchy. If P1 contains just one or two nasalized segment constraints, it will be those banning nasalized obstruents. As more nasalized segment constraints from the hierarchy are added to P1, the potential for sympathetic faith violations in the actual output increases, making the learning task more demanding. The possibility of a language with a larger set of transparent segments in nasal harmony is thus not excluded absolutely, but the probability of its occurrence is much reduced.[18] More generally, acquisitional factors will favor smaller P1 segments in grammars with opacity effects. These acquisitional dimensions of derivational opacity lend insight to the limited occurrence of segment transparency in the typology of nasal harmony. The acquisition of derivational opacity effects is undoubtedly deserving of more detailed study, and further research could productively be directed towards investigating this area.

Notes

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1. The above analysts vary in their treatment of laryngeals. See Walker (1998) and Walker and Pullum (1999) for a review of the issues and a proposal to situate them near vocoids in the hierarchy (note also Boersma 1998).

2. Certain Bantu nasal alternations are not included (Ao 1991; Odden 1994; Hyman 1995; Piggott 1996). See Walker (1998) for arguments that these result from cooccurrence prohibitions, not spreading of [nasal].

3. Nasal harmony in Applecross Gaelic presents further complexities that are not relevant to the basic typological categorization here. For fuller discussion, see Ternes (1973), van der Hulst and Smith (1982), and Walker (1998).

4. The transcriptions in (5) follow Ternes, who asserts that fricatives become nasalized in nasal spreading and remain fricated. For a review of the evidence for nasalized fricatives, see Cohn (1993a), Ohala and Ohala (1993), Walker (1998: §2.4), and references cited therein.

5. Independent evidence for initial syllable privilege in Tucanoan languages comes from a dialect of Orejon (Arnaiz 1988 cited by Pulleyblank 1989), where nasality in vowels clearly originates in the first syllable.

6. Aspects of the variable dependency approach are further developed and modified by Piggott (1996, 1999) and Piggott and van der Hulst (1997) in connection with a proposal that harmony with transparent segments involves [nasal] spreading at the level of the syllable rather than the segment. However, the central drawbacks for this line of explanation remain: it retains the assumption of variable dependency and fails to achieve a unified account for the complementary patterns. Boersma (this volume) proposes a different approach to Piggott's "Type A" and "Type B" harmonies, but his account still analyzes the patterns with transparency as a separate type of nasal harmony.

7. I characterize the feature [nasal] as binary, but whether it is treated as privative or binary does not signify here.

8. Note that liquids such as [l] or trilled [r] might arguably be treated as [–continuant]; however, these would be distinguished from the oral counterparts of nasal stops in the manner feature characterizing the liquid.

9. The relatively high placement of laryngeals [h, ʔ] in the nasal compatibility scale (see Note 1) also signals a difference between the scales, since laryngeals might well be considered to have a low sonority. See Boersma (1998, this volume) for discussion on this point (also Walker 1998).

10. Walker (1998) notes some language-particular variability in the ranking of voiceless fricatives and voiced stops in the nasalization hierarchy that seems to mirror variability in the sonority scale (Hooper 1972; Steriade 1982). This parallelism also might reasonably have a common basis: both continuancy and voicing increase sonority in obstruents and favor nasality; languages appear to vary in judging which property makes a greater contribution.

11. The following tableaux show the evaluation of candidates for a plausible input form. The input that corresponds to the actual underlying representation is determined by Lexicon Optimization (Prince & Smolensky 1993).

12. The tableaux displayed here show the core constraints interacting in the propagation of nasal harmony. There are, of course, other constraints that contribute to the selection of an overall well-formedness of the optimal output. For example, faithfulness for the feature specification [+nasal] (Ident(+nasal)) prevents nasality from being eliminated altogether from the input nasal stop (or vowel).

13. In vowel harmony, the spreading feature is crosslinguistically dispreferred when realized in combination with the segments behaving transparent (e.g. in Finnish, transparency avoids realizing [ɯ], [ɤ]). In nasal harmony it is clear that transparency of stops is driven by the extreme incompatibility of nasalization with obstruents. While analysts differ to some

extent on the precise characterization of the property defining an obstruent stop, all agree that at least in buccal segments (those articulated forward of the place where the velic valve joins the nasal and oral cavities) it is incompatible with a velic opening (see, e.g., Chomsky & Halle 1968; Ohala & Ohala 1993; Steriade 1993).

14. Cf. Walker (1996) and Ní Chiosáin and Padgett (1997), who propose a second level of input-output mapping with generation of a second evaluation set. The Sympathy approach eliminates the need for this second level.

15. Since fricatives also act transparent, *NasFric will also appear in P1, but I abstract away from that detail here.

16. Because of space limitations, attention is restricted here to only a few candidates. I assume that the alternative [w̃ãnĩ] loses on Ident-❀O[±voice] and [w̃ãn̥ĩ] is ruled out by a constraint against voiceless nasals that is undominated in Tuyuca. More generally across languages the nonoptimality of these candidates can be understood (at least in part) in terms of their significant weakening/loss of contrast between the series of stops (for some further discussion on this point see Walker 1998: 115–116). Note that in some languages an alternation between voiceless obstruent stops and nasals can occur to a limited extent in functional morphemes, which are typically more susceptible to neutralization of contrast. Robboy (1987) reports that in Guaraní nasal harmony a dative clitic postposition exhibits an alternation between [-pe] and [-mẽ]. This type of alternation does not take place, however, in roots of the language.

17. Note that the occurrence of *NasObsStop in P2 is not crucial in this particular form; however, in various derivational opacity effects it is evident that the winning constraint (the one in P1) contributes to selection of the sympathy candidate, although in this it is dominated by the conflicting constraint top-ranked in P2 (see e.g. Itô & Mester 1997; Walker 1998). An equivalent result is achieved under McCarthy's Selector Constraint model. Evidence from nasal harmony is discussed in a study of nasalization spreading across morpheme boundaries in Tuyuca (Walker 1998). In cross-morpheme spreading, obstruents act as blockers and sonorants become nasalized. *NasObsStop thus contributes to sympathy candidate selection in morphologically complex forms; it is dominated by the constraint driving morpheme-internal spreading but in turn outranks cross-morpheme spreading.

18. See Walker (1998: 156) for an argument that a grammar with transparent approximants is also difficult to acquire for perceptual reasons.

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Can 'phonological' nasality be derived from phonetic nasality?*

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Was nennt man denn eine 'fixe Idee'? Eine Idee, die den Menschen sich unterworfen hat. //
... Unverrückbar wie der Irrwahn eines Narren stehen jene Gedanken auf festem Fuße, und wer sie bezweifelt, der – greift das *Heilige* an! Ja, die 'fixe Idee', das ist das wahrhaft Heilige!

(Max Stirner, *Der Einzige und sein Eigentum*)[1]

Introduction

As the title of this paper indicates, I would like to discuss the question: Can 'phonological' nasality be derived from phonetic nasality? I will also provide an answer to this question. My answer will be: No. Given the evidence available, phonological 'nasality' is – as phonetically motivated concept – inadequate for an explanation of phonological phenomena.

What I would also like to do in this paper is to challenge the phonological mainstream. More specifically, based on Popper's arguments for rationalism and empiricism, I will claim that there is no well-defined phonetic framework which phonology could be based on. Furthermore, I will argue against the widely held belief that phonological 'nasality' (or any other phonologically relevant concept) can be derived from phonetics. The view I would like to present is a radical one: Using nasality as example, I will show that, even though there is an obvious link between phonology and phonetics, phonology is a purely cognitive function, on the one hand, and must be established independently of phonetics, on the other. Moreover, it is the phonology which provides (parts of) the motivation of the phonetic properties of a linguistic signal (not vice versa). In line with this position, I will show that there can be no relevant phonological theory in which phonology is motivated partly by phonetics, partly by other factors. I will claim that in such frameworks, the hypothesis that phonology is derived from phonetics (the 'Phonetic Hypothesis', 'PH') is always set up in a circular and thus unfalsifiable and non-empirical manner. This also means that in an explanation of why languages 'do' phonology, the question where phonology stops and where phonetics begins does not arise.

'Nasality' and 'nasalisation' are simply phonetic, i.e., speech implementational or perceptional, manifestations of a phonological, i.e., exclusively cognitive, unit which must be established theoretically independently of phonetics. I will point to a revised version of Element Theory ('ET') as a cognitive alternative to the PH.

1. In defense of method, empiricism and falsifiability

In this section, I will outline briefly why in my opinion there can be no empirical science without critical discussion based on "the method of bold conjectures and ingenious and severe attempts to refute them" (Popper 1973: 81). According to Popper, "All Knowledge is Theory-Impregnated, Including our Observations" (ibid.: 71). Even 'objective' knowledge acquired via our senses is dispositional because our sense organs are the result of a trial-and-error based evolution. This is why Popper sees his scientific method as an evolutionary approach: We make a hypothesis and try to refute it. If we err, we try another hypothesis; thus our knowledge is increased.[2]

Popper sums up his view on testability in the following way:

> … every scientist who claims that his theory is supported by experiment or observation should be prepared to ask himself the following question: Can I describe any possible results of observation or experiment which, if actually reached, would refute my theory? If not, then my theory is clearly not an empirical theory. For if all conceivable observations agree with my theory, then I cannot be entitled to claim of any particular observation that it gives empirical support to my theory. (Popper 1994b: 88)

So in order to achieve empiricism, the most important question one can ask about any assumption is: What would prove this assumption wrong?

Let me mention here that an assumption that is not testable, e.g., if it has been immunised against refutation (ibid.: 39) by the means of ad hoc auxiliary hypotheses, is not an empirical assumption.

Furthermore, I agree with Popper's view that "the aim of science is increase of verisimilitude" Popper (1973: 71). Popper distinguishes *truth* from *truth content*, i.e., the class of all statements which follow from a statement (ibid.: 48). While, for example, tautologies like *Tables are tables* are indubitably true, their truth content is zero. The truth of scientific theories, like Einstein's relativity theory, can never be verified and, since theories (usually) entail false statements, i.e., problematic data, they are (usually) to some extent untrue or, in other words, have some amount of falsity content, i.e., a higher falsity content than indubitably true tautologies. Consequently, when Popper says that science is about the search for truth (ibid.: 44), he is not interested in truth but in truth content. Also, since competing theories can often account for the same amount of data, i.e., have identical truth contents, but differ with respect to the amount of data problematic within their (respective) approaches, i.e., with respect to their falsity contents, Popper argues for a concept as aim of (empirical) science which encompasses both the demand for relatively high truth content and relatively low falsity content: this concept is *verisimilitude* (relative 'close-to-truth-ness').

Let me also point out that Popper does not claim that a theory which at some stage of its development is irrefutable is a useless theory: "It should be made quite clear that there are many examples in the history of science of theories which at some stage of the development of science were not testable but which became testable at a later stage … This should be a warning to those who are inclined to say that nontestable theories are meaningless" (Popper 1994b: 88). It should be noted that pointing to the possibility of future meaningfulness or even usefulness of a theory is a method in the tool-kit of theoreticians possessed by, i.e., addicted to, some fixed idea; they can always claim without any evidence that their theory is valuable now because it *might* become testable at some later stage. So I do find it necessary to add as a caveat that, on the basis of some possible future-specific value of a theory, any non-empirically minded theorist can regard their theory as equal in empirical value to a more testable theory. As I will show below, this is the method of numerous phonetician-phonologists which enables them to uphold the PH – no matter how untestable this claim is – by turning it into a dogma.[3]

To sum up, I have in this section provided a brief (and quite incomplete) outline of Popper's evolutionary approach to epistemology. The method of critical discussion of competing bold hypotheses in connection with ingenious attempts at refuting these hypotheses (to use Popper's jargon) is a prerequisite for empirical science. In other words, explanations which are set up in an unfalsifiable manner are not empirical.

2. The unfalsifiable status of the Phonetic Hypothesis

In this section, I will try to show that in order to maintain the PH, supporters of this assumption have to it set up in an irrefutable, i.e., non-empirical, manner. Since large parts of the phonological mainstream insist on the inclusion of the PH in the set of assumptions made by their (respective) frameworks, this majority will be shown to be concerned with the reinforcement of a fixed idea.

2.1 The irrelevance of the articulatory system to the study of phonology

First, I would like to state that this section (or any other part of my writings) are not intended to show that the study of the articulatory system (or the auditory system) is irrelevant. I myself find articulatory phonetics a most fascinating subject; the first part, i.e., two thirds, of my PhD thesis, discuss the phonetics of nasality and nasalisation while only the final third investigates non-phonetically motivated cognitive views on nasals. This, however, does not imply in any way that the phonology of a phenomenon is motivated by some properties of the articulatory (or any phonetically defined) system – nor that I am laying hand on the importance of phonetics as a scientific discipline by claiming in agreement with Jonathan Kaye that phonology is not motivated phonetically.

The argumentation of this section will mainly follow Kaye's argumentation against the widely accepted proposal that phonological phenomena are articulatorily motivated (Kaye 1989: 42–49). At the end I will outline an application of Kaye's arguments to frameworks which either assume an acoustic version of the PH or both an articulatory and an acoustic version.

In his discussion, Kaye uses both phonological processes and linguistic change as evidence for his claim that phonological phenomena are *not* based on properties of the articulatory system. This view currently defines an essential part of the conglomerate of theories labelled 'Government Phonology' ('GP') and sets it apart from most other phonological theories. Kaye points out that the articulatory version of the PH is based on the claim that phonological processes involve an increase in 'ease of articulation'. This assumption predicts the phonetic and phonological convergence of all human languages over time. Unfortunately, this assumption does not hold true: no such cross-linguistic convergence can be observed. For most proposed phonological processes there is a vast number of languages where they do not occur and where there is no evidence that would suggest the ongoing or future acquisition of these processes.[4]

Kaye finishes his discussion of the articulatory hypothesis by pointing out that phonetic processes do exist (ibid.: 49). So a d will sound slightly different before i than before a in all languages which have d, i and a. It is characteristic though for such phonetic processes to be "omnipresent" (ibid.) across languages, which is why they cannot be used to differentiate one phonological system from another or to establish the phonological part of Universal Grammar.

Let me add here that an acoustic version of the PH, e.g., Stevens and Blumstein (1978), would claim that phonological phenomena are motivated by perceptual reasons. Since all languages can be learnt natively by everyone, one is left to assume that the auditory system of all humans is identical – linguistically speaking. In line with the articulatory hypothesis, this would predict the universal convergence of all human languages, which, as pointed out by Kaye, completely eludes detection. (This is not to say that there is no relation between phonological structure and the acoustic signal.[5])

In addition, if one were to assume an articulatory and an acoustic version of the PH simultaneously, it would be necessary to establish independently what types of phonological phenomena would be predicted by the acoustic hypothesis, by the articulatory one or by both. To state without such independent evidence that both are necessary, that "different languages may apparently [sic] use either articulatory or acoustic features (or both)" (Lass 1984: 99) and that what kind of feature is actually used is a "matter for empirical investigation" (ibid.: 100) ensures that both the articulatory and the acoustic version of the PH are unfalsifiable, which again results in a non-empirical framework.

Let me also make the reader of this paper aware of the fact that it is true for almost all phonological phenomena (which are according to the supporters of the PH motivated by the properties of some phonetically defined system) that one can point to numerous languages (usually more than 50% of all known languages) where a given supposedly phonetically motivated phonological phenomenon does not occur. How can the speakers of such languages avoid giving in to their articulatorily based urge to increase ease of articulation? Obviously, the PH is not testable.

To sum up, there is no evidence for the proposal that phonological phenomena are caused or motivated by or based on properties of the articulatory or any other phonetically defined system, and all the available evidence is contrary to the PH.

2.2 Maintaining the Phonetic Hypothesis

In light of this evidence it is important to look at how supporters of the PH maintain their position. There are two main strategies in past and current literature both of which ensure that the PH is set up as an unfalsifiable dogma which is simply accepted and rarely (if ever) questioned: denial and flexibility.

2.2.1 *Strategy 1: Denial*

Phonologists who make use of the strategy of denial ignore counterexamples to the PH while they try to discover more and more cases where the PH does predict observable phenomena. For example, Kenstowicz (1994) and Lass (1984) provide an introduction to feature systems based on phonetically defined properties and a vast number of processes accounted for by these features. However, not once do they discuss the problem that for any language in which a given process does occur one can virtually always point to a language where it does not. Since all humans can learn any language natively they must have the same articulatory system. It remains therefore unclear why it is simply not a problem for Kenstowicz and Lass that most of the phenomena predicted by their theories do not occur in even half of the world's languages.

To counter this, one could point to the concept of parametric variation within Universal Grammar. This would mean that cross-linguistic differences are explained by different cognitively, not phonetically, defined systems. This, however, does not solve the problem: within such an approach the PH is never tested (cf. also Strategy 2, below) and all the available evidence can by definition only be in favour of it. Whenever the strategy of denial is used, the PH is consequently not an empirical assumption. I would like to suggest that the PH is rather a fixed idea and therefore a psychological and/or socio-political phenomenon.

2.2.2 *Strategy 2: Flexibility of applicability and the whodunit trap*

Strategy 2 is achieved by making the conditions on the applicability of the PH flexible. In a framework of this type, phonological processes are explained by the manipulation of cognitive yet phonetically motivated units. However, whenever phonetic measurements cannot explain observable patterns, other 'phonological' evidence which *cannot* be motivated by phonetics is employed to account for the problematic data. Since in such a theory there is no independently established criterion according to which one could decide when the effects of PH are countermanded by some other forces and to what extent, this flexible approach to falsifiability enables its practitioners to assume the PH without having to set it up in a testable manner. I should add that it would not save the PH to view it as a violable constraint. As was shown in some detail in Ploch (2001), the very concept of a violable constraint is not a scientific one simply because a violable constraint is not testable; in the end, a violable constraint can always be claimed to be outranked in all situations that would otherwise falsify it.[6]

A classic example of Strategy 2 can be found in Archangeli and Pulleyblank (1994): Archangeli and Pulleyblank's (henceforth 'AP') "Grounded Phonology" (ibid.) is a feature theory; features are called "F-elements" which form the "primitives of a formal model of phonological feature content" (ibid.: 47). Recognising the problem that an unconstrained combination of these F-elements would result in far too many theoretically possible phonological expressions (ibid.: 167),[7] AP propose "grounding conditions" (ibid.), i.e., "conditions used in natural language [which] directly reflect physical correlates of the F-elements involved. Thus, such conditions are physically *grounded*" (ibid.).

As example AP point to the F-element [+nasal] which in most cases co-occurs with the F-element [+voiced] (ibid.: 168). The main problem with Grounded Phonology is though that one of its fundamental assumptions, i.e., the grounding hypothesis, is not falsifiable: Even though any phonological process is 'grounded' in the universally shared articulatory system of humans, most of these processes do not occur in most other languages. Consequently, this non-occurrence constitutes a serious counterexample for Grounded Phonology; how can so many languages do without this 'grounding'? However, AP simply propose that the predictions of their grounding hypothesis can be violated. For examples, nasal consonants are voiced in most cases, and this can supposedly be phonetically motivated. Consequently, voiceless nasal stops ([+nasal, –voiced]), which do occur (e.g., in Angas, Kwangali, Burmese or Comaltepec Chinantec),[8] have to be allowed for somehow, and the stipulation allowing for such voiceless nasal consonants (henceforth 'NC') would have to be 'phonological', where the phonology involved would in such a case have to be independent of the very same phonetic properties which are assumed to motivate phonology.

Let me add here that the proposal of parametric rules does not solve this problem but merely names it. AP, like most linguists, simply assume the relevance of speech organs because *some* phonological facts can be accounted for this way. Whenever the PH makes wrong predictions AP allow for this via parametric variation in speech organ usage and in the applicability of the PH. Consequently, Grounded Phonology provides an explanation of phonological phenomena that could never be falsified which in turn is a hallmark of mythology and any pseudoscience. I should also point out that no account for whatever data provides evidence for itself; in other words, accounts cannot be scientifically verified by providing more and more examples where they work nor can they be made more likely to be true by an ever increasing number of data accounted for (cf. any work by Popper in the bibliography).

Finally, one could try to counter my claim that the PH is unfalsifiable in the following way:[9] The fact that phonological phenomena are never phonetically counter-natural but are always neutral with respect to phonetic naturality or even phonetically natural is sound empirical evidence for the PH. And not only that; in addition, it can be observed that the overwhelming majority of phonological processes *are* phonetically natural. Most importantly, since, it *is*, on the one hand, conjecturable, i.e., theoretically possible, that phonetically counter-natural processes exist, while such counter-natural phenomena do, on the other hand, not occur, the PH is set up in a testable manner, is tested and is, as it turns out, unrefuted. Again, we see that the PH is an empirical assumption of great scientific value due to its high degree of explanatory power!

This is a very interesting attempt to save the PH; interesting because it almost works. What prevents it from succeeding – because of which the PH remains unfalsifiable – is its failure to distinguish two notions one of which is a hyponym of the other: 'relation', or '(non-directional) link', 'connection', 'match', and its hyponym 'motivation', or '(causal) link'. Neglecting that there *are* phonetically counter-natural phenomena (Kaye 1989: 47; Ploch 1999b: Section 1.3.3.), e.g., the elimination of final obstruent devoicing (after previous introduction) in a number of varieties of Yiddish ('retrograde sound shift') (Weinreich 1958), let us agree that there is a clear link between phonology and phonetics: phonetics and phonology often match (even though there are also a few/some/many mismatches). This situation, however, implies in no way that the phonetics involved motivate the phonology and that 'therefore' the phonology is phonetically grounded. It seems, there is a wide-spread confusion of 'relation' and 'motivation'. It can, for example, also be found as major element in the plot of many whodunit films in which the police arrest the wrong guy. Their mistake, which we could call 'falling into the whodunit trap', is always the same: they assume incorrectly that merely because they have found a story which accounts for the facts, that this provides evidence for their story. Our 'innocent protagonist guy', however, does not logically need to be the motivating factor for the murder only because it is possible to establish a connection/link between him and the murder.

More generally, a link between A and B does not in itself provide evidence for the hypothesis that A motivates B or that B motivates A; whether the phonology motivates the phonetics or vice versa are two hypotheses which have to be set up in a testable manner in order for us to be able to evaluate their verisimilitude. Let us also not forget that A and B might as well be linked by a third, C, which motivates (parts of) A and is in some relation to B. Consequently, it cannot be inferred from the fact that many if not most phonological processes are phonetically natural that the phonetics involved motivate the phonology. Whenever this point is not understood, any phonetics-phonology match provides 'evidence' for the PH, and the directionality of motivation from phonetics to phonology is never questioned, i.e., it is uncritically, and thus unscientifically, taken for granted.

Note also that it *is* possible to set up the PH in a refutable manner: As Kaye (1989: 42ff.) has pointed out, a falsifiable version of the PH predicts the wholesale convergence of human languages (at least up to a certain point, a point which should, in my opinion, also be predicted by some other testable assumption).[10] Such a convergence is not only not attested but is also not supported by even a shred of evidence.

As I have shown in this section, the PH can only be maintained within a phonological theory by making it unfalsifiable. Supporters of such a framework achieve this by ignoring counterexamples to the PH, by adopting a rather flexible approach to its applicability and/or by falling into the whodunit trap.

2.3 Phonetic definitions of nasality

Since the PH forms an intrinsic part of mainstream phonology, one would expect that there actually *is* a phonetic definition of widely accepted 'phonetically defined' concepts like nasality. In this section I will first look at Entenman (1976) who shows some of the difficulties in providing a phonetic definition of nasality.[11] Subsequently I will discuss Vaissière (1988), Ladefoged (1989) and Huffman (1989) whose findings (in my view) show that nasality can neither be defined via reference to velum or velopharyngeal opening (Vaissière) nor in terms of nasal airflow (Huffman) and that the existence of a well-defined phonetic framework as basis for phonology is a myth (Ladefoged).

2.3.1 *Entenman (1976): The problematic status of the concept 'nasality'*

2.3.1.1 *Acoustic definitions.* In a chapter on the phonetics of nasality, Entenman points out that it is quite difficult to define nasality in acoustic terms (Entenman 1976: 28–42). So there is no acoustic feature that when added to those of an oral vowel (henceforth 'OV') produces a nasalised version of that vowel. For example, nasalisation of a vowel often leads to a modified perception of its quality. According to House and Stevens (1956) (measuring vowels produced by an electrical voice tract analog), Formant 1 shifts up in nasalised vowels, but more so for [i] than for [a]. Fant (1960) and Ohala (1971) take this as evidence for the claim that low vowels are more difficult to nasalise (perceptually) than high vowels. However, Dickson (1962) cannot find this raise in F1 bandwidth consistently while Delattre (1968) finds it in English and Portuguese but not in French.

Nasality can also not be defined as lowering of F1 intensity. Even though nasal vowels (henceforth 'NVs') may have lower F1 intensity than oral ones (cf. Björk 1961), this intensity loss, as Dickson (1962) shows, is not consistent. Also, Hattori et al. (1958) cannot find evidence for it at all.

Furthermore, Schwartz's (1971) research reveals that many of the acoustic characteristics of NVs could be obtained by means other than opening of the velopharyngeal port. It is therefore often unclear whether acoustic data which could indicate nasalisation actually does so.

In light of this evidence it can be said that neither a raise in F1 bandwidth, lowering of the intensity of Formant 1 nor any other measurable variation provides an adequate definition of phonetic nasality, i.e., a phonetic definition on the basis of which phonological nasality could be predicted accurately.

2.3.1.2 *Articulatory definitions.* The second problem Entenman (ibid.: 42–48) discusses is that there is also no easily available definition of nasality based on its physiological correlates. Opposed to the impression a student of current mainstream phonology might get, Entenman's view is that "Nasality is far more than the acoustic result of opening the velum during speech" (ibid.: 42). He points to the findings of Lubker and Schweiger (1969) who tested whether there is a correlation between a high rate of nasal airflow and perceived nasality. Their research discredits the relevance of nasal flow rates as part of a definition of nasality because it shows that even though opening of the velum will often result in an increase in perceived nasality, 52% to 79% of the variation in perceived nasality was due to reasons other than the amount of nasal flow. For example, the degree of velopharyngeal opening needed to produce nasality is dependent on vowel quality (cf. House & Stevens 1956). Similarly, Bell-Berti (1973) and Lubker et al. (1970) show that different vowel qualities correspond to different velar positions (cf. Entenman 1976: 49ff.). To be perceived nasal, [a] needs a larger velopharyngeal opening than [i] or [u], [i] needs a larger one than [u]. It follows that nasality cannot be defined as opening of the velum.

The argument is complicated further (ibid.: 47) by Minifie et al.'s (1970) research which shows that the tongue retraction observed in French NVs resulting in pharyngeal adjustment can also be found in low vowels. Since all French NVs are low, it is not clear whether the tongue retraction observed is a characteristic of nasal or low vowels. Consequently, tongue retraction can in such cases not be used to define nasality.

To sum up, Entenman's research makes it abundantly obvious that (until 1976) there was no phonetic definition of nasality. However, this did not prevent him or others, including virtually all nasality experts[12] as well as the influential team 'Chomsky and Halle' (1968), to accept the PH.

Finally, let me add a metatheoretical comment not mentioned by Entenman: In order to establish any phonetic definition of nasality to which phonological 'nasality' could then be reduced, what one considers to constitute phonological nasality would still have to be motivated independently of phonetic nasality; otherwise any such reduction would be circular; in other words, *any* phonetics-dependent theory of phonology is seriously flawed.

2.3.2 *Vaissière (1988): Prediction of velum movement from phonological specifications*

Vaissière tries to find a set of assumptions which correctly predicts "velum height, velum movement velocity, and timing of velum movements relative to the speech waveform and to movements of other articulators" (Vaissière 1988: 124) for segments specified as [+nasal] in a "given phonological representation" (ibid.: 125). This research shows that the feature value setting [+nasal] alone cannot accurately predict velum height: both the maximum velum height of consonants specified as [–nasal] and the minimum height of [+nasal] consonants is dependent on the context (ibid.: 126). Furthermore, anticipatory velum lowering in CVN-sequences "seems to begin during or prior to the first consonant" of such sequences. This means that the presumably phonetically defined feature [±nasal] cannot adequately predict velum movement nor can velum movement adequately predict phonological 'nasality'.

Interestingly, Vaissière's research makes it obvious that the phonetically defined concept 'nasality' does not correlate straightforwardly with opening of the velopharyngeal port. Nasality is not only dependent on velum height but also on the phonetic and/or presumed (phonetically motivated) phonological environment, i.e., on [±strong], on tongue height (ibid.: 137ff.) and the feature [±stressed] (ibid.: 134). In addition, Vaissière tries to predict velum movement from *presupposed* phonological specifications. In other words, the supposedly phonetically motivated feature [±nasal] is assumed to be phonologically relevant without evidence to support this. The fact that Vaissière nevertheless assumes the phonological feature [±nasal] and thus some version of the PH shows that Vaissière treats the PH as a given which no evidence needs to be provided for. Finally, what phonological features Vaissière's predictions are dependent on varies across speakers (ibid.: 122, 134). Since the predictive power of Vaissière's approach does not reach beyond idiolects, it is inadequate as an empirical tool for the establishment of the *phonology* of 'nasality'. To be fair, Vaissière does not try to derive phonological representations from velum movement but velum movement from phonological representations. However, Vaissière's research shows that phonological nasality – 'phonetically' defined via reference to velum movement – does not correspond to phonetic nasality nor vice versa.

2.3.3 *Ladefoged (1989): The non-existence of a well-defined phonetic framework*

In a section on "Universal phonetics and phonology", Ladefoged (1989: 9ff.) discusses the phonetic basis of the IPA chart.[13] Note that the symbols provided by the IPA are classified according to only *some* of the articulatory properties of the sounds transcribed: which articulatory properties are assumed to be relevant for this classification is motivated 'phonologically', i.e., independently of the very same phonetic properties which are hypothesised to motivate phonology. Since I have shown above that characteristics of the articulatory apparatus are not relevant to phonology, it is clear that the IPA, when assumed to be phonologically relevant, cannot make valid phonological predictions. So Ladefoged admits that there is no well-defined phonetic framework "that allows [phoneticians] to describe linguistic sounds in terms of what are taken to be extra-linguistic categories such as voicing or nasality" (ibid.: 12). He also states that "there is no theoretical basis for the existing phonetic framework" (ibid.) because it can always be modified to incorporate contrasts yet to be discovered in some language. Furthermore, innately endowed phonetic capabilities can in Ladefoged's view not be determined independently (ibid.: 13). What is utterly surprising is the fact that he – together with mainstream 'phonology' – nevertheless considers articulatory effort (which cannot be determined independently!) to be "important in the formation of phonological patterns" (ibid.: 12). I am unclear about the basis of his assumption.

I conclude that due to the highly flexible nature of the applicability of the framework inherent in the IPA (cf. 2.2, Strategy 2), the IPA is solely a table of pre- and pseudotheoretical symbols, employed by linguists to transcribe subjective sound experiences or even objectively measured sounds. This means that even though these characters are used by virtually all phonologists, they are mere letters and have no explanatory power; for example, the classification of [ɴ] as '(pulmonic voiced) uvular NC' or as a unit defined by even more phonetic and even objectively measurable details contains no phonologically relevant information per se – other than its classification as 'unit', i.e., *phonological* unit, a classification which is entirely phonological and *cannot* be established on the basis of the acoustic signal or any knowledge about the speech physiology ('articulatory phonetics') involved. Furthermore, the assumption that there is a well-defined phonetic framework which can explain or motivate phonological phenomena is a fallacy or a myth for which no-one has ever provided any evidence.

2.3.4 *Huffman (1989): Nasal airflow and articulatory landmarks for Nasal*

Huffman tries to provide a definition of (speech implemented) nasality by establishing what constitutes a phonetic change significant enough "along a phonetic dimension" (Huffman 1989: 12) to justify the characterisation of a segment as phonetically nasal. Due to the relative inaccessibility of the velum, Huffman bases her findings on nasal airflow measurements. She shows that the definition of onset and offset of nasalisation is not a matter of identifying when nasal flow turns on and off (ibid.: 24ff.; cf. Vaissière, above). The evidence for this stems from Moll (1962), Clumeck (1976), van Reenen (1982) and her own research (ibid.): Moll finds velopharyngeal opening on English vowels in the context of OCs. Similarly, Clumeck shows velopharyngeal opening for English low vowels in oral contexts. Van Reenen provides X-ray tracings of OVs of a Canadian French speaker which exhibit velopharyngeal opening. In her own research, Huffman finds "many instances of nasal flow on phonemically oral segments in oral contexts" (ibid.: 24).

Huffman's solution is to compare nasal flow rates of nasal and oral segments in identical or at least similar contexts in order to establish an "orality threshold" (ibid.: 30), i.e., a definition of "what may be considered typically oral" (ibid.). Nasal flow rates above this orality threshold can then be assumed to reflect contextual (phonetic) nasalisation.

Additionally, Huffman proposes a theory of constraints on the temporal distribution of the phonetic properties which realise phonological features. This theory is dependent on a theory of the temporal location of phonetically defined targets (ibid.: 35ff.). Since Huffman's nasal flow measurements show that Yoruba and Akan speakers make consistent differences in timing for [+nasal] versus [–nasal] segments, [+nasal] segments are assigned long targets (windows with duration), while [–nasal] ones are assigned short targets (points in time without duration) (ibid.: 50). [+nasal], i.e., long, targets are constrained by "articulatory landmarks" (ibid.: 35), i.e., "a small set of subsegmental structures [which] determine the location and duration in time of targets along phonetic dimensions" (ibid.). Based on this theory, Huffman establishes nasal airflow levels which "reflect target levels for nasality" (ibid.: 49). NCs show nasal flow rates 3–5 times as high as the rates in corresponding OCs, while NVs have nasal flow rates only 2–3 times as high as comparable OVs (ibid.: 49). This, so Huffman, should be part of an account of the phonetic properties of phonological nasality.

There are, however, a number of problems with Huffman's approach. Firstly, what is considered to be phonetically nasal does *not* correspond to the presence of nasal airflow; (phonologically) 'oral' segments may contain nasal flow. Therefore Huffman is forced to establish orality thresholds, i.e., limits above which phonetically defined nasal flow rates are assumed to actually reflect (phonologically relevant) phonetic nasality. Furthermore, she is not able to propose a universal orality threshold which holds for all segments specified phonologically as [+nasal] or at least one for NVs and one for NCs: Huffman admits that different speakers show different values for "the absolute amount of nasal flow present in their speech" (ibid.: 31). Similarly, different vowel qualities and places of articulation correspond to different nasal flow rates. So for each speaker different orality thresholds must be established for each vowel quality and each place of articulation (ibid.). Moreover, nasal flow levels in oral segments vary over time and the orality thresholds to be established must thus be allowed to vary over time too (ibid.). It can thus be said that in line with Vaissière's research, Huffman's proposals are, due to their idiolect-specificness, not useful for phonological theory. Assuming that phonetic nasality is universal (or universally available) in that it refers in some way to phonological units that are part of Universal Grammar, it also remains unclear for the same reason in what way Huffman's findings about nasal flow rates bear any relevance on speech implementation and why nasal flow should not merely be considered a by-product.

The second major problem of Huffman's proposal is that it contains a circular argument. Huffman (ibid.: 55) states:

> Under the assumption that phonological [sic] feature specifications are the primary [sic] determinants of segment quality, assignment of articulatory landmarks should follow [sic] from the interpretation of specifications for one or more feature(s).

This means that Huffman measures nasal flow rates of segments specified as such and for nasality or orality (non-nasality) by phonology. In other words, phonological segments are assumed to be phonologically [+nasal] or [–nasal] without the provision of evidence for the phonological relevance of phonetic properties. Segments thus characterised are then tested for phonetic nasality via airflow measurements. Consequently, phonological nasality is in some mysterious way based on phonetic nasality while phonetic nasality is established on the basis of phonological nasality. This is tantamount to saying that Huffman's findings are relevant if they are relevant. I therefore draw the conclusion that Huffman provides no evidence for the phonetic or phonological relevance of nasal airflow rates. Note also that in Huffman's view,

> this method of analysis is intended as a tool for investigating details of timing of the phonetic implementation of known [sic] phonological feature specifications, rather than as a diagnostic of the proper characterization – phonological or phonetic – of nasalization on a segment. For instance, the orality threshold approach does not provide any *a priori* method for identifying categories … in degree of nasalization. (ibid.: 33)

So it remains unclear why Huffman nevertheless bases her measurements on phonetically defined 'known' feature specifications, thus creating a circular argument.

Finally, Huffman also has to admit that the oral/nasal boundaries established via her method "will not necessarily have perceptual relevance" (ibid.). This question is left to future research (ibid.). Since language-specific articulatory specifications of speech have to be learnt by a child, it is necessary for that child to be able to perceive these specifications. This means that Huffman's proposals *must* be perceptually relevant in order to be linguistically relevant at all. Due to the questionable status of the perceptual relevance of her findings, it unfortunately remains open in what way they could possibly be part of an explanation of linguistic data.

As I have shown in this section, Huffman's research about nasal flow levels only relates to specific manners and places of articulation and suffers from a certain kind of idiolect-specificness. Furthermore, her argumentation is circular, it is not clear in what way her results are perceptually relevant, and there is no evidence to support the claim that her proposals bear any relevance to linguistic research.

2.3.5 *Phonetic definitions of nasality: Conclusion*

Having looked at Entenman, Vaissière, Ladefoged and Huffman, I conclude that, to my knowledge, there is no phonetic definition of phonological 'nasality'. All mainstream phonological theories which assume the PH, i.e., all mainstream phonological theories, do so without the relevant evidence.

2.4 The Phonetic Hypothesis in action

In this section I will discuss Browman and Goldstein (1986) (Section 2.4.1) and Kawasaki (1986) (Section 2.4.2) who incorporate a version of the PH into their frameworks. I will show that in both cases, this results in a number of wrong predictions which the respective authors simply ignore. This will provide further evidence against a phonologically relevant and yet phonetically motivated definition of nasality.

2.4.1 *Browman and Goldstein (1986): Articulatory phonology*

Browman and Goldstein ('BG') propose articulatory gestures as units which phonological representations are based on. Since movement is inherent in the definition of gestures they provide in BG's view "an explicit and direct description of articulatory movement in space and over time" (Browman and Goldstein 1986: 222). Speech in this framework is thus seen as a sequence of overlapping articulatory movements. According to BG, such a gestural analysis has the advantage over other phonological theories that it explains both articulatory movements and phonological structure and provides "a principled link between phonological and physical description" (ibid.: 219).

BG provide two gestural analyses as evidence for their claim: a discussion of English s-stop clusters (ibid.: 226ff.) and a comparative analysis of English nasal-stop clusters and Chaga prenasalised stops.[14] In the following, I will only look at the data involving nasals.[15]

In their comparison of Chaga prenasalised stops with English nasal-stop clusters, BG (ibid.: 229–237) try to show that a phonological framework based on articulatory gestures can adequately explain the distributional patterns of such sequences. Based on Anderson (1976), BG (ibid.: 229) provide the following feature matrices to distinguish prenasalised stops (1a) from nasal-stop clusters (1b):

(1)

	a. m	b	b. m	b
cons	+		+	+
nasal	+	–	+	–
ant	+		+	+
cor	–		–	–
⋮				

In BG’s view, “the structures represented in [(1a) and (1b)] might be expected to lead to different phonetic entities” (ibid.). In terms of articulatory gestures, one would predict a gestural differentiation between the bilabial closure gestures of prenasalised stops as opposed to nasal-stop clusters. BG would expect a single bilabial closure gesture (‘BCG’, abbreviation mine) for prenasalised stops and two BCGs or one longer BCG for nasal-stop clusters. Note that since BG are unclear about whether (phonological) nasal-stop sequences correspond to two BCGs or one BCG longer than for (phonological) prenasalised stops, it remains also unclear in what way and based on what evidence the phonetics, i.e., articulatory gestures, motivates the phonology here.

Be that as it may, according to BG, if English nasal-stop clusters as in camper and canker are analysed as segment sequences, a gestural analysis could only back this up if the sequences in question were to display either two BCGs or one BCG longer than a BCG in a prenasalised stop. However, in English, BG find a single BCG “regardless of whether the consonantal portion is described as a single consonant (/b/, /p/ or /m/) or as a consonant cluster (/mp/ or /mb/)” (ibid.: 233). Similarly, in Chaga there is only one BCG for single and for prenasalised voiced consonants (p, m, mb). Chaga mp [m̩p], on the other hand, shows in BG’s opinion the result of two overlapping BCGs. If gestural representations are assumed to motivate phonology, English nasal-stop clusters and Chaga single stops, nasals and prenasalised voiced stops are, in my opinion, predicted by BG to occur as phonological class, i.e., to display similar patterns of phonological behaviour; mp (with syllabic [m̩]), on the other hand, should behave differently. Unfortunately, BG do not discuss this prediction.

Let us now try to find out whether BG’s gesture-based account of nasal-stop sequences and prenasalised stops can help us understand the behaviour of the phonological units involved. Opposed to English nasal-stop clusters, Chaga prenasalised stops occur word-initially. BG (ibid.: 236) try to explain this difference in the following way:

> The simplest statement is as a distributional, or phonotactic, difference. That is, in Chaga, such gestural structures can occur in word (and/or syllable) ini-

> tial position, whereas in English the same gestural structures cannot occur in initial position.

As it turns out, BG's explanation of the phonotactic difference in question consists merely of a description of this difference. BG's account itself makes no predictions about the phonological behaviour of English nasal-stop sequences or Chaga prenasalised stops that can be supported by independent evidence (or by the English or the Chaga data), which, astonishingly, is not in conflict with BG's scientific methodology.[16] I can therefore claim that BG's analysis has absolutely no explanatory power, i.e., it does not add anything to an explanation of the attested distributional difference. Apparently, the PH fails.

It is now obvious that BG's gestural framework also makes no phonologically relevant predictions about the nasal data provided by them. For the reasons stated, I consider their theory to be ineffectual as phonological framework. How BG can possibly come to the conclusion that "such gestural descriptions are useful as a basis for phonological description" (ibid.: 240) remains totally unclear.

2.4.2 *Kawasaki (1986): Experimental phonology*

Kawasaki follows Hyman's (1975) hypothesis that cases of denasalisation of nasal stops preceding OVs in languages with nasal-oral vowel opposition adjacent to nasal and oral consonants is due to perceptual reasons. Let me first provide some examples:[17]

(2)	*Guaraní*		*Cubeo*	
	mẽ^{n}daré	'widow(er)'	^{n}dahákɨ	'come!'
	mẽ́nã	'spouse'	nãh̃ṍkó	'shrimp'
	^{m}baʔé	'thing'	^{m}bákó	'mama'
	mãʔẽ́	'seeing'	ɲãmã́ko	'deer'

In both Guaraní and Cubeo, NCs are realised as (prenasalised) voiced stops when followed by an OV.[18] In Kawasaki's view,

> some kind of automatic or commonly encountered perturbation of one segment by another [i.e., nasalisation of vowels after nasal stops] may be taken for granted and factored out of the phonetic percept constructed for a word, as long as the segment responsible for the perturbation is detected … If the perturbing segment is not detected, then the perturbation is not expected and is not factored out; it is then included as part of the phonetic percept of the word. (ibid.: 86f.)

Kawasaki supports his claim by two experiments with native American English speakers which show that "the degree of perceived nasality of a vowel is enhanced by the attenuation of adjacent nasal consonants or, conversely, is reduced by the presence of adjacent nasal consonants" (ibid.: 94). In languages like Guaraní and Cubeo a nasalised vowel preceded by a nasal stop is a perceptually ambiguous situation: an underlyingly oral vowel following a nasal stop is phonetically, i.e., non-distinctively, nasalised; a nasalised vowel following a NC could thus be underlyingly oral or nasal. Kawasaki's proposal is that as long as the source of a nasalisation process, the nasal stop, can be detected (perceptually) the nasalisation in the target, the following nasalised vowel, can be weak. However, if the source is undetectable, nasalisation in the target is strong. In Guaraní and Cubeo with underlying nasal-oral distinction in vowels, nasalisation of vowels following nasal stops is predicted to be weak because the source, i.e., the nasal stops, are clearly nasal. On the other hand, NCs are denasalised or, in other words, made more undetectable (as regards nasality) when preceding underlyingly oral vowels. This results in a situation where such OVs will be perceived clearly oral since NVs in the same context would be strongly nasalised due to the low degree of detectability of nasality in denasalised nasal stops. Consequently, so Kawasaki, denasalisation of this type can be explained as perceptually and ultimately phonetically motivated phenomenon.

The main problem of Kawasaki's explanation of alternations between nasal and (prenasalised) voiced stops is that it ignores all cases where languages have nasal-oral vowel oppositions in the context of nasal and oral consonants (just like Guaraní and Cubeo) but where nasal stops do *not* get denasalised when preceding OVs. Consider the following examples from Auca (Pike & Saint 1962), an Ecuadorian language:[19]

(3) *Auca*

⁽ᵐ⁾bã́mõ	'whole seed'
⁽ᵐ⁾békã	'he drinks'
mã́mõ	'take, bring'
ṍma	'feather'

The data in (3) provide clear counterexamples to Kawasaki's hypothesis. In Auca, nasal stops are *not* denasalised before OVs (ṍma).[20] It remains an open question under which circumstances Kawasaki's hypothesis will work and when it will not. If NCs are denasalised when preceding OVs in order to increase the perceived degree of orality of these OVs, why can Auca speakers handle the hypothesised perceptual difficulties such sequences (NC+OV) entail, without denasalisation of the nasal stops? Even if there were some evidence for the claim that NCs in present day Auca undergo denasalisation when preceding OVs, the assumption that this can be motivated phonetically leaves it unclear why the phonetic result of such a process, i.e., denasalised nasal stops, is different from the result in e.g., Guaraní. In other words, this version of the PH says nothing about why nasal consonants (presumably denasalised) are realised as prenasalised voiced stops in Guaraní while they are not in Auca. Furthermore, whenever one were to look at a language which has a 'surface' series of nasal and voiced stops and of nasal and oral vowels and were to ask whether Kawasaki's hypothesis will work in this language, the best, i.e., most precise, answer one could give is 'maybe'. There is not even any 'statistical prediction' in Kawasaki's approach, which, even if it did exist, would still not provide any evidence for Kawasaki's perceptual version of the PH (cf. above). Remember that explanations *cannot* be confirmed nor can they be probabilified by 'confirming' data.[21]

A similar perceptually motivated approach can be found in Hawkins and Stevens (1985) who make the following statements:

> Some languages have the same number of nasal as non-nasal vowels, with no reported differences in quality between the two sets. In a substantial minority of languages that contrast nasal and non-nasal vowels, there is a reduced number of nasal vowels ... Most commonly it is the mid vowels that are missing in these imbalanced systems ... The problem of reduced discriminability [caused by nasalisation] is thereby avoided in that only those vowels with the most distinctive values of *F* 1 are retained. (Hawkins & Stevens 1985: 1574)

As it is typical for phonetically motivated explanations, Hawkins and Stevens account for a phonological pattern, e.g., missing nasalised mid vowels, phonetically, viz., as avoidance of nasality-induced reduced discriminability. It does, however, not seem to matter to them that, contrary to their predictions, many languages do not display any difficulties with the supposedly phonetically motivated phonological system that some languages, in line with their assumptions, try to avoid. So if a number of languages do not exhibit nasalised mid vowels due to perceptual reasons, why do such vowels occur in other languages (without any evidence that the nasal mid vowels which do occur are necessarily unstable)? Like Kawasaki's approach, Hawkins and Stevens's explanation apparently works when it works.

It is now clear that Kawasaki's (and Hawkins & Stevens's) acoustically or perceptually motivated proposals add nothing to an explanation of the phonological phenomena involved.

3. Nasal harmonies

In this section, I will look at Piggott's (1987, 1992) explanation of nasal harmony and will argue that Piggott's articulatorily 'motivated' framework, i.e., his version of feature geometry, cannot provide a decriptively or explanatorily adequate explanation of the phenomena involved.

3.1 Feature geometry

Let me start by pointing to the falsity content which follows from the assumption of feature geometry (cf. Archangeli & Pulleyblank 1994; Clements 1985; Sagey 1986; McCarthy 1988; Pulleyblank 1995). Due to the presupposition of the PH, feature geometry is fundamentally flawed. In addition, this theory has the problem that articulatory phonetics motivates an essential part of the definition of class nodes and terminal features without making any predictions about valency or the feature content of terminal nodes. In other words, there is no evidence provided by articulatory phonetics which supports the assumption of either monovalency, binarity or multivalency, or the restriction of terminal nodes to those with feature content. Note that the feature [laryngeal] – which in Pulleyblank's (ibid.) view cannot occur terminally – is just as much phonetically motivated as [labial] – which may occur terminally in his system.

So the evidence for the proposal of unary class nodes versus binary terminal features as well as the arguments for the restriction of terminal nodes to those having feature content come exclusively from phonological analyses. So in Pulleyblank's version of feature geometry it is necessary to create a framework containing two co-dependent, not independent, modules, a phonetic and a cognitive one. Let me point to another example of this: even though the applicability of the phonetic notions incorporated by nodes and features, like [dorsal] or [±ATR], is (supposedly) phonetically motivated, the very choice of the features involved and the different types of valency of nodes and features has to be stipulated within the cognitive module as long as no phonetic evidence can be found to support this claim. This is to say that as long as it is possible to 'correct' problems of the PH within the cognitive module, the PH is not falsifiable. Since in such an approach – immunised against refutation – all evidence can only be in favour of the PH, it can be said that examples of so-called 'empirical' evidence in favour of any of Pulleyblank's distinctions, i.e., the set of examples where the PH works, do not make the PH contained in his framework even a fraction more testable. As I have said above: no explanation can be probabilified or confirmed by 'confirming' data; explanations can only be corroborated by showing that they can survive severe tests better (i.e., have a lower falsity content) than competing explanations (cf. Note 21).

It remains therefore unclear why Pulleyblank (1995) follows Sagey's (1986), Ladefoged and Halle's (1988) and Ladefoged's (1989) proposal that "the features that define and play a role in phonological processes bear a direct relation to physiological properties of the vocal tract and to acoustic properties of the speech signal" (Pulleyblank 1995: 8).

3.2 Piggott's (1992) account of nasal harmony within feature geometry

Piggott (1992) subcategorises cross-linguistically observable nasal harmony phenomena into two harmony systems and one fusional system ("pseudo-harmony", ibid.: 35). To illustrate the failure of Piggott's feature geometry-based approach, I will only discuss some of Piggott's predictions concerning the first two harmonic systems, which I will refer to as types 'A' and 'B'.

According to Piggott, type A harmonies can be found in Warao (cf. Osborn 1966), Capanahua (cf. Loos 1967; Safir 1982) and some Malayo-Polynesian languages. Type B harmonies occur in a number of Amerindian languages of South-America including many languages of the Tupí and Tucanoan families, e.g., Southern Barasano (cf. Smith & Smith 1971), an Eastern Tucanoan language. Consider the following data:

(4)	*Type A: Warao*		*Type B: Southern Barasano*	
	inãw̃ãh̃ã	'summer'	mãh̃ã́ŋɨ̃	'comer'
	mõj̃õ	'cormorant'	ã́j̃ã	'a snake'
	hĩh̃ã	'kind of bird'	ẽh̃ṍ	'flu'
	mõãũ	'give it to him!'	ŋã́mṍr̃õr̃ĩ	'ear'
	mẽh̃õkohi	'shadow'	kã́mõkã́	'a rattle'
	tewẽke	'kind of bird'	w̃ãtĩ́	'demon'
	terẽ	'it broke'	r̃ĩã́	'children'
	jã	'walking'	j̃ũkã́	'a drink'
	etere	'bell'	^{m}bári	'food'
	ja	'sun'	juká	'vulture'

Piggott analyses Warao and Southern Barasano (henceforth 'SB') as left-to-right harmonies. One of the main differences is that while in SB (type B) there are no blocking expressions, in Warao (type A) only w, j, h and vowels are transparent and do not block nasal spread.[22] Furthermore, both type A and B languages have a series of neutral stops and one of nasal stops; however, while type A languages may have a series of voiced stops – prenasalised in some languages – type B languages must have this additional series. Also, while in type A languages the series of voiced stops might or might not be in complementary distribution with the nasal series, in type B languages it always is. If these two series are in complementary distribution in a language, the voiced stops are obligatorily followed by an OV, while nasal stops always precede NVs.

Let me point out here that there are three relevant types of consonants in *all* type B languages and they can be summed up as in (5). Note that there are languages, e.g., Cubeo (cf. Section 2.4.2 and Salser 1971), which display the consonantal alternations in (5) but where the domain for orality or nasality agreement is categorically precisely one onset-nucleus pair ('ON' pair/sequence), i.e., nasality never spreads beyond one ON-sequence. Let me call this agreement between a nucleus and its (preceding) onset *nasal sharing*. So based on the above it can be said that type B languages (which are languages where nasality spreads through a whole domain, i.e., beyond one ON-pair) always also exhibit nasal sharing:

(5) *Nasal sharing: A must in type B languages*

Expression	*Pattern*	/_ Ṽ		/_ V	
T-expressions	T	TṼ	tã	TV	ta
N-, D-expressions	N ~ $^{(N)}$D	NṼ	nã	$^{(N)}$DV	$^{(n)}$da
G-expressions	G̃ ~ G	G̃Ṽ	j̃ã	GV	ja

To account for these types of nasal harmonies, Piggott (ibid.: 49) proposes the hierarchical ordering of [nasal] shown in Figure 1.

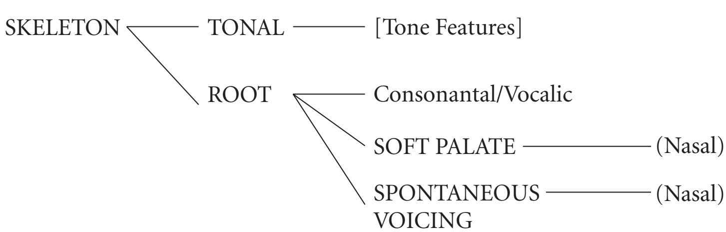

Figure 1. The hierarchical ordering of [nasal] according to Piggott

In Piggott's view, the feature [nasal] is dependent on the Soft Palate node in type A languages but on the Spontaneous Voicing node in type B languages. The Spontaneous Voicing node is phonetically 'motivated' as node for sonorancy. Furthermore, he claims that it is the Soft Palate node dominating [nasal] which spreads in type A languages, while in type B languages the feature [nasal] itself, linked to Spontaneous Voicing, spreads through a harmony domain from sonorant to sonorant.

The arguments for this re-arrangement of the feature [nasal] within the geometrical hierarchy are dubious. In Piggott (1992: 37), [nasal] is dominated by the Soft Palate node which in turn is dominated by the Root node. This ordering is according to Piggott "argued for in Piggott (1987)" (Piggott 1992: 37). However, in Piggott (1987: 229), i.e., Piggott's modification of Clements's (1985) original, "the feature nasal is linked directly to the root node". Neglecting this inconsistency, the approach discussed here (Piggott 1992) predicts in Piggott's own view that the harmony pattern of type A languages "can only be triggered by a consonant" (Piggott 1992: 34), while in languages of type B all sonorants may be triggers. Piggott's account also predicts the observable fact that, as demonstrated above, there are no opaque and no blocking 'segments' (Piggott's term) in type B, while in type A languages some consonants are opaque segments and only non-continuant obstruents may block spreading. Which expressions are opaque or transparent or block nasal harmony is in Piggott's analysis subject to further language-specific constraints.

There is unfortunately not enough space here to discuss Piggott's article in detail but let me present the main arguments against Piggott's account. I will show that his claims about nasal harmony are ad hoc, ignore typological evidence and make a number of predictions which are wrong to such an extent that any attempt to save this feature geometry-based approach will appear futile.

Firstly, as I have pointed out in Section 3.1, feature geometry – popular as it might be – is simply not an empirical approach to phonology because one of its key assumptions, an articulatory version of the PH, is set up in an unfalsifiable manner. (It is unfalsifiable because any language that can successfully 'resist' some consequence of the supposed physiologically motivated urge to increase ease of articulation does not weaken such a version of the PH; such languages are not even interesting as far as the supporters of the PH are concerned.)

Secondly, even if one were to neglect the basic problems with logic inherent in feature geometry, Piggott's approach contains an ad hoc 'explanation' because the feature [nasal] is the only one that to Piggott's knowledge "may be organized under more than one node" (ibid.: 75). Piggott justifies this by pointing out that this "may be a reflection of the fact that [nasal] is neither a structure feature nor is it correlated with the action of an articulator; it is strictly related to airflow" (ibid.). Assuming that nasality is only related to airflow and that Piggott's theory is motivated by articulatory phonetics, there should simply not be a thing such as the phonological concept of phonetically motivated nasality if all other features are correlated to structure or articulator actions (and let us also neglect here whether or not and in what way structure is phonetically motivated). Futhermore, airflow measurements are supposedly a substitute for measuring the degree of velum lowering (and thus of velopharyngeal opening), made use of because the velum is difficult to access via measurements other than those established on the basis of potentially harmful X-ray tracings). Therefore, airflow measurements are indeed correlated to an articulator (in some sense); in any case, Piggott's remark that [nasal] "is strictly related to airflow" (as opposed to being related to an articulator) makes little sense. So [nasal] should in a PH-based 'phonological' 'theory' (as feature geometry is) behave like any other feature, i.e., be universally linked to one and the same node. Obviously, in an untestable theory, even this 'universal' link is now universal only in some 'parameterised' way, and importantly, this parameterisation *cannot* be phonetically motivated; Piggott's merely indicates that it *may* be, without looking at the details. The moment one however does indeed look at them, the phonetic motivation in the 'parameterised universal' linking of [nasal] to two nodes turns out to be question-begging.

Moreover, in Section 2, I have provided evidence which makes it abundantly obvious that the feature [nasal] is *not* strictly related to airflow.

To sum up this argument against Piggott's account, even if one ignores the general problems of the articulatory hypothesis – and why should one? – Piggott's version of feature geometry is not phonetically motivated even though his chosen framework supposedly is (but really is not). Additionally, his modifications increase the degree of stipulation within feature geometry.

My third argument argument against Piggott's account is concerned with the consonantal patterns displayed in (5) which can be found in Cubeo and all type B languages. To explain the data in question, Piggott (ibid.: 55) provides a rule, which he calls "voice fusion", that fuses Spontaneous Voicing nodes within a syllable in a way such that the nucleus of a syllable dominates the left-adjacent onset. He formulates this voice fusion rule for SB (ibid.: 55) and for Guaraní (ibid.: 60) in the following way:

(6) *Voice fusion*
"SV-nodes [i.e., Spontaneous Voicing nodes] are fused within a syllable; the features of the right node (i.e., the nucleus or the head of the syllable) dominate."

In his view this predicts that oral sonorants are followed by OVs while nasal sonorants are followed by nasal vowels. However, even though one would expect that it is possible for Piggott to motivate independently via the science of articulatory phonetics which consonantal segments are specified for Spontaneous Voicing, Piggott has to look at the phonetically unmotivated part of the phonologies of the languages involved and stipulate for each of the languages discussed by him which segments are specified for Spontaneous Voicing and which ones are not. Articulatory phonetics does obviously not even provide the information necessary to establish a correlation between major segment classes and Spontaneous Voicing. For example, Piggott is not able to provide articulatory evidence for predictions about which of the segment classes 'obstruents', 'laryngeals', 'sonorants', and so forth, may or must be specified for Spontaneous Voicing (ibid.: 57f.). This shows that either the proposal of Spontaneous Voice fusion, that of phonetically motivated segment classes or both of these claims are rather ad hoc. In any case, what is or is not 'spontaneously voiced' cannot be motivated phonetically, no matter how phonetic this term may sound.

Fourthly, in Piggott's (ibid.: 34) own words, "Since only [+consonantal] segments are underlyingly specified for such a node [i.e., the Soft Palate node], this [type A] harmony pattern can only be triggered by a consonant". Let me remind the reader that Piggott analyses Warao as a type A language with nasal harmony spreading from left to right. Piggott therefore predicts that there should be no word in Warao which starts with a NV since the nasality on that vowel should have been triggered by a consonant to its left (7a). Similarly, a NV should not be preceded by an oral glide (7b). Moreover, a blocking expression, e.g., a voiceless obstruent, should never be followed by a NV (7c):

(7) *Type A data problematic for Piggott: Warao*

a.	ũĩ	'angoleta bird'	b.	hĩh̃ã	'kind of bird'
	ĩõ	'kind of turtle'		jã	'walking'
	õkõ	'kind of bird'		tewẽke	'kind of bird'
c.	terẽ	'it broke'			
	sãĩ	'sound of talking'			
	tãẽ	'it fell'			

More generally, if Piggott's account for type A languages holds true, a Warao NV should be preceded by an obligatory NC independently of whether the nasality of this consonant is underlying or derived. Piggott does not discuss this prediction nor does he mention that data detrimental to his analysis does exist. Note that *all* of the data in (7) contradict two interdependent predictions by Piggott about type A languages: not only is he wrong in claiming that only consonants may be underlyingly nasal; opposed to his view, nasal harmony of type A may not only be triggered by consonants but also by vowels.

This is not to say that there are no type A languages as Piggott predicts them. For example, those languages which exhibit type A spreading of nasality, i.e., harmony blocked by certain consonants, and which simultaneously disallow NVs preceded by OCs in left-to-right harmonies, do exist: Piggott (ibid.: 41) points to the Sundanese data in Robins (1957), which appears to display rightward type A spreading but no word-initial NVs or other counter-evidence. However, since there *are* type A languages like Warao which contradict Piggott – there is, e.g., Secoya (Johnson & Peeke 1962; Ploch 1997) – the dichotomy between type A and type B languages as proposed by him cannot account for human languages: it has become apparent that Piggott's proposal that the feature [nasal] can be attached to either the Spontaneous Voicing or the Soft Palate node can be proven wrong.

My fifth and final argument against Piggott's account of nasal harmony phenomena is of a typological nature. Piggott (ibid.: 45–61) discusses two type B languages, SB and Guaraní.[23] Both of these languages display nasal sharing as illustrated in (5) for G- and N-expressions and nasal harmony unblocked by T-expressions; T-expressions may precede either type of nucleus, nasal or oral. As pointed out above, Piggott's explanation of nasal sharing is voice fusion (cf. (6)). This claim enables him in both languages to propose only one series of underlying 'segments' for the two observable surface series of N-expressions ('nasal stops') and D-expressions ('(prenasalised) voiced stops'). The point relevant here is that in SB he derives N-expressions from D-expressions while in Guaraní D-expressions are derived from N-expressions. Piggott's analysis can therefore only be maintained if there is independent evidence for the typological categorisation implicit in his account. So, if his analysis is worth its salt then a cross-linguistic survey of languages *without* nasal harmony but with one series of 'voiceless stops' and only one series of either voiced stops *or* nasal stops should demonstrate two types of languages: Firstly, those with an underlying series of 'nasal stops' and no series of underlying 'voiced stops' (prenasalised or not), and secondly, those with an underlying series of (maybe prenasalised) voiced stops and no series of underlying nasal stops. However, "Every language has at least one PNC [primary NC] in its inventory" (Ferguson 1963), and such a generalisation cannot be made about voiced stops. In other words, an underlying series of voiced stops implies a series of nasal stops but not vice versa. This means that it is implicit in Piggott's view that languages which do not display nasal harmony cannot have a series of voiced stops without having a series of nasal stops; languages with nasal harmony as analysed by him, on the other hand, might have a series of voiced stops without a nasal series. It can therefore be said that Piggott's account is contrary to typological evidence.

Let me add that those phonologists who do not assume an underlying series of NCs *always* propose an underlying series of voiced or prenasalised voiced stops which is in variation with a series of corresponding NCs. This is evidence against the proposal of underlying voiced stops but not of nasal stops for any language independently of whether or not that language displays some kind of nasal assimilation and of whether this assimilation is achieved via nasal spreading through a whole word, nasal sharing or both.[24]

Let me sum up my critique of Piggott's account of nasal harmony phenomena: Firstly, Piggott's analysis is within the framework of feature geometry. Secondly, Piggott's 'revolutionary idea' to assume that the feature [nasal] can be dependent on either the Soft Palate node or the Spontaneous Voicing node cannot be motivated phonetically – which it should be in feature geometry – and this alteration increases the degree of stipulation inherent in his approach. Thirdly, Piggott cannot motivate independently which consonants are specified for Spontaneous Voicing. In other words, within Piggott's phonetically motivated framework, the assumption of voice fusion as well as of Spontaneous Voicing remains unmotivated by phonetics; the non-application of the PH is here as elsewhere completely ad hoc (Strategy 2, flexibility of applicability). Fourthly, Piggott cannot account for data found in many type A languages, i.e., one of the types of nasal harmony languages predicted by him. Specifically, the prediction that in type A languages only consonants may underlyingly be specified for nasality and trigger nasal spreading can be proven wrong. Fifthly, contrary to typological evidence, Piggott has to propose an analysis for a certain subtype of type B languages (exemplified by SB) in which for him there are no underlying NCs.[25]

4. Suggesting a cognitive alternative

Having deconstructed the PH, I would like to look briefly at a possible alternative explanation of the attested phonology-phonetics matches which does not presume a directional (motivating) link from phonetics to phonology. The alternative I have in mind is the latest revised version of Element Theory ('ET'):[26] Phonological representations are viewed as the addresses of the hearer's mental (cognitive) lexicon, with syntactic and semantic information as contents of these addresses. Phonotactic constraints, whether seen as static (distributional) restrictions or (dynamic) processes, are not motivated by or established on the basis of the properties of the articulatory or auditory system. The phonological part of the Language Acquisition Device does not take into account that language is spoken or heard. As opposed to approximately 20 (or more) binary features used by current phonetically grounded frameworks, ET only employs six so-called elements as ultimate melodic units: A, I, U, ʔ, H, L. When linked to skeletal points (cf. Kaye et al. 1990; Brockhaus 1995a), each of these elements is directly interpretable – without any intermediary phonetically defined phonological level of representation.[27] GP's explanation of the observable link between phonology and phonetics is that elements are thought to correspond to acoustic cues; there is little agreement on how direct or mediated this relationship is.[28] As a consequence, elements are associated with typical pronunciations; so A (in isolation) is typically realised as a- or r-type sound while there is no evidence for the phonological relevance of many of the phonetic differences catered for by the IPA ([a ɐ ɑ ɒ æ r ɾ ɼ ɽ ɹ ɻ ʀ ʁ]).[29]

According to ET, most parts of the phonetic signal contain no phonologically relevant information, and only a small subset of all the acoustic properties of a signal are cognitively dealt with by the phonology. In this way, a child acquiring some language cannot recognise the relevant traces 'by analysing the patterns emerging from a study of the phonetics' without knowing a priori what to look for.

More generally, nothing can be learnt ever by an assumed tabula rasa-brain. In order to learn, our brain must be able to tell whether two objects it 'encounters', i.e., processes, say, *A* and *B*, are similar as far as the brain is concerned. In order for it to be able to tell, it must be able to decide whether *A* and *B* share some common property, and at some point, when the brain makes its first similarity decision, it must know, before having processed anything, what the relevant common property it has to check for is supposed to be. So there *must* be a priori relevant categories for the brain. There can be no learning by practice or repetition without cognitive a priori, i.e., innate, categories, and since such a priori categories require the learner to check whether something encountered contains or does not contain some a priori category, all practice/repetition or imitation-based learning requires the application of trial-and-error-based learning.[30]

Furthermore, elements can be fused. Fused elements also have typical pronunciations; for example, A fused with I (dominated by a nucleus) always sounds like an e-type vowel. When linked to skeletal points, elements occur within so-called phonological expressions ('PEs'). Within a PE, elements are of one of two status types: head or operator. A PE may contain any number of operators and zero to one head(s). Elements co-occurring in one PE are said to be *fused* (symbolised by the fusion operator '·'). By convention, PEs are symbolised by parentheses, heads are underlined. A few examples: (U) and ($\underline{\text{U}}$) are simplex expressions containing the U-element. (U) is headless, ($\underline{\text{U}}$) is U-headed; (A · I), (I · $\underline{\text{A}}$) and (A · $\underline{\text{I}}$) are complex PEs containing A and I, (A · I) is empty-headed/headless, (I · $\underline{\text{A}}$) is A-headed, (A · $\underline{\text{I}}$) I-headed.[31]

Now consider the following (incomplete set of) findings of ET: [e] (not [ɛ]) has been shown to correspond to (A · $\underline{\text{I}}$) *and* (I) in Okpe (Cobb 1997: 144ff.), while (A · $\underline{\text{I}}$) is pronounced [ɛj ~ ej] in South-Eastern British English (*b<u>ai</u>t*, cf. Kaye 1997:217) and [e] in German (Ploch 1993); (I), realised as [e] in Okpe, sounds like [ɩ] in English (Kaye, ibid.) and German (excluding certain Austrian varieties).[32] The important thing to keep in mind is that the semi-automatic and semi-conscious classification of sounds according to phonetically motivated 'established' and thus unquestioned distinctions seems to be more misleading than helpful.

In relation to our discussion of nasality, it suffices to say here that the low tone element L has the following typical pronunciations (Ploch 1999b: 169):

(8) *The phonetic realisations of* L

	in nuclei	*in onsets and onset licensees*
L-*operator*	low tone/pitch	nasal stop
L-*head*	vocalic nasality	voicing in stops/fricatives, prenasalisation in voiced stops

For example, m will usually be phonologically motivated by (U · ʔ · L) in onset position, a voiced b as in French or Spanish, but not as in English, by (U · ʔ · $\underline{\text{L}}$). In nuclear position, (A · L) or (L · $\underline{\text{A}}$) motivates à; (A · $\underline{\text{L}}$), ã.[33]

This brief introduction shows that in ET, the phonology motivates (parts of) the acoustic signal: elements correspond to acoustic cues without being motivated by them. Importantly, while in more mainstream frameworks phonology is assumed to be phonetically grounded even though this hypothesis has to be immunised against refutation by not applying it whenever it would otherwise be proven wrong, the imprecise match between phonology and phonetics falls out of ET: Since there are other motivating factors for phonetics, e.g., accents (group-specific group marks, Kaye 1997), and the physiological make-up of humans (universal phonetic processes), there is a vast amount of phonetic 'packaging' (Kaye, ibid.) that surrounds acoustic cues. So it makes, for example, no phonological difference whether short a in English is pronounced [æ] or [a]. Similarly, there is only evidence for one type of phonological 'nasality' even though it correlates phonetically with different amounts of nasal airflow dependent on vowel quality (or consonantal place of articulation), language, stress, speaker, etc. It is also completely uninteresting (phonologically speaking) whether the phonetic synthesis of nasality involves tongue retraction – resulting in pharyngeal adjustment (cf. Minifie et al. 1970 regarding pharyngeal adjustment).

What all of these different phonetic versions of nasality have in common is that they provide the cue which is viewed by the Language Acquisition Device as an instantiation of some cognitive concept, say, the L-element.

So where does that leave us? Can these acoustic cues be established by studying phonetic data? No. As I have demonstrated above, the research of phoneticians and grounded phonologists alike shows clearly that there is no phonetic definition of phonological 'nasality'. How then do we phonologists decide which phonetic details are phonologically motivated and which ones are not? Remember that this cannot be established on the basis of phonetic measurements because such data always presuppose known phonological feature specifications. In other words, how do we know what to assume as known phonological specifications if the phonetic signal merely contains the relevant cues but no information on how to recognise them. The answer is astonishingly simple. It is simple because it only contains two methodological steps both of which have been in use by phonetically grounded phonologists for decades: (a) an analysis of the contrasts a language employs, on the one hand, and (b) of its phonotactic constraints, on the other.

So for Huffman, Vaissière, Ladefoged, van Reenen and all the other phonetic researchers referred to above, those instantiations of nasal airflow are assumed to be phonologically relevant which contrast with other categories/segments in similar phonological contexts. To say that nasality is phonologically relevant because it is what distinguishes the onset in SEBE ⟨met⟩ from the ones in ⟨bet⟩, ⟨pet⟩, etc., shows that the decision to count 'nasality' (i.e., that which distinguishes m from b, p) as phonological matter is *not* phonetically motivated for phonetically grounded phonologists. It is the phonological behaviour, i.e., the fact that m *behaves* differently from other segments/phonological expressions (by distinguishing meaning), which provides the argument for the assumption of 'nasality' as phonological notion. Similarly, nasal harmony phenomena (as discussed above) are not phonologically interesting because of the phonetic phenomenon 'nasal airflow' – which is not to say that airflow could not be an interesting phonetic topic or that a phonetic investigation of nasal airflow could not give rise to phonologically interesting questions. However, whether or not a phonetic phenomenon is relevant to the study of phonology can never be decided on the basis of phonetic measurements but via an analysis of the phonological behaviour of categories none of which can be motivated phonetically. This is the meaning of the notion 'cognitive motivation' or of Kaye's 'cognitive' approach to phonology (Kaye 1989). And so nasal harmony is an interesting topic for phonology because it *cannot* be predicted by the science of phonetics; if it could, either all human languages should do nasal harmony or the PH should be able to predict under which circumstances phonetic urges are disregarded and how and/or to what extent, otherwise falsifiability in this version of the PH would be lost. As long as phonetic science can only make phonological phenomena 'likely' in a manner so imprecise that any amount of phonology-phonetics matches will do as evidence for the PH and no cross-linguistically established degree of non-application of the PH or non-manifestation of phonetic urges will refute the PH, the PH remains a myth, albeit a socio-academically successful one.[34] Also, it cannot be repeated often enough that the PH, like any other hypothesis, cannot be confirmed or probabilified by providing more and more examples where it 'works'.

So, if both phonetically grounded and cognitive phonologists establish that which they consider to be phonologically relevant independently of phonetic measurements, what is the difference, or, what is new about ET? Does it not merely highlight something that has been known before the advent of Government Phonology? No. Even though it is true that ET employs methods discovered by its predecessors, mainstream phonologists – who also use contrasts and constraints to determine phonological relevantia – are constantly misled by the PH: On the one hand, phonological 'nasality' is established in mainstream phonology by an analysis of the contrasts and phonotactic constraints attested in a language (where this analysis is *not* predictable from phonetic measurements), while the same non-phonetically motivated notion 'phonological nasality' is simultaneously claimed to be phonetically motivated (with no conclusive evidence to support this since all phonetic-phonology matches do not per se argue for the PH and could also be explained by Kaye's Cognitive Hypothesis ('CH'; cf. Kaye 1989, my term). Clearly, it is not the case that phonetic phonology and cognitive phonology exclude each other mutually: phonetic phonology makes use of both the PH and the CH (and thus is compatible with cognitive phonology to some extent) while cognitive phonology only employs the CH, not the PH (and is thus completely incompatible with the popular unfalsifiable version of phonetic phonology). Since there is no evidence for the PH, it may, according to Occam's Razor, have to be abandoned; what is left is the CH, resulting in a so-called 'cognitive view' of phonology (cf. Kaye 1989). In other words, a cognitive phonology contains less redundancy and has therefore more explanatory power than a phonetically grounded framework.

Conclusion

Based on Popper's falsifiability criterion for empirical science, I have tried to show in this paper that all the available evidence is against any articulatory or acoustic version of the PH. Furthermore, there is to my knowledge no phonological framework that supports the PH and that does not have to either ignore the vast number of counterexamples or simply allow for them. In addition, I have argued that Piggott's explanation of nasal harmony phenomena which he delivers within feature geometry is non-empirical in parts, in other words, it is, at present, explanatorily inadequate.

It appears that it is not possible to predict on the basis of measurements of phonetic nasality when phonologists would want to assume the presence of non-phonetically, i.e., cognitively, defined phonological nasality or (phonologically relevant phonetic) surface nasality; phonetically grounded phonology must always establish these known phonological feature specifications of nasality (or of any phonological unit or property) via consultation of the system of contrasts and the processes attested. I therefore conclude that phonological 'nasality' is a cognitive unit, i.e., a unit which is not motivated by phonetics and which corresponds in some way (that was not elaborated upon in this paper) to some range within the acoustic signal (and possibly to other things). To try to establish phonological 'nasality' on the basis of phonetic measurements appears futile. The phonology is, as it turns out, *not* motivated by the phonetics.[35]

Hayes's (1995) "dilemma of phonetic naturalness" (ibid.: 1) – the (phonetically) unexplained problem that the "tongue (and the ear) have preferences", that "these preferences seem to govern a great deal of segmental phonology" and that it remains open "how [...] these preferences [are] to be reflected in the formal phonological grammar" (ibid.) – is solved: phonology need not explain phonetic preferences which are not phonologically motivated, and phonological phenomena that can be described via reference to their phonetic properties need not be motivated by them. Hayes' problem with what he calls mainstream phonology in that it mostly ignores the naturalness dilemma by providing "phonological representations [which] are impoverished and schematic, encoding only a tiny part of the richness of articulatory and perceptual phenomena" (ibid.) is imaginary: Only because he assumes (without any evidence) that it is the aim of phonology to model or explain phonetic 'richness', it is a problem when a phonological frameworks does not model that richness. His conclusion that phonologists should try to understand better the factors in phonology that result from the "bumpy playing field" (ibid.: 14) – where the metaphor of the bumpy playing field refers to the fact that most phonological representations cannot capture the complexity of the phonetics involved – is thus a non-result.

It appears that as long as phonologists are not willing to drop the PH and the idea that phonetic richness should be encoded phonologically, they will make no progress in the direction of an adequate explanation of the relation between phonology and phonetics.

Let me finish by mentioning again that I do not want to imply that phonetics is, in general, an irrelevant scientific discipline which should be abandoned. As pointed out above, it may, in certain circumstances, be useful to study the phonetic details of a signal because this might give rise to phonologically interesting ideas, which might then, in turn, be formulated as testable hypotheses leading ultimately to progress in phonology. However, whether or not a phonetic detail turns out to be phonologically relevant is not a priori clear and can only be decided independently of phonetics. Clearly, phonological 'nasality' is not motivated by any phonetically measurable unit and, more generally, phonology is not motivated by phonetics.

Abbreviations

BCG	bilabial closure gesture
CH	Cognitive Hypothesis
ET	Element Theory
NC	nasal consonant
NV	nasal vowel
GP	Government Phonology
OC	oral consonant
OV	oral vowel
PH	Phonetic Hypothesis
SB	Southern Barasano

Notes

* I would have liked to thank the late Katrina Hayward (SOAS) for helping me find some of the relevant phonetic literature; her untimely death has unfortunately made this impossible. Further, I would like to express my gratitude to the members of the audience at HILP 4 who made comments after my talk. Thanks also to Pieter van Reenen for his comments as the first reviewer of this paper. Finally, let me point out that the line of argument pursued in the following would not have been possible without and owes much to Jonathan Kaye's deconstruction of the mainstream hypothesis that the phonology is motivated by the properties of the articulatory system (cf. Kaye 1989).

1. Cf. Stirner (1972: 46f.). Translation from Stirner (1907: 55f.): "What is it, then, that is called a 'fixed idea'? An idea that has subjected the man to itself. // … Undislodgeable, like a madman's delusion, those thoughts stand on a firm footing, and he who doubts them – lays hands on the *sacred*! Yes, the 'fixed idea', that is the truly sacred!"

2. Let me point out to those who think that Popper is outdated or that Feyerabend, Kuhn or Lakatos have shown that Popper's falsificationism is naive or useless that to date I have not seen any arguments for such a view; cf. Ploch (2002) and Note 1 in Ploch (in prep.).

3. Other relevant works by Popper are: Popper (1989, 1972, 1994a). In relation to Feyerabend's 'arguments' against method portrayed in Feyerabend (1975), let me mention (a) that Feyerabend confuses questions of factuality (what so-called scientists do, quid facti) with what Popper talks about, i.e., questions of logical validity (quid juris), and (b) that there is due to this situation not a single argument in Feyerabend's *Against Method* against Popper's testability-based method of trial-and-error.

4. There is no space here to look at Kaye's rejection of his devil's-advocate type counter-arguments against attempts to save the PH, cf. Kaye (ibid.).

5. For a general discussion of invariant acoustic correlates of phonological contrasts, cf. Stevens and Blumstein (1981); for invariant cues for place of articulation in stops, cf. Stevens and Blumstein (1978); for acoustic correlates of the distinction between nasal and oral vowels, cf. Hawkins and Stevens (1985).

6. For a more detailed discussion of this point, cf. Ploch (in prep.).

7. Cf. the chapter "The feature [nasal]" in Ploch (1999b).

8. Angas is a Chadic language spoken in Nigeria, cf. Burquest (1971). Kwangali is a South-west African Bantu language (cf. Dammann 1957). Cf. also Silverman (1996) pointing to Okell (1969) and Dantsuji (1984), Dantsuji (1986), Dantsuji (1987) for Burmese; and pointing to Anderson (1989), Anderson et al. (1990), Pace (1990) and Silverman (1995) for Chinantec.

9. In answer to a question I had raised after Dolbey and Hansson's talk at HILP 4 (Dolbey & Hansson 1999), Andrew Dolbey came up with the argument presented in the following paragraph (cf. Chapter 1, Ploch 1999b).

10. Kaye does not refer to the PH under this name nor does he investigate it from a falsifiability-based angle. Kaye talks about the hypothesis that phonological phenomena are motivated by the properties of the articulatory system and, more specifically, about the

mainstream claim that phonological phenomena exist in order to increase ease of articulation, and names the wholesale (phonetic/phonological) convergence of human languages as a predicted consequence of this hypothesis. From my Popperian angle this means that if this hypothesis can be 'parameterised' or not-applied in any other fashion (or for any other reason) whenever it would otherwise be proven wrong, it becomes an immunised and hence unfalsifiable assumption, and this is precisely how the supporters of the PH maintain it.

11. Entenman points to a number of challenging arguments against a phonologically relevant definition of 'nasality' motivated by phonetics. These arguments, however, do not lead him to the conclusion that phonology is independent of phonetics. In spite of the evidence against the PH collected by himself he unfortunately chooses to ignore this evidence. So whenever in this section I come to the conclusion that evidence provided by Entenman is contrary to the PH, this is my conclusion, not Entenman's.

12. To name just a few of these researchers and some of the relevant literature, cf. Chen (1975), Chen and Wang (1975), Clumeck (1975, 1976), Ferguson (1963), Hyman (1972, 1975), Lipsky (1973a, 1973b, 1975), Ruhlen (1973, 1975, 1978), and, more recently, Herbert (1986) and Piggott (1987, 1992). Today Piggott seems to have rejected the PH (cf. Piggott 1999).

13. For a more recent version of the IPA (revised to 1993 and updated to 1995), cf. Nolan (1995).

14. Chaga (kiChaka) is a Bantu language spoken in Tanzania, BG's Chaga data is taken from Nurse (1979). For their research BG recorded a male speaker of Chaga and a female speaker of American English (ibid.: 230).

15. For a more detailed discussion of the short-comings of BG's approach including a deconstruction of their analysis of English sC-clusters, cf. Ploch (1997, 1999b).

16. Note that BG do not admit that, in spite of all their precise phonetic measurements, their approach has an epistemological problem nor do they discuss in what way their findings provide new phonological insights. That some phonological distribution that cannot be motivated on the basis of articulatory gestures can be described in terms of articulatory gestures, *that* is the so-called insight.

17. Kawasaki (ibid.: 85) states that "nasal consonants are realized as partially denasalized near OVs in a number of languages, e.g., Amahuaca (Osborn 1948), Apinaye (Burgess & Ham 1968), Gbeya (Samarin 1966), Guaraní (Gregores & Suárez 1967), Otomi (Blight & Pike 1976), Siriono (Priest 1968) and Wukari Jukun (Welmers 1968, Hyman 1975)"; cf. Kawasaki (1986: 96ff.). The examples in (2) are from Gregores and Suárez (1967) for Guaraní, and from Salser (1971) for Cubeo. Kawasaki does not mention Cubeo. For Sirionó, cf. also Firestone (1965); for Guaraní, Lunt (1973) and Rivas (1974). Acute accents symbolise stress in Guaraní but high pitch in Cubeo.

18. In these languages there is a phenomenon that I would like to refer to as nasal sharing: there are no voiced stops preceding NVs and no nasal stops preceding OVs. For example, *ᵐbã, *ma are ill-formed, while ᵐba, mã are well-formed.

19. Acute accents in Auca represent high pitch. However, Pike and Saint (ibid.) refer to this suprasegmental phenomenon as "stress". Note that domains ('words') in Auca can be 'stressed' on more than one vowel.

20. The optional prenasalisation in Auca is taken from Pike and Saint (1962).

21. This is a matter of logic, cf., e.g., Popper (1972) and Ploch (in prep.); I challenge any readers who disagree to show me the logics involved.

22. In languages of type A which, as opposed to Warao, have intervocalic ʔ, ʔ behaves like w, j, h and vowels, and is always transparent to and a landing site for nasal spreading. Note also that the SB data in (4) does not help to clarify whether nasality in this case spreads leftwards or, as Piggott assumes, rightwards. Piggott (ibid.: 47–55) discusses the directionality of SB harmony. For the purposes of this section, I will agree with the assumed directionality (left to right).

23. Note that prenasalised voiced stops appear to block nasal spreading in Guaraní. That it is still classified here as type B language has to do with the fact that T-expressions do not block nasal spreading in Guaraní. As long as it is clear what occurs and does not occur in a given language, terminology does not matter.

24. For a discussion and rejection of other analyses in which nasal stops are derived from underlying voiced stops, e.g., Hyman (1972) and Schachter and Fromkin (1968), cf. Ploch (1997: 266f.) and Chapter 2 in Ploch (1999b).

25. Today, Piggott (1999) rejects the PH and subscribes, in agreement with Kaye and many supporters of Government Phonology ('GP'), to a cognitive explanation of the phonology of nasality (the 'Phonological Hypothesis').

26. For the first published version of ET, cf. Kaye et al. (1985); for an overview over the latest revised version, cf. Cobb (1997) and, more recently, Ploch (1999b: Chapter 4).

27. Cf. also Harris (1996); note however that Harris still uses a number of elements that have been eliminated from the version of ET presented here.

28. Cf. Williams (1998: 40ff.), working on the phonological basis of speech recognition and referring to Stevens and Blumstein (1981) findings regarding such invariant cues.

29. This is not to say that the phonetic differences between e.g., [a ɐ ɑ ɒ æ] may not be phonologically motivated. Note also that an A-element linked to a nuclear point is realised as a-type sound, linked to an onset or (if rhymes are postulated) a postnuclear rhymal position ('coda') as r-type sound. Furthermore, the evidence for saying that a-type vowels and r-type consonants are motivated by one and the same element A comes from English and German. Let me briefly sum up the English facts: As Kaye (1993) points out, in South Eastern British English ('SEBE'), r as so-called hiatus breaker does not only occur in examples like ⟨car⟩ kʰɑː(ɐ) versus ⟨car is⟩ kʰɑːrɪz or ⟨beer⟩ biːɐ versus ⟨beer is⟩ biːrɪz, but also where there is no evidence for postulating a (possibly underlying) domain-final r, e.g., in ⟨law and⟩ lɔːrʌnd or ⟨sofa is⟩ sofɐrɪz. This provides evidence for ET's claim that the A-element – which is present in ɔ in ⟨law⟩ and in ɐ in ⟨sofa⟩ – spreads from a domain-final vowel containing A to the following empty onset of the domain to its right, where it is pronounced as r-type consonant. For the German evidence, cf. Ploch (1993).

30. This argument is a paraphrased version of an argument in Popper (1983: 39ff.) and Popper (1989: 43ff.). This is also why Popper (1989: 47), with Popper (1989) being the written-up version of a lecture given in 1953 (Popper 1989: 33), i.e., before Chomsky (1957), talks about "inborn expections" that the new-born baby has, about "inborn knowledge" which is "although not *valid a priori* ["The newborn child may be abandoned, and starve"],

… *psychologically or genetically a priori* [Popper's emphasis]", which is "prior to all observational experience", which is about the "expectation of finding regularities", "without implying that these 'expectations' are conscious". Popper is not mentioned by Chomsky.

31. Note: by convention, $(\mathrm{A} \cdot \mathrm{I}) = (\mathrm{I} \cdot \mathrm{A})$, $(\mathrm{A} \cdot \underline{\mathrm{I}}) = (\underline{\mathrm{I}} \cdot \mathrm{A})$; but: $(\mathrm{A} \cdot \mathrm{I}) \neq (\mathrm{A} \cdot \underline{\mathrm{I}})$.

32. I am currently preparing an article about the vocalic systems of a number of varieties of German.

33. For arguments regarding the correspondences in (8), cf. Part II in Ploch (1999a). In Ploch (1995) and Ploch (1999b), there are however arguments that show that French NVs contain L as operator. Cf. the works cited for more discussion.

34. In Ploch (1999a), I investigate the psychological and ensuing academico-cultural mechanisms involved in the maintainance of academic (and other) myths.

35. For a more detailed discussion of my (cognitive) views on nasality, cf. Ploch (1999b).

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Voice

The role of phonology and phonetics in Dutch voice assimilation

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1. Introduction[1]

In many languages, the voiced/voiceless distinction is neutralized for obstruents in syllable-, word-, or phrase-final positions. Final obstruents in these languages are always realized as voiceless, or vary between voiced and voiceless, depending on their segmental context.

In Dutch, the realizations of syllable-final obstruents and obstruents at the end of grammatical words are mainly determined by the nature of the following segments. Classical generative analyses of Dutch therefore assume variants of phonological rules (1a, b) (Trommelen & Zonneveld 1979; Berendsen 1983; Booij 1981, 1995), and rule (1c) (Gussenhoven 1986). These rules determine whether the relevant obstruents are realized as voiced or voiceless. Since they have the same effects on underlyingly voiced as well as voiceless obstruents, they neutralize the distinction between these obstruents. Each rule is restricted to obstruents in one type of segmental context. Rule (1a) precedes (1b) (Trommelen & Zonneveld 1979: 102; Booij 1995: 59), and (1c) (Gussenhoven 1986: 186).

The classical generative analyses also assume rule (1d). This rule devoices fricatives that are preceded by obstruents. It is a neutralization rule, like rules (1a–c), as it deletes the distinction between underlyingly voiced and voiceless segments. It differs from rules (1a–c) in that it affects initial, instead of final, obstruents.

(1) Phonological rules determining the realization of obstruents with respect to [voice].

a. Final Devoicing (FD). This rule devoices obstruents that are word-final (Trommelen & Zonneveld 1979; Berendsen 1983), or syllable-final at the lexical level (Booij 1981, 1995).
e.g. /hɔn**d**/ –FD–> [hɔn**t**] 'dog'

b. Regressive Voice Assimilation (RVA). This rule voices obstruents followed by underlyingly voiced stops.
e.g. /ka**s** + buk/ –RVA–> [ka**z**buk] 'cash book'

c. Intervocalic Voice Assimilation (IVA). This rule optionally voices obstruents that are at the end of grammatical words and in intervocalic positions.
e.g. /ʋe**t** + ɪk/ –IVA–> [ʋe**d**ɪk] 'know I'

d. Progressive Voice Assimilation of fricatives (PVA). This rule devoices fricatives preceded by obstruents.
e.g. /stup + **z**aut/ –PVA–> [stup**s**aut] 'pavement salt'
The PVA rule is fed by FD.
e.g. /ba**d** + **z**aut/ –FD–> ba**tz**aut –PVA–> [ba**ts**aut] 'bath salts'

More recent analyses (Lombardi 1997, 1999; Grijzenhout & Krämer 2000; Wetzels & Mascaró 2001) explain the realizations of final and initial obstruents in Dutch within an Optimality Theory approach (Prince & Smolensky 1993; McCarthy & Prince 1993, 1995). In common with the analyses adopting FD, RVA, and PVA, they assume that all final obstruents are specified as voiced before voiced stops, and as voiceless in all other positions in the output of phonology. Fricatives following obstruents are specified as voiceless. These specifications form the input to the phonetic component.

This paper argues that the classical generative analyses as well as the analyses framed within Optimality Theory do not present an adequate account of the facts. It presents an alternative analysis which claims that the realizations of coda obstruents and obstruents at the end of grammatical words result from an interaction between phonology and phonetics. Phonology distinguishes the word and syllable final obstruents from the obstruents that are lexically in onset positions, and the phonetic component determines whether the final obstruents are realized as voiced or voiceless. The realizations of fricatives in onset positions, on the other hand, are assumed to be completely determined by phonology.

The analysis is based on the assumption that the grammar includes a phonological and a phonetic component. The output of phonology is the input of phonetics. The phonetic component translates the abstract representations from phonology into articulatory or perceptual targets (see e.g. Keating 1988; Cohn 1993). The most important differences between the two components are listed in (2).

(2) Differences between phonology and phonetics

Phonology	Phonetics
– symbolic representations;	– physical representations;
– processes refer to feature values. Their effects cannot be gradient;	– processes interpret feature values in continuous time and space. Their effects can be gradient;
– processes may refer to the underlying representations of strings of segments;	– processes can only refer to the output of phonology, i.e. to phonological representations;
– processes are in force before a string enters phonetics.	– processes apply after a string has left phonology.

Segments need not be fully specified for all features when they enter the phonetic component. Those features that are not specified do not get articulatory or perceptual targets. At the moment their targets would be achieved, the positions of the relevant articulators are free. These articulators then take positions required for the realizations of the surrounding segments in order to reduce articulatory effort (Keating 1988). This implies that segments which are not specified for a certain feature sometimes sound as if they were specified with the plus value, and sometimes as if they were specified with the minus value of that feature. An obstruent which is unspecified for [voice], for instance, sometimes sounds as voiced, and sometimes as voiceless, depending on factors such as its place of articulation, the speech rate, and the type of surrounding segments.

The paper is structured as follows. First, a new analysis is developed for the realizations of coda obstruents as voiced or voiceless (Section 2). Then, a new analysis is presented for the voiceless realization of underlyingly voiced fricatives in onset position (Section 3). Finally, it is shown that the overall analysis can account for all variational data (Section 4).

2. The realization of coda obstruents

2.1 Introduction

This section argues that previous analyses of the realization of coda obstruents as voiced or voiceless in Dutch should be replaced by an analysis which assumes the Permanent Neutralization Hypothesis. Such an analysis is proposed in Section 2.3. The Permanent Neutralization Hypothesis is not affected by the problems that beset previous phonological analyses (see Section 2.2), while it can account at least for the same data (Section 2.4).

2.2 Problems for previous analyses

All previous phonological analyses of the realizations of final obstruents in Dutch face several problems. Those analyses adopting FD, RVA and IVA are problematic because they have to assume that RVA and IVA follow FD. They therefore assume that the only purpose of these rules is to assign [voice]-features to obstruents which have undergone FD, i.e. to assign [voice]-specifications to obstruents for which the [voice]-distinction is not relevant. It is much simpler to assume that there are no such rules, and that neutral obstruents receive their [voice]-specifications in the same way as at least some of the non-neutral obstruents, or, alternatively, receive the unmarked [voice]-specifications (in which case they would be voiced in intervocalic positions and voiceless elsewhere, as in Lombardi 1995a and Wetzels 1997). Yet another alternative, and the one that is explored in this paper, is that phonetic implementation determines whether neutral obstruents are realized as voiced or voiceless.

The second problem for these analyses is that they cannot explain why rules (1a–c) apply to the same type of obstruents. These rules assign [+voice] and [–voice] features to neutral obstruents. These obstruents consequently cannot be distinguished from non-neutral ones, since both types of obstruents are specified as [+voice] or [–voice]. Analyses assuming rules (1a–c) consequently fail to account for the difference between neutral and non-neutral obstruents in onset positions. Obstruents that are lexically in coda positions undergo FD and are therefore neutral in [voice]. These obstruents can be in onset positions at the surface. A relevant example is the /t/ in *weet ik* /ʋet ɪk/ ‘know I’. This /t/ is word-final and therefore in coda position at the lexical level. At the surface, it can be in onset position, as the string can be realized as $[(\text{ʋe})_\sigma(\text{tɪk})_\sigma]$. Neutral onset obstruents do not behave as onset obstruents that are non-neutral, since they can undergo IVA in intervocalic positions. The string *weet ik* /ʋet ɪk/, for instance, can be pronounced as [ʋedɪk], whereas *water* /ʋatər/ 'water' cannot be realized as [$(\text{ʋa})_\sigma(\text{dər})_\sigma$]. If the neutral obstruents cannot be distinguished from the non-neutral ones, this fact cannot be easily explained, and requires the stipulation that IVA is only applied to word-final, i.e. neutral, obstruents (cf. rule (1c) above). Such a stipulation is unnecessary if neutral obstruents can be distinguished from non-neutral obstruents, and only those obstruents can be realized unfaithfully to the underlying [voice]-specifications that are marked as neutral. The fact that FD affects the same type of obstruents as IVA, and also as RVA, is then not mere coincidence.

A final problem with the rules in (1a–c) is that they are assumed to be completely phonological in nature. There is no conclusive evidence for this assumption, since the realizations of the relevant obstruents are, for instance, not dependent on their underlying representations. On the contrary, there are good reasons to regard these processes as phonetic. First, if they are phonetic, they do not result from special constraints or rules that assign [voice]-features to neutral obstruents, which is intuitively correct (see above). Second, the variation in the realizations of coda obstruents as voiced or voiceless in coda-onset clusters, which is summarized in (3), is easy to explain:

(3) Variation in the realizations of coda obstruents as voiced or voiceless in coda-onset clusters.

a. Obstruents preceding voiced stops are voiced less often when they follow voiceless segments than when they follow voiced ones (Demeulemeester 1962). The /t/ in *roestbruin* /rustbrœyn/ 'rust-brown', for instance, is less often realized as voiced than the /t/ in *roetbruin* /rutbrœyn/ 'bistre'.

b. When the speech rate increases, a coda and the following onset obstruent are more often both realized as voiced or voiceless (see Kaiser 1958; Slis 1982; Menert 1994).

c. Coda obstruents preceding underlyingly voiced onset obstruents are more often realized as voiced when the following obstruents are stressed than when they are stressless (Slis 1983). The obstruent cluster in *nicolaa*/sb/*eetslaan* 'Nicolaas Beets street' with stress on the fourth syllable is for instance more often realized as completely voiced than the cluster in *a*/sb/*ak* 'ashtray' with stress on the first syllable.

d. Men realize coda-onset obstruent clusters as voiced more often than women (Kaiser 1958; Slis 1982, 1983).

e. When speakers are emotional, they realize coda-onset obstruent clusters as voiced less often (van Ginneken 1935; Meinsma 1958; Demeulemeester 1962).

If the realization of coda obstruents as voiced or voiceless is completely determined by phonetic implementation, the observations in (3) do not imply that factors such as the speaker's gender, rate of speech, and emotional status play a role in phonology (see Slis 1985). These factors are then only relevant in the phonetic component, where they are also needed to determine, for instance, the intensities and durations of segments. The assumption that the realizations of coda and word-final obstruents as voiced or voiceless are determined in the phonetics keeps the phonological component as simple as possible, without unduly complicating the phonetic component.

Analyses framed within Optimality Theory partly suffer from the same problems as the classical generative analyses. They also assume special processes in order to account for the realizations of coda obstruents with respect to [voice]. In addition, they also assume that phonological processes, instead of phonetic ones, are responsible for the realizations of neutral obstruents as voiced or voiceless. It is unclear whether the analyses within Optimality Theory can explain why the obstruents which are realized unfaithfully to the underlying representations with respect to [voice] are all of the same type. The analyses which have been proposed so far do not account for the voiced realization of word-final obstruents in intervocalic positions.

Summing up, an alternative approach should be found, mainly because the previous analyses regard processes that are phonetic as phonological. Such an alternative approach should be formulated in such a way that the unfaithful realizations of final obstruents with respect to [voice] result from a constraint which makes that the relevant obstruents are neutral, and a phonetic mechanism which determines whether these neutral obstruents are realized as voiced or voiceless.

2.3 The Permanent Neutralization Hypothesis

The realization of final obstruents as voiced or voiceless can be adequately accounted for under the Permanent Neutralization Hypothesis. Analyses which adopt this hypothesis correctly express neutralization, while the realizations of final obstruents as voiced or voiceless are assumed to be due to the phonetic component.

The Permanent Neutralization Hypothesis states that obstruents which are neutral are deprived from their [voice]-specification in some way, and remain unspecified in phonology and phonetics. They are permanently unspecified for [voice]. Non-neutral obstruents, on the other hand, are specified as [+voice] or [–voice] in the input and output of phonology. The hypothesis correctly accounts for neutralization for the following reasons. First, neutral obstruents are indeed neutral since the underlyingly voiced obstruents among them are indistinguishable from the underlyingly voiceless ones. Second, the neutral obstruents can be distinguished from the non-neutral ones. Third, neutral obstruents are not assigned [voice]-specifications by special processes.

Since neutral obstruents are unspecified for [voice] in the phonetic component, the phonetic component determines whether they are realized as voiced or voiceless.[2] The (de)voicing processes are therefore phonetic in nature, which is in accordance with the conclusions of Section 2.2. A neutral obstruent is realized as voiced if, given its physical properties and those of its surrounding segments, a voiced realization can be produced with less effort than a voiceless one. Otherwise, it is realized as voiceless. The physical properties of the segments are determined by their feature specifications, as well as, for instance, by their stress level, intensity, and the rate at which they are uttered.

The obstruents that are neutral have in common that they are in coda position at the lexical level. The easiest way to formulate neutralization would therefore be as a process that affects coda obstruents at the lexical level. The Permanent Neutralization Hypothesis consequently states that all obstruents that are lexically in coda positions are unspecified for [voice].

The Hypothesis is illustrated by the examples in (4). "T" stands for a "coronal stop unspecified for [voice]", "$_{\sigma}$(" for the left edge, and ")$_{\sigma}$" for the right edge of a syllable.

(4) Illustration of the Permanent Neutralization Hypothesis

Underlying specification:	t)$_{\sigma}$	d)$_{\sigma}$	$_{\sigma}$(t	$_{\sigma}$(d
Neutralization:	T)$_{\sigma}$	T)$_{\sigma}$		
Phonetic form:	[t] or [d]	[t] or [d]	[t]	[d]

This illustration clearly shows that the Hypothesis supposes a distinction between segments specified as [–voice] and those unspecified for [voice] in Dutch. Segments specified as [–voice] are realized as voiceless, whereas segments unspecified for [voice] are variably realized as voiced or voiceless. Analyses incorporating the Permanent Neutralization Hypothesis are therefore incompatible with the claim that [voice] is a privative feature and the specification [–voice] does not exist, as proposed by Mester and Itô (1989), Cho (1990), and Lombardi (1995), among many others. Support for our assumption that [–voice] can be present in phonology is provided by Lombardi (1996) and Wetzels (1997). They show that various processes in a number of languages cannot be described without reference to [–voice].

The Permanent Neutralization Hypothesis can be incorporated into Optimality Theory. Constraints should then be ranked in such a way that output candidates are optimal only if their coda obstruents are unspecified for [voice] at the lexical level. I assume that the coda obstruents are unspecified because of the high ranking of the constraint *[voice] which wants all obstruents to be unspecified for [voice] (5a). In addition, following e.g. Lombardi (2001), I assume MaxFeature-constraints. These constraints state that every feature in the input must have a correspondent in the output. If the MaxFeature(voice)-constraints dominate *[voice], *[voice] has no effect. Since *[voice] should have no effects on onset obstruents, onset obstruents have to satisfy a MaxFeature(voice)-constraint which is ranked higher than *[voice]. The coda obstruents, on the contrary, have to satisfy a MaxFeature(voice)-constraint which is dominated by *[voice], as they are affected by *[voice]. We therefore need two instances of MaxFeature(voice). Following Beckman (1995, 1997), Lombardi (1999), and many others, I consequently adopt positional faithfulness constraints. I adopt the constraints (5b, c).

(5) Constraints expressing the Permanent Neutralization Hypothesis

a. *[voice]: no obstruent has a [voice]-feature.

b. MaxFeatureOnset(voice): Every [voice]-feature in the input has a correspondent in the output if it belongs to an onset segment. Abbreviated as MFO(voice).

c. MaxFeatureCoda(voice): Every [voice]-feature in the input has a correspondent in the output if it belongs to a coda segment. Abbreviated as MFC(voice).

(6) Constraint ranking: MFO(voice) >> *[voice] >> MFC(voice)

Ranking (6) ensures that coda obstruents are unspecified for [voice] in the output of phonology, as tableau (7) shows for the word *bad* /bad/ 'bath'. In the tableau, "T" stands for an alveolar, and "P" for a bilabial stop which is unspecified for [voice].

(7) Neutralization as lack of specification

bad /bad/ 'bath'	MFO(voice)	*[voice]	MFC(voice)
(bad)$_\sigma$		**!	
(bat)$_\sigma$		**!	
☞ (baT)$_\sigma$		*	*
(PaT)$_\sigma$	*!		*

There are two alternatives to this analysis. One explains the data with a highly ranked constraint that demands that coda segments are not specified for [voice]. The other approach assumes IdentFeature-constraints, which require corresponding features in the input and the output to be identical (McCarthy & Prince 1995), instead of MaxFeature-constraints. Both analyses fail to account for the fact that neutralization cannot be avoided by the non-realization of coda obstruents (Lombardi 2001). The non-realization of segments implies violations of the constraint MaxIO, a constraint which demands that every segment in the input has a correspondent in the output (McCarthy & Prince 1995). In order to account for the fact that neutral obstruents are always realized, analyses that assume Ident(voice) as well as analyses that assume a constraint prohibiting coda obstruents from being specified for [voice] have to stipulate that MaxIO is highly ranked in every language. The analysis presented here does not have to stipulate the position of MaxIO in the constraint hierarchy. Coda obstruents that are neutral and those that are deleted all violate MFC(voice), and consequently perform equally well with respect to all constraints except MaxIO. Independent of its position, MaxIO therefore prevents coda obstruents from being deleted instead of being neutralized in the proposed analysis. This is illustrated by tableau (8), which shows that in the proposed analysis deletion of obstruents is blocked even if MaxIO is ranked very low.

(8) Obstruents cannot be deleted instead of being neutralized.

rood /rod/ 'red'	MFO(voice)	*[voice]	MFC(voice)	MaxIO
☞ (roT)$_\sigma$			*	
(ro)$_\sigma$			*	*!

To recapitulate, the Permanent Neutralization Hypothesis accounts for the realizations of final obstruents as voiced or voiceless in Dutch. It states that obstruents that are in coda positions at the lexical level are unspecified for [voice], and that the phonetic component determines whether they are realized as voiced or voiceless. The hypothesis therefore implies that the phonetic component provides an accurate prediction of the environments in which coda obstruents are produced as voiced or voiceless. This prediction will be argued to be valid in the next section.

2.4 The phonetic implementation of neutral obstruents

2.4.1 *Introduction*

The Permanent Neutralization Hypothesis is only valid if the phonetic component realizes neutral obstruents as voiced where coda obstruents are voiced, and as voiceless where coda obstruents are voiceless. Sections 2.4.2 to 2.4.4 show that this is the case: neutral obstruents are generally realized as voiced before voiced stops (Section 2.4.2), and in intervocalic positions (Section 2.4.3), while they are generally voiceless in all other positions (Section 2.4.4).

2.4.2 *Neutral obstruents preceding voiced stops*

The phonetic component generally realizes the second parts of all neutral obstruents preceding voiced stops, or the first parts of these stops, with glottal vibration. According to van den Berg's (1988) findings, this implies that neutral obstruents before voiced stops tend to be perceived as voiced.

Glottal vibration is continuously present if the neutral obstruent is acoustically short, follows a sonorant or a vowel, and precedes a voiced stop. The obstruent is surrounded by segments that are produced with glottal vibration, and therefore with a closed glottis. It is consequently realized with a closed glottis as well. If the neutral obstruent is an acoustically short stop, it is consequently produced with ongoing glottal vibration since during its realization not enough air enters the vocal tract to impede the vibration of the vocal folds. If it is an acoustically short fricative, it is also realized with ongoing glottal vibration since the contrary aerodynamic requirements for the production of frication and vibration (Ohala 1983) can be easily met for a short period.

Glottal vibration is generally not present during the whole obstruent if the neutral obstruent is acoustically long, or does not follow a voiced segment. Continuous glottal vibration is difficult to realize under these conditions. The realization is difficult if the obstruent is an acoustically long fricative, because the contrary aerodynamic requirements for frication and vibration then have to be met for a long period. It is difficult if the obstruent is a long stop because the supraglottal air pressure then has to be kept lower than the subglottal one for a long time despite the fact that air is streaming from the lungs into the vocal tract. Finally, the realization of continuous glottal vibration is difficult for the same reasons if the neutral obstruent follows another neutral obstruent, since two fricatives are produced with frication for a long period, two stops are produced with one long closure, and a fricative and a stop are produced with frication and a closure, which both impede glottal vibration. Acoustically long neutral obstruents and those following other neutral obstruents are therefore seldom realized with ongoing vibration before phonologically voiced stops. They are nevertheless often perceived as voiced before voiced stops. After the vocal folds have ceased to vibrate during the obstruent (or obstruent cluster), they have to start to vibrate again before the release of the following underlyingly voiced stop, in order to realize this stop as voiced. Exact timing of voice onset is more demanding than inexact timing, which means that inexact timing is preferred if possible, i.e. if the segment preceding the voiced stop is unspecified for [voice]. In that case, the vocal folds start to vibrate well before the stop is released. The first phase of the stop or even the second phase of the preceding neutral obstruent is realized with glottal vibration, and the neutral obstruent is perceived as voiced.

To sum up, the phonetic component often realizes neutralized obstruents as voiced if they precede phonologically voiced stops. This implies that if coda obstruents are regarded as neutral with respect to [voice], their realizations as voiced before voiced stops can be regarded as determined by the phonetic component.

2.4.3 *Neutral obstruents in intervocalic positions*

The phonetic component often realizes obstruents which are neutral with respect to [voice] as voiced if they are truly intervocalic, i.e. if they are directly preceded and followed by vowels at the surface. Truly intervocalic obstruents are perceived as voiced mainly if they are acoustically relatively short (Lisker 1957). This implies that whenever neutral intervocalic obstruents are realized as relatively short, they are perceived as voiced. Presumably, they are realized as short especially in fast speech.

Since function words are generally not preceded by glottal stops, postvocalic word-final obstruents followed by vowel-initial function words are often truly intervocalic. Their frequent realizations as voiced in fast speech (Ernestus 1997) can consequently be seen as the phonetic implementation of obstruents neutral with respect to [voice].

2.4.4 *Neutral obstruents in all other positions*

The phonetic component realizes all obstruents which are neutral with respect to [voice] and are not directly followed by a voiced stop or a vowel as voiceless. First, it realizes neutral obstruents as voiceless if they precede voiceless obstruents. The first obstruent in an obstruent cluster is generally perceived as voiceless if the vocal folds vibrate neither during its second part nor during the first part of the following obstruent (van den Berg 1988). Vocal fold vibration is absent during a phonologically voiceless obstruent which is preceded by a neutral obstruent because the phonologically voiceless obstruent has to be realized as voiceless, i.e. without glottal vibration. Vocal fold vibration is also absent during the second part of the neutral obstruent because the glottis is already open, or is opened during the production of this obstruent in order to produce the following phonologically voiceless segment as voiceless. Both a neutral obstruent and the following phonologically voiceless obstruent are therefore realized for the largest part without glottal vibration. They are both perceived as voiceless.

Second, the phonetic component realizes obstruents unspecified for [voice] as voiceless if they precede major phonological boundaries, such as those of the Utterance and the Intonational Phrase (Nespor & Vogel 1986). Obstruents preceding these boundaries are relatively long (Wightman et al. 1992; Cambier-Langeveld 1997), and long obstruents tend to be perceived as voiceless (Slis & Cohen 1969). Obstruents preceding important phonological boundaries are therefore generally perceived as voiceless, unless special action is taken in order to make them sound as voiced. In the case of obstruents unspecified for [voice] no such action is taken, as they are not specified as [+voice]. They sound as voiceless.

Third, the phonetic component often realizes neutral obstruents as voiceless if they are followed by a vowel-initial word. At the surface, word-initial vowels are often preceded by glottal stops, especially if they bear stress and are part of polysyllabic words (Jongenburger & van Heuven 1991). For the production of glottal stops, the vocal folds have to be firmly pressed onto each other. Glottal vibration is then impossible. If the vocal folds cease vibrating before the release of the preceding obstruent, this obstruent can be perceived as voiceless. Glottal vibration ceases early especially if the preceding obstruent is neutral, as neutral obstruents have no targets for glottal vibration. Neutral obstruents preceding vowel-initial words are therefore often realized as voiceless.

To sum up, it appears that coda obstruents need not be specified as [–voice] in order to be realized as voiceless in the environments in which they are perceived as such. They are realized as voiceless in these environments also if they are unspecified for [voice]. Neutralization as lack of specification up to the phonetic component can therefore replace the phonological rule of FD.

Finally, it is unknown whether the phonetic component realizes neutral obstruents as voiceless if they precede sonorants, which should be the case if the Permanent Neutralization Hypothesis correctly describes the voiceless realizations of final obstruents. The realizations of neutral obstruents before sonorants will be known only after research has shown which phonetic properties determine whether obstruents before sonorants are perceived as voiced or voiceless.

2.5 Conclusion

Previous analyses of the realizations of coda obstruents as voiced or voiceless, which assume that the voicing and devoicing processes are completely phonological, are unsatisfactory in that they fail to account for the fact that these processes exhibit a number of characteristics more typical of phonetic processes. We therefore proposed a new analysis which assumes the Permanent Neutralization Hypothesis. According to this hypothesis all neutral obstruents are unspecified for [voice], and it is the phonetic component which determines whether they are realized as voiced or voiceless. The analysis is able to account for (at the very least) the same facts as regards the realizations of final obstruents as the previous analyses.

The Permanent Neutralization Hypothesis can only be accepted if it allows an adequate account of the voiceless realization of onset fricatives in obstruent clusters. In previous analyses (Trommelen & Zonneveld 1979; Berendsen 1983; Gussenhoven 1986; Booij 1995; Grijzenhout & Krämer 2000; Wetzels & Mascaró 2001), the voicelessness of these fricatives is assumed to be an instance of assimilation: the fricatives are voiceless because the preceding obstruents are voiceless. Under the Permanent Neutralization Hypothesis, such an analysis is impossible since the coda obstruents preceding the fricatives are not voiceless, but unspecified for [voice]. A plausible analysis of the voiceless realization of onset fricatives is therefore required which does not depend on the [voice]-specifications of the coda obstruents. The next section presents such an analysis.

3. The realization of onset fricatives

The voiceless realization of onset fricatives in obstruent clusters has probably a phonological origin. The realizations are not as variable or gradual as the realizations of coda obstruents, and consequently seem to result from a categorical change in [voice]-features. They do not result from lack of specification at the phonetic level of all onset fricatives because underlyingly voiced fricatives in utterance-initial positions are generally realized as voiced, whereas they are not more easily realized as voiced than as voiceless. These utterance-initial fricatives would be regularly voiceless if their realizations were completely determined by phonetic implementation.

The voiceless realization of onset fricatives in obstruent clusters is probably related to the weakness of the voiced/voiceless opposition for fricatives. The first evidence for this weakness is provided by production data. The great majority of speakers of Modern Dutch invariably pronounce words that were /ɣ/- or /v/-initial in Middle Dutch with initial [x] and [f]. In addition, most people from the Western part of the Netherlands, from Friesland, and from the areas near the central areas along the Rhine, regularly realize word-initial /z/ as [s] (see e.g. Collins & Mees 1981: 159; Gussenhoven & Bremmer 1983: 57; Slis & van Heugten 1989). Finally, some speakers of Dutch never realize fricatives as voiced, not even intervocally.

Second, the weakness of the voiced/voiceless opposition is evident from the small numbers of word-pairs minimally differing in whether the first obstruent is a voiced or a voiceless fricative. There are only 9 minimal word pairs with initial /f/ and /v/, and 11 pairs with initial /s/ and /z/ (see (9)), and a significant number involve archaic or infrequent members such as [fɛil], [fi:r], and [fɑt].

(9) Minimal word-pairs with /f/–/v/ and /s/–/z/

			/f/–/v/			
faal	[fa:l]	'fail'	–	*vaal*	[va:l]	'faded'
fat	[fɑt]	'dandy'	–	*vat*	[vɑt]	'hold'
fee	[fe:]	'fairy'	–	*vee*	[ve:]	'cattle'
feil	[fɛil]	'failing'	–	*vijl*	[vɛil]	'file'
fel	[fɛl]	'fierce'	–	*vel*	[vɛl]	'skin'
fin	[fɪn]	'Finn'	–	*vin*	[vɪn]	'fin'
fier	[fi:r]	'proud'	–	*vier*	[vi:r]	'four'
fout	[fɑut]	'mistake'	–	*vouwt*	[vɑut]	'folds' (verb form)
fries	[fris]	'Frisian'	–	*vries*	[vris]	'freeze'
			/s/–/z/			
saai	[sa:j]	'boring'	–	*zaai*	[za:j]	'sowing'
sagen	[sa:ɣən]	'legends'	–	*zagen*	[za:ɣən]	'to saw'
C	[se:]	'letter C'	–	*zee*	[ze:]	'sea'
sein	[sɛin]	'signal'	–	*zijn*	[zɛin]	'to be' or 'his'
sijs	[sɛis]	'siskin'	–	*zeis*	[zɛis]	'scythe'
cent	[sɛnt]	'cent'	–	*zend*	[zɛnt]	'send'
set	[sɛt]	'set'	–	*zet*	[zɛt]	'move'
Sien	[sin]	'Sien' (name)	–	*zien*	[zin]	'to see'
sier	[si:r]	'show'	–	*zier*	[zi:r]	'the least bit'
sonde	[sɔndə]	'probe'	–	*zonde*	[zɔndə]	'sin'
sul	[səl]	'softy'	–	*zul*	[zəl]	'will'-2nd person singular

The weakness of the voiced/voiceless opposition contrasts with the strength of the opposition for stops. This opposition is strong, as is evident from the fact that underlyingly voiced stops in onset positions are seldom realized as voiceless, and that there are many minimal word pairs with /t/ and /d/, and /p/ and /b/. Some minimal pairs can be found in (10). Several pairs, such as [pak] 'parcel' – [bak] 'bin', and [pɛrk] 'bed in garden' – [bɛrk] 'birch', consist of members which are highly frequent, and can occur in nearly identical contexts.

(10) Some minimal word-pairs with /p/–/b/ and /t/–/d/

			/p/–/b/			
paard	[pa:rt]	'horse'	–	*baard*	[ba:rt]	'beard'
pak	[pak]	'parcel'	–	*bak*	[bak]	'bin'
pad	[pat]	'path'	–	*bad*	[bat]	'bath'
part	[part]	'part'	–	*Bart*	[bart]	'Bart' (name)
pauw	[pau]	'peacock'	–	*bouw*	[bau]	'building'
peer	[pe:r]	'pear'	–	*beer*	[be:r]	'bear'
perk	[pɛrk]	'bed in garden'	–	*berk*	[bɛrk]	'birch'
pont	[pɔnt]	'ferry-boat'	–	*bont*	[bɔnt]	'fur'
poot	[po:t]	'paw'	–	*boot*	[bo:t]	'boat'
pot	[pɔt]	'jar'	–	*bot*	[bɔt]	'bone'
preken	[pre:kən]	'to preach'	–	*breken*	[bre:kən]	'to break'
prul	[prɵl]	'trash'	–	*brul*	[brɵl]	'roar'
pui	[pœy]	'façade'	–	*bui*	[bœy]	'mood'
			/t/–/d/			
tak	[tak]	'branch'	–	*dak*	[dak]	'roof'
tas	[tas]	'bag'	–	*das*	[das]	'scarf'
teken	[te:kən]	'sign'	–	*deken*	[de:kən]	'blanket'
teren	[te:rən]	'to live on'	–	*deren*	[de:rən]	'to harm'
tik	[tɪk]	'tap'	–	*dik*	[dɪk]	'thick'
toen	[tun]	'then'	–	*doen*	[dun]	'to do'
tol	[tɔl]	'top'	–	*dol*	[dɔl]	'crazy'
tolk	[tɔlk]	'interpreter'	–	*dolk*	[dɔlk]	'dagger'
tor	[tɔr]	'beetle'	–	*dor*	[dɔr]	'barren'
top	[tɔp]	'top'	–	*dop*	[dɔp]	'shell'
tooi	[to:j]	'decoration'	–	*dooi*	[do:j]	'thaw'
tuin	[tœyn]	'garden'	–	*duin*	[dœyn]	'dune'
turen	[ty:rən]	'to peer'	–	*duren*	[dy:rən]	'to last'

To sum up, underlyingly voiced fricatives in onset positions are more often unfaithfully realized as voiceless than stops. Their voiceless realizations are probably due to phonological processes related to the weakness of their voiced/voiceless opposition.

These facts can be accounted for within Optimality Theory. Because of the weakness of their voiced/voiceless opposition, fricatives have to satisfy a faithfulness constraint with respect to [voice] that is ranked lower than the faithfulness constraint to be satisfied by stops (see (11)).

(11) Relevant IDENT(voice) constraints:

IDENTFRIC(voice):	If a fricative has a specification for [voice] in the output as well as in the input, these two specifications are identical.
IDENTSTOP(voice):	If a stop has a specification for [voice] in the output as well as in the input, these two specifications are identical.
Ranking:	IDENTSTOP(voice) >> IDENTFRIC(voice)

IDENT(voice) was first referred to in McCarthy and Prince (1995). I assume that IDENT(voice) is a family of constraints, and that each class of segments has to satisfy a different member. The ranking of the members is determined by the effort needed to realize and perceive the voiced/voiceless distinction on the relevant segments. If it takes little effort to express the distinction, the member will rank high; if keeping up the distinction requires a lot of effort, the relevant member of the IDENT(voice) family will rank low. Since the cues for voicing are language specific, the effort needed to keep the distinction is probably different for each language. As a consequence, the ranking of the members of IDENT(voice) is presumably language-specific. In Dutch, IDENTSTOP(voice) dominates IDENTFRIC(voice) because glottal vibration may be an important cue for voicing, and glottal vibration is more easily produced in stops than in fricatives. In fricatives it has to be produced simultaneously with frication, although the requirements for the production of frication and glottal vibration respectively are nearly the exact opposite of each other.

Onset fricatives are realized as voiceless when following other obstruents. IDENTFRIC(voice) must therefore be dominated by a constraint prohibiting fricatives from being voiced after obstruents. It is presumably dominated by constraint (12).

(12) NOVOICED OBSTRUENTS IN CLUSTERS (NVOC): an obstruent in a cluster is not voiced.

The existence of the NVOC constraint is plausible, as it is generally more difficult to realize obstruents in clusters as voiced than as voiceless (see §2.4.2). Moreover, in Dutch, hardly any obstruent in a word-medial cluster is specified as [+voice] (Zonneveld 1983).

Underlyingly voiced stops following other obstruents are generally realized as voiced. NVOC therefore does not affect these stops, and must therefore be dominated by IDENTSTOP(voice). It is also dominated by MFO(voice) (see (5a)), as the voiceless realizations of the fricatives in onset positions do not result from lack of specification at the phonetic level. All this adds up to the following constraint ranking:

(13) Constraint ranking having the effect that onset fricatives in clusters are [–voice]

MFO(voice), IDENTSTOP(voice) >> NVOC >> IDENTFRIC(voice)

This ranking holds for the post-lexical level, since the information of which fricatives are preceded by obstruents, and consequently which voiced fricatives violate NVOC, is only available at that level. There is no reason, however, why we could not assume that the ranking also holds for the lexical level.

If the Permanent Neutralization Hypothesis and the constraint ranking in (13) are accepted, obstruents can be unspecified for [voice] in the input of the post-lexical level. These obstruents should remain unspecified for [voice] up to the phonetic component. We therefore need one further constraint in addition to those in (13), i.e. DEP(voice), as defined by McCarthy and Prince (1995). This constraint prohibits the epenthesis of [voice]-features, and therefore prevents the assignment of [voice]-features to obstruents that are unspecified. It is probably ranked as high as MFO(voice) and IDENTSTOP(voice), as it is never violated.

Tableaux (14)–(16) show that constraint ranking (13) plus DEP(voice) provides the correct outputs for stops and fricatives in onset and coda positions. First, tableau (14) shows this for fricatives in utterance-initial positions. These obstruents have the same [voice]-specifications in the optimal output candidates as in the inputs. Second, Tableau (15) shows that underlyingly voiced fricatives preceded by obstruents are voiceless in the optimal output candidates. This tableau is assumed to hold for the post-lexical level. If it has to hold for the lexical level, and if the Permanent Neutralization Hypothesis is accepted, the ranking in (6) has to be added in order to make the candidate with neutral coda obstruents the optimal one. Finally, Tableau (16) shows that the constraint ranking ensures that the [voice]-specifications of stops in onset positions are not affected. In the tableaux, "S", "F", and "P" represent different types of obstruents unspecified for [voice].

(14) Utterance-initial /z/

zee /ze:/ 'sea'	Dep(voice)	MFO(voice), IdentStop(voice)	NVOC	IdentFric(voice)
☞ (ze:)$_\sigma$				
(se:)$_\sigma$				*!
(Se:)$_\sigma$		*!		

(15) /z/ preceded by an obstruent (generally an instance of PVA)

stoepzout /(stu:P)$_\sigma$(zauT)$_\sigma$/ 'pavement salt'	Dep(voice)	MFO(voice), IdentStop(voice)	NVOC	IdentFric(voice)
(stu:P)$_\sigma$(zauT)$_\sigma$			*!	
☞ (stu:P)$_\sigma$(sauT)$_\sigma$				*
(stu:p)$_\sigma$(sauT)$_\sigma$	*!			*
(stu:p)$_\sigma$(SauT)$_\sigma$	*!	*		
(stu:P)$_\sigma$(SauT)$_\sigma$		*!		

(16) Stop preceded by an obstruent (a possible instance of RVA)

afbeelden /(aF)$_\sigma$(bel)$_\sigma$(dən)$_\sigma$/ 'to depict'	Dep(voice)	MFO(voice), IdentStop(voice)	NVOC	IdentFric(voice)
☞ (aF)$_\sigma$(bel)$_\sigma$(dən)$_\sigma$			*	
(aF)$_\sigma$(Pel)$_\sigma$(dən)$_\sigma$		*!		
(av)$_\sigma$(bel)$_\sigma$(dən)$_\sigma$	*!		**	
(aF)$_\sigma$(pel)$_\sigma$(dən)$_\sigma$		*!		

To sum up, this section presented an analysis of the realization of onset fricatives, which claims that the voiceless realizations of underlyingly voiced fricatives after obstruents is phonological in nature, and that the weakness of the voiced/voiceless opposition for fricatives explains why only fricatives are devoiced. Since previous analyses do not explicitly explain why the devoicing is restricted to fricatives, this analysis is superior to previous analyses. It is compatible with the Permanent Neutralization Hypothesis, as it does not depend on the [voice]-specifications of coda obstruents. This means that the Permanent Neutralization Hypothesis does not interfere with a proper account of the voiceless realizations of onset fricatives, and no objections can be raised against it in that respect.

The analysis presented is naturally only valid for the grammars of speakers who voice fricatives. It is unnecessary for speakers who always realize them as voiceless, since these speakers have no voiced fricatives in their lexicons.

4. Variation in the realizations of obstruent clusters

There is a certain amount of variation in the realization of obstruents as voiced and voiceless in Dutch that has defied previous phonological analyses. This variation can be accounted for by the overall analysis developed in this paper, since it assumes coda obstruents to be unspecified for [voice] at the phonological as well as the phonetic level, and regards the voiceless realizations of onset fricatives as resulting from the interaction of the constraints NVOC and IDENTFRIC(voice). This is demonstrated by the following explanations of observations A–H.

Observation A: An obstruent preceding a voiced stop is less often realized as voiced when it follows a voiceless segment than when it follows a voiced one (see (3a)).

Explanation: Obstruents preceding voiced stops are unspecified for [voice]. In Section 2.4.2 it was argued that neutral obstruents preceding voiced stops are often realized with continuous glottal vibration, i.e. as voiced, if they follow vowels or sonorants. If they follow obstruents, they are not realized with continuous glottal vibration. They are only realized as voiced if the vocal folds happen to start to vibrate well before the release of the following voiced stop. An analysis incorporating the Permanent Neutralization Hypothesis therefore correctly predicts that obstruents preceding voiced stops are more often voiced when they follow vowels and sonorants than when they follow obstruents.

Observation B: Not only obstruents preceding voiced stops, but also those preceding underlyingly voiced fricatives (Van Rijnbach & Kramer 1939), especially /z/ (Gussenhoven & Bremmer 1983), are sometimes realized as voiced. The fricatives are then realized as voiced as well. For instance, the word *klapzoen* /klɑpzun/ 'smacking kiss' is then pronounced as [klɑbzun].

Explanation: Fricatives normally do not surface as voiced. Many word-initial fricatives that used to be voiced in Middle-Dutch are nowadays underlyingly voiceless for most speakers (Gussenhoven & Bremmer 1983), and consequently are seldom voiced. The remaining fricatives, mainly /z/, are generally voiceless in obstruent clusters because NVOC normally dominates IdentFric(voice) (Section 3). These fricatives surface as voiced only if faithfulness of the output to the input is considered to be highly relevant, as in formal speech (van Oostendorp 1997), and IdentFric(voice) is raised to dominate NVOC. If the fricatives are realized as voiced, they voice preceding coda obstruents in the same way as voiced stops do: they make the vocal folds vibrate during these obstruents, which are unspecified for [voice], or during their own first parts (see Section 2.4.2). The overall analysis proposed here can apparently explain why obstruent clusters ending in fricatives are occasionally realized as voiced.

Observation C: A voiced obstruent in onset position is sometimes preceded by a voiceless obstruent in coda position (Van Rijnbach & Kramer 1939; Kaiser 1958; Slis 1982). The word *asbak* /ɑsbɑk/ 'ashtray', for instance, is sometimes realized as [ɑsbɑk] instead of [ɑzbɑk], and *stoepzout* /stupzɔut/ 'pavement salt' as [stupzɔut] instead of [stupsɔut].

Explanation: According to the Permanent Neutralization Hypothesis, an obstruent in coda position is unspecified for [voice]. It is therefore realized as voiceless when such a realization is easier than a voiced one. When it is realized as voiceless before a voiced obstruent, a voiced obstruent in onset position is preceded by a voiceless obstruent in coda position.

Observation D: An underlyingly voiced stop in onset position is sometimes realized as voiceless if it follows an obstruent, especially a fricative (Demeulemeester 1962; Slis 1983) such as in *asbak* /ɑsbɑk/ 'ashtray', or an obstruent following another obstruent (Demeulemeester 1962), as in *rotsbank* /rɔtsbɑŋk/ 'reef'.

Explanation: According to the Permanent Neutralization Hypothesis, obstruents in coda positions are unspecified for [voice]. If the production of glottal vibration requires articulatory effort, they are therefore realized without glottal vibration. Underlyingly voiced stops following neutral obstruents that are realized without glottal vibration resemble phonologically voiced stops in utterance-initial positions with respect to their production: the vocal folds have to start to vibrate during their realizations. It was shown by van Dommelen (1983), among others, that the vocal folds sometimes do not start to vibrate before the release of an underlyingly voiced stop in utterance-initial position. This probably means that the vocal folds may also start to vibrate late in underlyingly voiced stops that follow (neutral) obstruents realized without glottal vibration. These stops are then perceived as voiceless. The voiceless realizations of underlyingly voiced onset obstruents in clusters can therefore be explained by the Permanent Neutralization Hypothesis in combination with the mechanisms of phonetic implementation.

Observation E: Assimilation depends on speech rate (Kaiser 1958; Slis 1982; Menert 1994). At a rapid speech rate,

– stop-stop clusters are more often realized as completely voiced,
– fricative-stop clusters are more often realized as either completely voiced or voiceless,
– obstruent-fricative clusters are more often realized as completely voiceless,

than at a lower rate of speech (see also (3b)).

Explanation: When the speech rate increases, segments become shorter. This shortening of the segments implies that glottal vibration is more easily maintained during neutral obstruents preceding voiced stops. These neutral obstruents are consequently realized with glottal vibration and therefore as voiced more often in fast speech than in slow speech.

The shortening of the segments also implies that if a neutral obstruent is realized without glottal vibration, for instance because it is a fricative, the following underlyingly voiced stop is more often realized without glottal vibration either. Since the stop is shorter, less time is available for the vocal folds to start to vibrate before its release. When the vocal folds do not start to vibrate before the release of the stop, the whole obstruent cluster is perceived as voiceless. Obstruent clusters, especially those starting with fricatives, are therefore realized as voiceless more often in fast speech than in slow speech.

Finally, the shortening implies that if the vocal folds always stop vibrating minimally at a certain absolute interval before a phonologically voiceless obstruent, such as a fricative in an obstruent cluster, they stop vibrating relatively earlier in fast speech than in slow speech. As a consequence, obstruent-fricative clusters are more often completely voiceless in fast speech.

Observation F: Obstruent clusters preceding stressed vowels are more often realized as voiced than those preceding stressless vowels (see (3c)).

Explanation: Faithfulness of the output to the input is more important for stressed syllables than for stressless ones (Beckman 1997). Underlyingly voiced stops that are stressed are therefore more often realized as voiced than stressless ones. The same holds for underlyingly voiced fricatives: if they are stressed, IDENT-FRIC(voice) is more often ranked above NVOC, and consequently they are more often realized as voiced than if they are stressless. Since underlyingly voiced obstruents that are stressed are more often realized as voiced, i.e. with glottal vibration, obstruents unspecified for [voice] preceding them are as well. This implies that stressed vowels are more often preceded by voiced obstruent clusters than stressless ones.

Observation G: Men pronounce obstruent clusters as completely voiced more often than women do (see (3d)).

Explanation: Men have longer and heavier vocal folds than women. According to Slis (1982), this implies that the vocal folds of men maintain vibration more easily. It is therefore easier for men than for women to realize obstruent clusters with ongoing vocal fold vibrations. Men consequently more often pronounce neutral obstruents and neutral obstruent clusters surrounded by voiced segments as voiced.

Observation H: When speakers are emotional, they less often realize obstruent clusters as completely voiced (see (3e)).

Explanation: When speakers are emotional, more especially when they are angry, they tend to speak with force (Meinsma 1958; Demeulemeester 1962), i.e. with a strong air stream from the lungs into the vocal tract. This strong air stream prevents the vocal folds from closing. Emotional speakers therefore tend to realize neutral obstruents without glottal vibration, and consequently as voiceless in clusters.

It appears, then, that the overall analysis presented in this paper has the added advantage of being able to handle effectively, and without overgeneralization, the variation in the realization of obstruents as voiced and voiceless in Modern Dutch. Previous analyses failed to account for this variation.

5. Conclusion

This paper presented a new analysis of the realization of coda and onset obstruents as voiced or voiceless in Dutch. It was argued that previous analyses are not adequate, especially because they cannot explain the variation in the realizations of obstruent clusters. A number of requirements were formulated that any analysis has to meet in order to be adequate. These requirements give rise to the Permanent Neutralization Hypothesis, which states that obstruents in coda positions are unspecified for [voice] in the phonological and phonetic component, and that the phonetic component consequently determines whether they are realized as voiced or as voiceless. Final devoicing and voice assimilation of coda obstruents then result from an interaction between phonology and phonetics. Under the Permanent Neutralization Hypothesis, the voiceless realization of onset fricatives preceded by coda obstruents cannot be considered to be an instance of [voice]-assimilation. This paper therefore presented a new analysis of this type of devoicing: it is assumed to be related to the weakness of the voiced/voiceless opposition for fricatives, and to result from the interaction between the constraint IdentFric(voice) and a constraint prohibiting voiced obstruents in clusters. Unlike previous analyses, this analysis explains why only fricatives devoice in onset positions. The Permanent Neutralization Hypothesis in combination with this analysis can explain all realizations of neutral obstruents and onset fricatives.

Notes

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2. It is assumed here that if an obstruent is realized as voiced, it is perceived as voiced, and if it is realized as voiceless, it is perceived as voiceless.

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Final Devoicing and the stratification of the lexicon in German*

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0. Introduction

This paper examines German Final Devoicing in Optimality Theory (OT) and shows that a full account of the data requires not only an explanation for Final Devoicing itself, but also a model of the stratification of the lexicon. The point of departure of this study is the observation that although various recently proposed analyses of German Final Devoicing in OT seem to make equally good predictions for the voicing of obstruents in the word-final position, none of them makes the right predictions for all data when ambisyllabic obstruents are also considered.

In the first part of the paper, the data for Final Devoicing in the word-final position are introduced, as well as the different optimality-theoretic analyses. In the second section, it is shown that additional data involving ambisyllabic obstruents in the native vocabulary cannot be accounted for by these analyses in a straightforward way. The third section introduces a model of the stratification of the lexicon, in which the phonological grammar of the language consists of the markedness constraints only. The faithfulness constraints can appear between each markedness constraint. This implies that there can in principle exist as many lexical strata as there are markedness constraints. Finally, it is shown in the last section how an account involving two kinds of analyses for Final Devoicing plus the model for the stratification of the lexicon introduced in the preceding section can explain all the data.

1. Final Devoicing in the absolute final position

1.1 Data and pre-OT analyses

Independently of the analysis, German Final Devoicing is a classical case of phonological neutralization. Neutralization implies a reduction of the segment inventory in certain contexts. In a neutralizing position only a subset of the segments of a language may appear. In German, most obstruents are voiceless in the syllable coda, which is the standard position for neutralization. In the absolute final position, as shown in the examples in (1), all obstruents are voiceless.

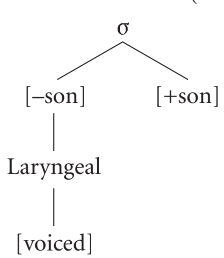
(1) Final Devoicing in the absolute final position

a.	loben	[lo:.bn̩]	'to praise'	Lob	[lo:p]	'praise, N.'
b.	Hände	[hɛndə]	'hands'	Hand	[hant]	'hand'
c.	kluge	[klu:gə]	'clever, inflected'	klug	[klu:k]	'clever, uninfl.'
d.	brave	[bʁa:və]	'good, inflected'	brav	[bʁa:f]	'good, uninfl.'
e.	niesen	[ni:zn̩]	'to sneeze'	nies	[ni:s]	'sneeze, imp.'
f.	Orange	[oʁãʒə]	'orange, N.'	orange	[oʁãʃ]	'orange, adj.'

Two approaches to Final Devoicing have been proposed in the literature. First we have what can be called the neutralizing coda-based approach, which has been defended by Brockhaus (1995), Hall (1992), Rubach (1989), Vennemann (1972) and Wiese (1996) a. o. In this approach, it is the fact that the obstruents are in the coda which is responsible for their neutralization.

Second, there is the onset-based approach of Lombardi (1991, 1995), who formulates Final Devoicing as a filter restricting the occurrence of voiced obstruents to the syllable onset. According to Lombardi's filter in (2), obstruents are only allowed to be voiced before tautosyllabic sonorants, which, for German, amounts to restricting the occurrence of voiced obstruents to the onset position. In this approach, then, it is the fact that the obstruents are in the onset that explains the possibility of their being voiced.

(2) Lombardi's filter (1991, 1995)



1.2 The positional onset-based approach to Final Devoicing in OT

Turning now to the optimality-theoretic analysis of these accounts, it has been observed that numerous languages display certain contrasts only in their syllable onsets, while neutralizing them in the coda (see Beckman 1997, 1998; Harris 1997; Lombardi 1991, 1995; Padgett 1995; Steriade 1997 and Trubetzkoy 1939).[1]

In the framework of OT, Beckman proposes positional faithfulness, which decomposes a given faithfulness constraint into multiple ones according to the position of the segment in the syllable. In the case of Final Devoicing, faithfulness of [voice] in an onset obstruent makes more specific requirements than general faithfulness of [voice]. Compare the two constraints in (3) and (4). *VdObstr, a markedness constraint formulated in (5), is ranked between these two constraints in Tableaux 1 and 2, which show an adaptation of Beckman's approach for the words *blind* and *blinde*. The result is that a voiced obstruent is only possible in a syllable onset, but nowhere else. In the syllable coda, an obstruent surfaces as voiceless.

(3) Faithfulness constraint (Beckman 1998: 38)
Ident(voice)
For all segments *x*, *y*, where $x \in$ Input and $y \in$ Output, if *xRy*, then *y* is [voice] iff *x* is [voice].
"Correspondent segments must agree in voicing."

(4) Positional faithfulness constraint (Beckman 1998: 38)
$\text{Ident(voice)}_{\text{Onset}}$
For all segments *x*, *y*, where $x \in$ Input and $y \in$ Output and *y* is syllabified in onset position, if *xRy*, then *y* is [voice] iff *x* is [voice].
"Onset segments and their input correspondents must agree in voicing."

(5) *VdObstr: Obstruents are voiceless.

NoCoda has been added for the sake of clarity. NoCoda (Prince & Smolensky 1993) forbids codas. This constraint is low ranking in German.

(6) NoCoda: Syllables have no coda.

/blɪnd/ 'blind'	$\text{Ident(voice)}_{\text{Onset}}$	*VdObstr	Ident(voice)	NoCoda
☞ .blɪnt.		*	*	**
.blɪnd.		**!		**
.plɪnt.	*!		**	**

Tableau 1: *blind* in the positional faithfulness approach.

/blɪind+ə/ 'blind, inflec.'	IDENT(voice)$_{Onset}$	*VDOBSTR	IDENT(voice)	NOCODA
☞ .blɪn.də.		**		*
.blɪn.tə	*!	*	*	*
.plɪn.də	*!	*	*	*
.plɪn.tə	*!*		**	*

Tableau 2: *blinde* in the positional faithfulness approach.

1.3 The neutralizing coda-based approach to Final Devoicing in OT

Similarly, the coda-based approach can be expressed with two markedness and one faithfulness constraints interacting in the same way as the two faithfulness and one markedness constraints of the preceding subsection. One constraint is a special case of the other, in the sense that the violations of the specific constraints form a subset of the violations of the general case (see Kager 1999 for an approach to nasal vowels on those terms). The positional markedness constraint *VDOBSTR$_{(CODA)}$ in (7) (henceforth abbreviated as FD for Final Devoicing) posits that obstruents in the syllable coda are voiceless. The other constraints are identical to the ones above.

(7) *VDOBSTR$_{(CODA)}$(FD): Obstruents in the syllable coda are voiceless.

/blɪnd/	FD	IDENT(voice)	*VDOBSTR	NOCODA
☞ .blɪnt.		*	*	**
.blɪnd.	*!		**	**

Tableau 3: *blind* in the neutralization approach.

/blɪnd+ə/	FD	IDENT(voice)	*VDOBSTR	NOCODA
☞ .blɪn.də.			**	*
.blɪn.te.		*!	*	*

Tableau 4: *blində* in the neutralization approach.

Alternatively, Itô and Mester's (1998b) approach, which uses the local conjunction of constraints (Smolensky 1995), can be shown to make the same predictions for *blind* and *blinde*. The conjoined constraint in (8) is violated if both NOCODA and *VDOBSTR are violated. The kind of local conjunction of constraints needed for Final Devoicing prohibits accumulated markedness effects: simultaneous violation of two markedness constraints in a single domain is worse than violation of each of them in two different domains. In the case at hand, it is worse to violate both NOCODA and *VDOBSTR in a single segment –

necessarily the coda – than to violate each of these constraints in two different segments – like the onset and the coda of a syllable.

A possible drawback is the fact that the domain of the conjoined constraint has to be specified in the constraint itself, which leads to a certain amount of redundancy. The local domain of the conjoined constraint is the segment (expressed by δ in (8)).

(8) NoCoda &$_δ$ *VdObstr: local conjunction of NoCoda and *VdObstr.

/blɪnd/	NoCoda &$_δ$ *VdObstr	Ident(voice)	*VdObstr	NoCoda
☞ .blɪnt.		*	*	**
.blɪnd.	*!		**	**

Tableau 5: *blind* in the local conjunction of constraints approach.

/blɪnd+ə/	NoCoda &$_δ$ *VdObstr	Ident(voice)	*VdObstr	NoCoda
☞ .blɪn.də.			**	*
.blɪn.tə		*!	*	*

Tableau 6: *blinde* in the local conjunction of constraints approach.

One of the major problems of the constraint conjunction approach is that there is no apparent limit to the possible conjunctions. If two constraints can be conjoined, so can three, four and so on. Constraints can also be conjoined with themselves. In contrast, parametrizing constraints for prosodic positions is much more restricted because the number of prosodic positions is limited.

The coda and the onset approaches are equally adequate to explain Final Devoicing in the word-final position.[2] Both contain the same amount of complexity in the formulation of the required constraints, since they use one constraint of one kind, either faithfulness or markedness, sandwiched between two constraints of the other kind. The low-ranking NoCoda doesn't play any role in the words examined here. Up to this point, then it does not matter which analysis is chosen.

2. Final Devoicing in ambisyllabic obstruents

The conclusion of Section 1 is that the behavior of the obstruents in the word-final position does not allow us to choose between the two approaches. It might be the case that other syllable positions can help to make the decision. Interesting cases are those in which an obstruent is both coda and onset at the same time, the so-called ambisyllabic position. If these obstruents are always voiceless, this would speak in favor of the coda approach. But if the ambisyllabic obstruents can be voiced, the positional faithfulness approach should be preferred. However, as we will see in a moment, the data are not so simple, and unfortunately do not really bear on the decision as to which approach is the best. At the end, both approaches will be necessary.

Before going on with the review of the obstruents' behavior with respect to Final Devoicing, it must be shown that ambisyllabic obstruents are needed in German independently of the Final Devoicing cases.

Stressed syllables in German are bimoraic (Féry 1997), or, according to some frameworks, require two positions on the skeletal tier (Hall 1992; Vennemann 1994; and Wiese 1996 a. o.). The strongest argument for the bimoraicity or bipositionality of stressed syllables comes from the fact that lax vowels are not allowed in unequivocally open syllables, as shown in (10a, b), but require a closing consonant, ambisyllabic or not, as illustrated by the data in (10c).

(10) Lax vowels

a. Not allowed in word-final open syllables

Ótto	[ɔṭo]	*[ɔṭo]	name
Káffee	[kaf̣e]/[kaf̣ə]	*[kaf̣ə]	'coffee'

b. Not allowed in hiatus position

Día	[diː.a]	*[dɪ.a]	'slide'
Ruín	[ʁu.iːn]	*[ʁʊ.iːn]	'ruine'

c. Allowed in closed syllables

Müll	[mʏl]		'garbage'
Birne	[bɪʁ̯.nə]		'pear'
Robbe	[ʁɔḅə]		'seal'

Turning now to Final Devoicing, two cases must be distinguished. The truly core native German vocabulary allows only voiceless ambisyllabic obstruents, as illustrated by the words in (11). These words seem to speak in favor of the coda approach, because, if Final Devoicing results from onset faithfulness, it is not clear why ambisyllabic obstruents should always be voiceless. Since they are onsets as well as codas, positional faithfulness to [voice] should lead to voiced obstruents in this position. In contrast, if Final Devoicing is neutralization in the coda, then voiced ambisyllabic obstruents are always voiceless as a result of their being in the coda of a syllable, and, as shown above, obstruents are obligatorily neutralized in this position. The difference between the two approaches is shown in Tableaux 7 and 8 with the hypothetical input */gə.ʃnɪdn̩/ for *geschnitten* 'cut, part. of *schneiden*' with a voiced ambisyllabic obstruent.

Tableau 7 in the coda approach accounts for the non-occurrence of such obstruents, whereas Tableau 8 in the positional faithfulness approach makes the wrong predictions.

(11) Ambisyllabic obstruents

offen	[ɔf̣n]	'open'	Sippe	[zɪp̣ə]	'family, clan'
Masse	[maṣə]	'mass'	Mitte	[mɪṭə]	'middle'
lache	[laχ̣ə]	'laugh', 1st.pers.sg	Backe	[baḳə]	'cheek'

gəʃnɪdn/ *geschnitten* 'cut'	FD	Ident(voice)	*VdObstr	NoCoda
☞ gə.ʃnɪṭn̩		*		*
gə.ʃnɪḍn̩	*!		*	*

Tableau 7: *geschnitten* (with input *geschnidden*) in the coda neutralizing approach.

gə.ʃnɪdn̩/ *geschnitten* 'cut'	Ident(voice)$_{Onset}$	*VdObstr	Ident(voice)	NoCoda
wrong winner: gə.ʃɪḍn		*		*
gə.ʃɪṭn	*!		*	*

Tableau 8: *geschnitten* (with input *geschnidden*) in the positional faithfulness approach.

However, if a slightly enlarged lexicon is taken into consideration, a certain number of words with voiced ambisyllabic obstruents, mostly stops, emerge. The lists in (12) and (13) show words with voiced ambisyllabic fricatives and with voiced ambisyllabic stops respectively. (12) is adapted from Jessen.[3] It is a nearly complete list for the fricatives. The list for the stops in (13), which is also adapted from Jessen, is far from being complete.

(12) Lax vowel + voiced fricative

a. [z]: *Dussel* [dʊz̩l̩] or [dʊsl̩] 'idiot', *Schussel* [ʃʊzl̩] or [ʃʊsl̩] 'scatterbrain', *Baiser, Blizzard, Faiseur, Liaison, Maisonette, Puzzle, Saison, Slezak*

b. [v]: *Bonaventura, Cheviot, clever, Covercoat, Evergreen, evviva, Jawlensky, Lewa, Rêverie, Livingstonefälle, Paulownia, Przywara, ravvivando, Sowjet, Struwwelpeter, Trevizent, Wlassowa, Zarewna*

c. [ʒ]: *Wuschel* [vʊʒl̩] or [vʊʃl̩] 'mop of frizzy hair'

(13) Lax vowel + voiced stop (Jessen 1997: 143)

Bagger 'excavator', *Egge* 'harrow', *Flagge* 'flag', *Kogge* 'cog', *krabbeln* 'crawl', *Roggen* 'rye', *Schmuggel* 'smuggling', *Ebbe* 'low tide', *knabbern* 'nibble', *Paddel* 'paddle', *Widder* 'ram', *Robbe* 'seal', *Kladde* 'notebook', *Krabbe* 'crab', *schrubben* 'scrub', *flügge* 'fledged', *Dogge* 'Great Dane', *dribbeln* 'dribble', *Troddel* 'tassel', *Quaddel* 'rash', *Modder* 'mud', *meschugge* 'crazy'

Most words in (12) are unmistakenly foreign, but not so much the words in (13). These are loans from Dutch or Yiddish (*Paddel, Dogge* and *dribbeln* from English) or historically derived from the Low German dialect spoken in Northern Germany (see Pfeifer et al. 1993; Wurzel 1980: 980 and Kloeke 1982: 34 a. o.).[4] The words in (12) which are not foreign, like *Dussel* and *Wuschel* have the same status as the words in (13) and no difference will be made between them in the following, even if there are many more ambisyllabic voiced stops than fricatives. They will be analyzed below as nearly native.

Tableaux 9 and 10 show that it is now the positional faithfulness approach which makes the right prediction.

/ʁɔbə/ Robbe	NoCoda &$_{\delta}$ *VdObstr	Ident(voice)	*VdObstr	NoCoda
wrong winner: ʁɔp̩ə		*		*
ʁɔb̩ə	*!		*	*

Tableau 9: *Robbe* in the local conjunction of constraints approach.

/ʁɔbə/ Robbe	Ident(voice)$_{Onset}$	*VdObstr	Ident(voice)	NoCoda
☞ ʁɔb̩ə		*		*
ʁɔp̩ə	*!		*	*

Tableau 10: *Robbe* in the positional faithfulness approach.

We are now confronted with the problem that native and nearly native words seem to require different analyses depending on the degree of their nativization. In terms of the optimality-theoretic approaches that have been discussed above, it has been shown that the words in (11) require an approach based on coda neutralization, whereas the words in (12) and (13) speak in favor of an onset-based positional faithfulness approach. However, positing two different analyses for two sets of data from the same language and from the same, or nearly same, level of the lexicon – the native lexicon – is highly undesirable. It will be shown in Section 5 that all data can be accounted for with one analysis. Since this analysis depends heavily on a theory of the stratification of the lexicon, this theory must first be introduced.

3. Stratification of the lexicon

3.1 The division of the lexicon into native and non-native vocabularies

Since Wurzel's work on the phonology of German in the seventies and early eighties, the German vocabulary has usually been considered to be divided into two categories of words, the native and the non-native ones, as shown in (14). This binary distinction aimed at replacing the traditional etymological division of the lexicon into *Erbwörter* 'inherited words', *Lehnwörter* 'loanwords' and *Fremdwörter* 'foreign words'. It is strictly synchronic and based exclusively on the phonology. Native words are described by a certain set of grammatical regularities of German and non-native words by another.

(14) Phonological and synchronic binary division of the lexicon
- a. Native words: *Hahn* 'cock', *Krug* 'jug', *Kirsche* 'cherry', *Gold* 'gold', ...
- b. Non-native words: *Diner* 'dinner', *Chemie* 'chemistry', *Präsident* 'president', *Rarität* 'rarity', *kapitalistisch* 'capitalistic', *tolerierbar* 'tolerable', *marschieren* 'to march', ...

Some problems arise with the binary hypothesis, the most serious one being related to the definition of the non-native words as a single phonological class. The difficulty comes from the fact that a twofold division of the lexicon is not sufficient to account for all data accurately, especially in the framework of traditional generative phonology, which considers phonological rules as obligatory. A definition of the native vocabulary is relatively simple and straightforward, but this is not true of the non-native words. In this framework, if a rule applies, then it applies to the whole class of words. To see the problem more clearly, consider the word-initial realization of voiceless [s]. This segment is not possible in the native words, as shown in (15a). The native words begin with voiced [z] or with alveopalatal [ʃ], but never with voiceless [s]. In one part of the vocabulary, called here Class 1, [s] can appear before [k], like in *Skelett* and *Skat*, but in no other environment.[5] In a second set of words, called Class 2, [s] can appear before consonants, like in *Steak* and *Slalom*, but not before vowels, as illustrated by *Salto* and *Sowjet*. In a further class of words, Class 3, [s] can appear everywhere, including before vowels, as shown by the words *City*, *Single* and *Surf*. It is not clear how a twofold division of the lexicon can account for such data.

(15) No [s] word-initially
- a. Always fulfilled in the native words: *Sense* [zɛnzə], *Sprache* [ʃpχa:xə], *Schule* [ʃu:lə]

b. Not fulfilled in the non-native words:
Class 1: [s] appears only before [k]: *Skelett* [skəlɛt], *Skat* [skɑ:t] (but *Spedition* [ʃpeditsio:n], *stornieren* [ʃtɔʁ̯ni:ʁn̩])
Class 2: Before all consonants: *Steak* [ste:k], *Slalom* [slɑ:lɔm] (but not before vowels *Salto* [zalto], *Sowjet* [zovjɛt])
Class 3: also before vowels: *City* [sɪti], *Single* [sɪŋl̩], *Surf* [sœʁ̯f]

The existence of these three non-native classes is based on independent evidence, like stress behavior (final stress in *Spedition, Skelett, Sowjet*), phonotactics as illustrated in (15), segmental make-up (final full vowel in *Salto* and *City*), morphology (non-native stressed suffixes in *stornieren*) and even orthography (*City, Surf*). Some of the properties of non-native words are more part of the phonology of German than others in the sense that the group of words displaying them is quite large (final stress, suffixation with nonnative suffixes like *-ieren*). *Spedition* and *stornieren* differ from *Steak* for instance because of the pronunciation of <st> and because of the orthography, which is adapted to German in the first cases but not in *Steak*. *Salto* and *Slalom* are even more peripheral because of their phonotactics: *sl* is not a frequent consonant cluster and nouns ending in *-o* are marginal. As to the Class 3 words, they are new loans, as attested by the various pronunciations of these words (see also below for additional arguments for classifying non-native words in different classes).

A second problem with a twofold division of the lexicon comes from the fact that, ideally, the segments' inventory of a language forms a closed class. However, this is only true of the native words. As soon as an enlarged lexicon is taken into consideration, things get more complicated. It is shown in (16) that the bilabial approximant [w] is excluded in most parts of the vocabulary. The non-native words *Watt* and *Whiskey* are pronounced [vat] and [vɪski] in German. But in *Walkman* or *Washington*, also non-native words, the bilabial approximant can be realized. The status of the nasal vowels is also unclear. In a large part of the non-native vocabulary, like in *Lampe, Champignon, blond*, etc., these segments are replaced by a sequence of an oral vowel plus a nasal consonant. However, other words, like *Renaissance* and *Ensemble*, are often realized with a nasal vowel. In these cases, a twofold division of the vocabulary is problematic, too.

(16) Restrictions against certain segments
a. No bilabial approximant [w] in some non-native words:
Watt [vat], *Quiz* [kvis] (but *Walkman* [wɔkmɛn])

b. No nasal vowel in some non-native words: *Lampe* [lampə], *Champignon* [ʃampiɲɔŋ], *blond* [blɔnt], *rund* [ʁʊnt] (but *Renaissance* [ʁənɛsãs], *Ensemble* [ãsãbəl], and also some pronunciations of *Chance* [ʃaŋzə/ʃanzə/ʃãs], *Ballon* [balɔŋ/balo:n/balõ], . . .)

In the following, a different, more complex model of the stratification of the lexicon is proposed, inspired by previous optimality-theoretic proposals, like the ones of Davidson and Noyer (1997), Itô and Mester (1995, 1998a), and Yip (1993). In these proposals, as well as in other, non-optimality-theoretic ones like Kiparsky (1968), Paradis and Lacharité (1997) and Silverman (1992), the different classes of words do not just coexist, but have a hierarchically organized structure. Before the model can be presented, it is necessary to take a look at some pre-theoretical properties of the lexicon which will help to motivate the model. For expository reasons, the next two subsections are called 'the native lexicon' and 'the non-native lexicon'. However, this subdivision is not an essential component of the model proposed here. Rather than a twofold division of the vocabulary, it is assumed that the lexicon contains a large number of hierarchically organized strata, some of which obey the German phonological restrictions more strictly than others. The part of the lexicon obeying these restrictions most closely is called the native words. In the peripheral parts of the lexicon, called the non-native words, the restrictions are gradually relaxed.

3.2 The native lexicon

First we will examine that part of the lexicon which meets the requirements of the strictest phonology of German. Some examples were presented in (14) and additional examples are listed in (17). (17a) gives a list of words of Germanic origin, like *Hund*, *Knopf* and *Arbeit*. Many words of French or English origin also belong to the native part of the lexicon on the basis of their phonology. Some words were borrowed from French in the Middle Ages (12th or 13th century), like *Reim, fein, Tanz, rund* and *Rosine* (see Volland 1986: 11) and have been completely adapted to the German phonology. Examples of words borrowed from English which belong to the core vocabulary are *Flipper, Bar* and *Quiz*.

(17) Native lexicon

a. Words with a Germanic origin (Wurzel 1980): *Hund* 'dog', *Knopf* 'button', *Arbeit* 'work', *Zunge* 'tongue', *lieb* 'kind', *Hornisse* 'hornet', *Wachholder* 'juniper', *Freiheit* 'freedom', *Arbeitslosigkeit* 'unemployment', . . .

b. Words with a French origin (Volland 1986: 11): *Reim* 'rhyme', *fein* 'fine', *Tanz* 'dance', *rund* 'round', *Rosine* 'raisin', ...
c. Words with an English origin (Galinsky 1980: 253): *Flipper, Bar, Tip, Quiz*, ...

Within the framework of this article, it is neither possible nor necessary to review the entire phonology of German. Instead a few important segmental properties will be listed.

It is shown in (18) that some segments belonging to the enlarged German inventory are absent from the native vocabulary, like for instance the labial approximant [w], the palatal nasal [ɲ], the postalveolar fricative [ʒ] and the nasal vowels [õ, ã, ...]. Other segments, like dental fricatives and pharyngeals are excluded from the entire lexicon.

(18) Phonemic restrictions of the native lexicon

a. No labial approximant [w]	*[kwiz] *Quiz* (E)	but [kvis]
b. No palatal nasal [ɲ]	*[baɲɛʁ] *bannière* (F)	but *Banner* [banɐ]
c. No voiced alveopalatal fricative [ʒ]	*[ʒibõ] *gibbon* (F)	but [gɪbɔn]
d. No nasal vowel [õ, ã, ...]	*[blõd] *blond* (F)	but [blɔnt]
e. No dental fricative [θ]	*[barθəlona] *Barcelona* (SP)	but [baʁ̯tsəlona]
f. No pharyngeal [ɦ], [ʕ]	*[mɔɦamɛt] *Mohamed* (Arab.)	but [h] or [x]

(19) lists some phonotactic restrictions which hold without exception in the native lexicon, like for instance the two kinds of Final Devoicing exemplified above, called here Final Devoicing I (19a) and Final Devoicing II (19b). Final Devoicing I says that obstruents are voiceless word-finally and Final Devoicing II that they are voiceless syllable-finally. (19c) posits that stops are aspirated before stressed vowels. Further restrictions are the following: a glottal stop is realized before a syllable-initial stressed vowel (19d), there is no lax vowel in open syllables (19e), no short tense vowel (19f) there is no final unstressed [e] (19g), no unstressed rounded front vowel (19h), no voiceless [s] and no palatal fricative [ç] are realized word-initially (19i and j), no sequence [ŋg] (19k), and finally, all obstruent sequences are voiceless (19l).

(19) Phonotactic restrictions of the native lexicon

a. Final Devoicing I: Obstruents are voiceless word-finally	*Rad* 'wheel', *los* 'off, free' [t, s]
b. Final Devoicing II: Obstruents are voiceless syllable-finally	*Mitte* 'middle', *Nüsse* 'nuts' [t, s]
c. Aspiration of the stops: Stops are aspirated foot-initially	*Tür* [tʰyːʁ̯] 'door', *bekánnt* [bəkʰant] 'known'
d. Glottal stop: [ʔ] is realized before stressed vowel	*Beamte* [bəʔámtə] 'civil servant', *Chaot* [kaʔóːt] 'chaotic person'
e. No lax vowel in open syllables	but only tense ones
f. No short tense vowel	but only lax ones
g. No final unstressed [e]	but only [ə]
h. No unstressed rounded front vowel	only stressed ones
i. No [s] word-initially	*sieben* 'seven' [z]
j. No [ç] word-initially	but only [k] or [ʃ]
k. No [ŋg]	*Zunge* 'tongue', *lang* 'long' [ŋ]
l. All obstruent clusters are voiceless	*Ast* 'branch'[st], *Katze* 'cat' [ts]

3.3 The non-native lexicon

As far as the non-native words are concerned, we see that some of the properties in (18) and (19) are practically never violated by the non-native words. Some interesting restrictions are listed in (20).[6] Together with phonetic or allophonic characteristics in the realization of some sounds, these properties characterize the German accent. Some native speakers of German have great difficulty suppressing them in the process of learning a foreign language.

(20) Exceptionless phonotactic restrictions (lead to German accent)

a. Final Devoicing I: Obstruents are voiceless word-finally.
b. Aspiration of the stops: Stops are aspirated foot-initially.
c. Glottal stop is realized before syllable-initial stressed vowels.

However, most of the properties in (18) and (19) can be violated in the non-native lexicon. Wurzel (1980) mentions the occurrence of the palatal nasal in (21b), of the nasal vowels in (21d) and also of the short tense vowels in (22b). Kloeke (1982) lists other properties of the non-native words, like the presence of a voiced postalveolar fricative in (21c) and a voiceless palatal fricative word-initially in (22f). Further properties which can be violated by the non-native words are also listed in (21) and (22).

(21) Violated phonemic restrictions

a. No labial approximant [w] *Walkman*
b. No palatal nasal [ɲ] *Bretagne, Champagner*
c. No postalveolar fricative [ʒ] *Gelee, Garage*
d. No nasal vowels [õ, ã, . . .] *Renaissance*

(22) Violated phonotactic restrictions

a. Final Devoicing II *Robbe* 'seal', *Puzzle, Dussel* 'idiot'
b. No short tense vowel *Ökonomie* 'economy'
c. No final [e] *Chile, Kaffee*
d. No unstressed rounded front vowel *möblíeren* 'to furnish'
e. No [s] word-initially *City, Steak, Sevilla, Software*
f. No [ç] word-initially *Chemie, China*
g. No sequence nasal + voiced dorsal stop [ŋg] *Ungarn, Mango*
h. No voiced obstruent clusters *Budget* [bydʒe:]

The non-native words have some properties which have been mentioned in the literature for other languages, but which are true for German, as well. These properties are summed up in (23).

(23) Properties of the non-native lexicon
a. Some violations are worse than others in being more non-native.
b. Loanwords on their way to nativization take over some properties of the borrowing language more quickly than others.
c. Some foreign sounds are adopted more easily than others.
d. The number of levels is unclear.
e. The position which a non-native word occupies in a hierarchy is not always clear-cut.

First, non-native words violate the constraints characterizing the native lexicon in various ways. The individual words do not violate all constraints at once, but typically involve only one or two violations, in other words, just a small fraction of the total number. Some violations are felt to be worse than others, because they are perceived as more non-native. Crucial for the non-nativeness of a word is thus not the number of violations that it contains, but the relative weight of the violated constraints (23a).

The second important observation which has already been made for other languages (by Fries & Pike 1949 for Mazateco; Holden 1976 for Russian and most clearly by Itô & Mester 1998a for Japanese) is that some properties are fulfilled earlier by non-native words on their way to nativization than others. Typically, the most serious violations are corrected first (23b).

The third property is that some foreign phonemes and sounds are taken over more easily than others, depending on the sounds and on the language. The non-native sounds also form a hierarchy (23c).

But, and this is the fourth property in (23d), the number of lexical levels or strata needed by the non-native lexicon is unclear.

Finally, the exact position which a non-native word occupies in a hierarchy is not always well-defined. A word like *City* [sɪti], for instance, is pronounced as [tsɪti] by others. It is thus not even always clear whether a word is native or not (23e).[7]

These properties must be accounted for by a model of the lexicon. A twofold division of the lexicon cannot explain them, since, in such a model, the non-native vocabulary is considered as an entity with immutable characteristics of equal value. In contrast, a model of the lexicon based on the principles of OT is able to explain all these properties, as shown in the next section.

3.4 A model of the lexicon

In OT, a grammar of a language consists of a strictly linear ranking of the universal constraints. Consider first the markedness constraints regulating the kind of phonemic and phonotactic restrictions which were exemplified in (18) and (19) and which were shown to be crucial for distinguishing between different levels of the lexicon. Ideally, these are of course also strictly linearly ordered. In (24), M_1 is the highest constraint, then M_2, M_3, etc. As an example, we can think of M_1 as the constraint militating against clicks, M_2 as the one against pharyngeals, M_3 as the one requiring a glottal stop, etc. (No attempt will be made here at describing the actual ordering of the constraints.)

(24) Linear ordering of the markedness constraints
$M_1 >> M_2 >> M_3 >> M_4 >> M_5 >> M_6 >> M_7 >> M_8 >> \ldots >> M_n$

Concentrating on the behavior of the lexical words with respect to phonemic and phonotactic restrictions, the native words fulfill all constraints up to a certain place in the hierarchy. This means that all high-ranking constraints are fulfilled by the words belonging to the core lexicon. These words violate low-ranking constraints, which can be claimed to be outside the phonology of German, but which are nevertheless present in all grammars, since the optimality-theoretic constraints are universal. Examples of such constraints which are systematically violated in German are given in (25). These constraints can be high-ranking in other languages (the ones in (25) are high-ranking in Hawaiian).[8]

(25) Examples of constraints systematically violated in German
a. *[f]: No Labial Fricative
b. *[t]: No Alveolar Stop

(26) illustrates the native grammar schematically. The markedness constraints active in German are fulfilled by the native words, some by default. F stands for the place in the hierarchy from which on the lower constraints are no longer satisfied.

(26) Grammar for the native words

$M_1 >> M_2 >> M_3 >> \ldots >> M_i >> M_j >> M_k >> F >> M_m$

Faithfulness constraints for the native words

Up to a certain point, it does not matter which input is chosen for the native words, since the non-optimal outputs are eliminated by the markedness constraints. Assume that the German word *blond* 'blond' takes the French pronunciation /blõd/ as input. Tableau 11 shows that the faithful candidate [blõd] has no chance of winning, since this candidate violates two high-ranking markedness constraints, FD and NoNasalVowel, not to speak of the syllable structure. The winner is the unfaithful candidate fulfilling the markedness constraints. Notice that another input could be chosen and the same result would have been obtained. This can be seen in Tableau 11, which illustrates the Richness of the Base, also called Freedom of the Input.[9] The actual violations of Faith in this tableau depend on which form is taken as the correspondent input. What is important to note is that the Faith violations are irrelevant – the first two constraints have already determined the optimal candidate.

/blõnd/, /blɔnt/, /blõt/, /blɔnd/	FD	NoNasalVowel	Faith (VdObstr,NasalVowel)
☞ a. [blɔnt]			
b. [blõt]		*!	
c. [blɔnd]	*!		
d. [blõd]	*!	*	

Tableau 11: Richness of the base.

In principle, the model shown in (26) also applies to the non-native words. Practically, however, it is a little bit more complicated because the phonology of the non-native words is more liberal, which implies that the markedness constraints do not play such an important role. In contrast, the faithfulness constraints gain more weight in the evaluation of the non-native words, since the non-native words are more faithful to their input – which then takes the form they have or had in their original language. In terms of the constraint ranking, faithfulness to the input can be effective at different places for different words. At the position where F stands, faithfulness is more important than markedness, and from this point on the markedness constraints are systematically violated. This is illustrated in (27). If F is located high in the hierarchy, the markedness constraints are not very effective and the output resembles the input, even if it violates many markedness constraints. (27a) is such a case. An unassimilated word like *rave*, which keeps its English pronunciation, could be an example, since it violates Final Devoicing. A word which would obey a hierarchy like (27b) would sound a little bit less foreign than a word under (27a). In (27c) it is shown that F can be low in the hierarchy, though not as low as for the native words. It is important to notice that the property of being more or less faithful to inputs is a property of the individual words or classes of words. The faithfulness constraints appear all over in the constraint ranking between the markedness constraints, as shown in (28), which illustrates the general model, and the individual words, groups of words or morphological classes rank themselves in the hierarchy with respect to the faithfulness constraints.

(27) Grammar for non-native words

a. $M_1 > \ > M_2 >> M_3 >> F >> \ldots >> M_i >> M_j >> M_k >> M_l >> \ldots >> M_n$

b. $M_1 >> M_2 >> M_3 >> M_4 >> F >> \ldots >> M_i >> M_j >> M_k >> M_l >> \ldots >> M_n$

c. $M_1 >> M_2 >> M_3 >> \ldots >> M_i >> M_j >> F >> M_k >> M_l >> \ldots >> M_n$

(28) General model

$M_1 >> F >> M_2 >> F >> M_3 >> F >> \ldots >> F >> M_i >> F >> M_j >> F >> M_k >> \ldots$

The model in (28) is extremely simplified. The effect of F is obtained by the combination of many different faithfulness constraints standing at different places in the hierarchy, as shown in Tableau 12 for the realization of [s]. A word like *Skelett*, which violates a relatively low-ranking constraint ($*_{\text{Word}}$[sk), is less foreign than *City* or *Surf*, which violate a higher-ranking constraint ($*_{\text{Word}}$[sV). This tableau illustrates how words in various stages of nativization fulfill the markedness constraints differently. The native words *Ski* and *sieben* fulfill all relevant markedness constraints. These words are sensitive to the Faithfulness constraint 5, which is the lowest faithfulness constraint for [s]. *Salto* is behaving like *sieben* w.r.t. [s]. Thus, if it is less nativized than *sieben* for other features – like the final [o] – this is not visible here. However, it is assumed that it fulfills a faithfulness constraint higher in the hierarchy exactly for these reasons: it is less nativized than *sieben*. *Skandal*, *Steak* and *City* are more faithful to their input and violate higher-ranking constraints. However, *Steak* is pronounced with [ʃ] far more often than *Skandal* which is always realized with [s] in the standard dialect. This is due to the fact the sequence [sk] is more acceptable than the sequence [st]. In the tableau, this difference is accounted for by the fact that *Skandal* fulfills a lower-ranking constraint for [s] than *Steak*. And finally, *City* fulfills a very high faithfulness constraint for [s]. The same word can be more faithful to the native pronunciation of German for other properties – like the quality of the vowel or the realization of <t> as a coronal stop, and not as a flap as in English. The markedness constraints responsible for the latter properties are ranked higher than the ones responsible for the pronunciation of <s> as [ʃ] before consonants. Interestingly, this kind of properties give evidence for the ranking of non-interacting markedness constraints.

	Faith [s]1	$*_{\text{Word}}$[sV	Faith [s]2	$*_{\text{Word}}$[sC	Faith [s]3	$*_{\text{Word}}$[sk	Faith [s]4	$*_{\text{Word}}$[s	Faith [s]5
sieben [s]		*!						*	
sieben [z]									*
Ski [s]								*	
Ski [ʃ]									*
Salto [s]		*!						*	
Salto [z]							*		
Skandal[s]						*		*	
Skandal[ʃ]					*!				
Steak [s]				*				*	
Steak [ʃ]			*!						
City [s]		*						*	
City [z]	*!								

Tableau 12: Word-initial [s].

Returning now to the properties of the non-native vocabulary which were listed in (23), we can see that they are taken account of and explained by the model.

The first property (23a) was that non-native words violate in various ways the constraints characterizing the native lexicon. Some violations are worse than others in the sense that they are less native. This property of the non-native vocabulary is accounted for by the model. Words violating high-ranking constraints sound more foreign – more non-native – than those which violate low-ranking constraints. This is because high-ranking constraints are a more inherent part of the grammar of a language than low-ranking ones.

The second property (23b) which is explained by the model is that loanwords on their way to nativization adapt themselves to the new language more quickly with respect to some properties than to others. Consider a French word taken over in German, as for instance the word *Landes*, which is the name of a region (29) and which has the same properties as "blonde". This word violates two constraints, first the high-ranking FD and second the constraint against nasal vowels, which is not so high-ranking. These two constraints must be satisfied if the word is nativized. But since FD ranks higher than NoNasVow, Final Devoicing will be satisfied before NoNasVow can be. There is no way that the reverse ordering could apply. A partial nativization like the one in (29b) is expected, but the reverse ordering of the nativization, like in (29c), is impossible. A similar point has been made by Itô and Mester (1998b) for Japanese with the word *Citybank*.

(29) *Landes* 'geographic name' (region in France)

a. FD >> . . . >> NoNasVow
b. [lãd] –> [lãt] Final Devoicing before oralization of the nasal vowel: Expected nativization
c. [lãd] –> *[land] Oralization before Final Devoicing: Not a possible nativization

As a correlate, it should be mentioned that, if words move at all, then in the direction of nativization, which means that words can evolve in the direction of fulfillment of the grammar. Single words become more native because they satisfy the grammar more by satisfying more constraints.

The third property (23c) that a model of the stratification of the lexicon should account for is that some foreign sounds are adopted more easily than others. The postalveolar fricative [ʒ] and the English sound [ɹ] – the retroflex *r* – are taken over into German without any problem. In contrast, the English interdental fricatives [θ] and [ð] have not been taken over and it is not very probable that pharyngeals, for instance, will ever become German phonemes. The model proposed here accounts for this property, as well. All sounds, whether they belong to the native inventory or not, are ordered in a hierarchy. This is illustrated in (30). The constraints prohibiting interdental fricatives [θ] and [ð], as well as pharyngeals are high in the hierarchy and as a consequence, these sounds cannot be easily integrated into the German segmental inventory. But the constraints against [ʒ] and [ɹ] are lower ranked and are violated in actual words.

(30) Non-native sounds
NoPharyngeal >> No [ð/θ] >> ... >> No [ɹ] >> ... >> No [ʒ] >> ...

A further property was that the number of levels is unclear. In the present model, the stratification of the lexicon is a direct consequence of the markedness constraints. In principle, there are as many levels as markedness constraints, since the effectiveness of the constraint hierarchy can be blocked by faithfulness constraints at each markedness constraint.

And finally, the exact position which a non-native word occupies in a hierarchy is not always well-defined. This property is explained by the fact that the position of F is not given once and for all, but is variable for many words. In addition to diachronic variation, individual differences are also expected. We are in the presence of a gradient phenomenon.

4. Final Devoicing in this model

We are now in a position to return to the problem which arose from the consideration of ambisyllabic obstruents, namely the different violations of Final Devoicing by different kinds of native words. It is shown in this last section that the model just discussed accounts for the data nicely.

An interesting fact about these data is that two classes of native words must be distinguished. First the core native ones, like *Mitte, Nüsse* and *geschnitten*, which do not tolerate ambisyllabic voiced segments, and second the slightly more peripheral words, like *Robbe*, *Roggen* and *Dussel*, which do. These words show that not only non-native words but also the native ones must be subdivided into several subclasses of words, depending on their behavior with respect to faithfulness constraints,. For the cases at hand, a positional markedness constraint (FD, short for *VdObstr$_{(\text{CODA})}$) is needed along with a general one (*VdObstr). There is no way of escaping the fact that the faithfulness constraint Ident(voice) is also subdivided into two, a positional and a general one, Ident(voice)$_{\text{Onset}}$1 and Ident(voice). In the analysis proposed here, the same faithfulness constraint can appear several times in the constraint hierarchy. This is what happens with Ident(voice)$_{\text{Onset}}$. Tableau 13 illustrates the analysis for the words *geschnitten* and *Bund*.

As shown in Section 2, FD, Id(voice) and *VdObstr are sufficient to explain the core native words – but not the nearly native ones illustrated in

Tableau 14. The lack of voiced ambisyllabic obstruents in a word like *geschnitten* in this part of the lexicon is accounted for only by an approach making use of FD. Positional faithfulness is not able to account for these words. Notice that a solution to the effect that there is no input with ambisyllabic voiced obstruent is not satisfactory, both because of Richness of the Base and on the face of alternations like *schneiden/geschnitten*.

In Tableau 13, IDENT(voice)$_{Onset}$1 is invisible. This is rendered in the tableaux by a darker shade of grey. The difference between the voicing of *b* in *Bund* and the voicelessness of *t* in *geschnitten* is explained by the place of IDENT(voice)$_{Onset}$2, which is ranked below FD, and to which these words are sensitive. Since *t* in *geschnitten* is not only the onset of the final syllable but also the coda of the preceding syllable, it is subject to FD before it is to IDENT(voice)$_{Onset}$2, and it is thus voiceless. [b] in *Bund* is just an onset, and can retain its voicing.

For the words illustrated in Tableau 14, positional faithfulness, thus ID(voice)$_{Onset}$, is needed. FD cannot explain why voiced ambisyllabic obstruents are now possible. A solution to the effect that FD is parametrized for different classes of words does not work, since then we would predict that all input voiced obstruents belonging to the same class as *Puzzle* and *Robbe* are realized as voiced, also in the absolute final position. But, as was shown above, Final Devoicing has an effect till relatively late in the lexicon, also in words which are clearly non-native.

	ID(voice)$_{Onset}$1	FD	ID(voice)$_{Onset}$2	ID(voice)$_{Onset}$	*VDOBSTR
/gəʃnɪdn/ *geschnitten* 'cut'					
☞ gəʃnɪtn̩			*		*
gəʃnɪdn̩		*!			
/bʊnd/ Bund 'federation'					
☞ bʊnt					*
bʊnd		*!			
pʊnt			*!		**

Tableau 13: Core native words.

	Id(voice)$_{\text{Onset}}$1	FD	Id(voice)$_{\text{Onset}}$2	Id(voice)$_{\text{Onset}}$	*VdObstr
/pʊzl̩/ *Puzzle*					
☞ pʊzl̩		*			
pʊsl̩	*!		*		*
/ʁɔbə/ *Robbe* 'seal'					
☞ ʁɔbə		*			
ʁɔpə	*!		*		*
/klʊb/ *Klub* 'club'					
☞ klʊp					*
klʊb		*!			

Tableau 14: Non-core native words.

5. Conclusion

This paper has proposed a model of the stratification of the lexicon which accounts for Final Devoicing data which at first sight seemed hopelessly contradictory. Both approaches to Final Devoicing which have been proposed in the literature, the neutralizing coda approach and the positional onset one, are needed for a full account of the data. A crucial aspect of the analysis is that faithfulness constraints can appear at different places in the hierarchy, whereas markedness constraints appear just once. Thus, the markedness constraints constitute the 'real' grammar of the language and non-native words fulfill the grammar in many different ways, some more, some less.

In the paper, only a few interactions between markedness constraints have been discussed. The constraint against pharyngeals has nothing to do with the constraint against voiced obstruents, for instance. The proposed constraint hierarchy only reflects the different degrees of assimilation of the sounds into the grammar of German. The fact that the hierarchy can provide a ranking for unrelated constraints is a welcome result since it confirms the idea of a total linear ordering of all constraints. Constraints which cannot interact are also ranked, but on a different basis.

Notes

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1. According to Steriade (1997), the final position or the position preceding a consonant correlates with the absence of the relevant phonetic cues, in our case, Voice Onset Timing on a following sonorant. In her acoustic account, only a following vowel provides the context in which laryngeal contrasts can be perceived. Steriade denies that syllable structure plays a role. The fact that a final position generally coincides with a coda and a prevocalic position with an onset is just epiphenomenal.

2. Words like *Redner* 'speaker' or *Adler* 'eagle' have two syllabifications and consequently two pronunciations, depending on the syllabification of the medial obstruent: it may be in the coda of the first syllable [aː.t.lɐ] or in the onset of the second syllable [aː.dlɐ] (see Vennemann 1972). These forms do not bear on the present issue.

3. Jessen (1997) is primarily concerned with the phonetic realization and the featural representation of the German obstruents.

4. An anonymous reviewer asks why the words from Dutch and Yiddish are not unmistakenly foreign. The reason is that they are perceived by many speakers as nearly native because of their trochaicity and their segmental make-up. Another anonymous reviewer denies the existence of a separate group of words altogether and would prefer to analyze them as native. However, the proposal of treating them as nearly native agrees with the intuitions of most phonologists working on German, as well as many non-linguist native speakers.

5. See Hall (1992), who analyzes this distribution as a case of dissimilation.

6. The uninteresting ones are the prohibitions against clicks, pharyngeals, etc.

7. An anonymous reviewer asks if the fact that some people say [tsiti] and others [siti] might be not simply be an indication that these people differ in the underlying form they postulate. At some point in their life, speakers of German will certainly have heard both pronunciations, thus allow for both inputs, and will have to choose the output they prefer. They will do that in agreement with their internalized grammar.

8. Though a low-ranking constraint like NoCoda is active in German and triggers the effect called *Emergence of the Unmarked* in McCarthy and Prince (1995), as attested by the fact that a word like *Judo* is always syllabified as *Ju.do* and never as *Jud.o*, for instance, no such effect can be observed for the constraints (25a and b). Thus [f] or [t] are never avoided which means that they are not subject to the *Emergence of the Unmarked.* I am not aware that the limits of *Emergence of the Unmarked* have been explored, yet.

9. Richness of the Base is to be taken with a grain of salt. For OT to be workable, the faithfulness constraints require that a lot of information be already present in the input(s) of some output form. Only allophonic variants or free alternations and the like allow the proliferation of several input forms.

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The laryngeal effect in Korean

Phonology or phonetics?*

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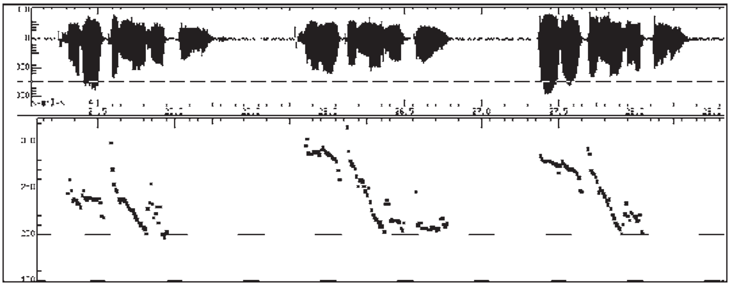
1. Background

It is well-known that voicing distinctions in prevocalic position can affect the fundamental frequency (F_0) of following vowels (Hombert 1977; Kingston & Diehl 1994; among others). Most of the literature on this issue, however, has dealt only with how the segmental effects of the binary voicing distinction between 'voiced' and 'voiceless' are different on the F_0 of the following vowel. The question arises how this effect would be realized in languages like Korean where obstruents with the same place of articulation can contrast in more than binary ways in phonation types.

Korean obstruents are all voiceless and generally grouped into three series, referred to as lenis (/p, t, k, c, s/), aspirate (/p^h, t^h, k^h, c^h/) and fortis (/p', t', k', c', s'/). Since each of the consonants in these groups can cause meaning contrasts, what exactly characterizes the featural specification of these series has been an issue. Generally the lenis is considered the least marked with no laryngeal specification at the underlying level, while the aspirate and the fortis are specified with [+spread glottis] and [+constricted glottis], respectively, under the laryngeal node.[1]

Korean obstruents have been reported to influence the F_0 of a following vowel (Kim 1965; Kagaya 1974; etc.). Specifically, a higher F_0 is found after aspirate and tense consonants but a lower F_0 after lenis consonants. The following picture illustrates these effects.

(1) Laryngeal effects on the F_0 in Korean



pa-lako malhay-pwa **p^{h}a**-lako malhay-pwa **p'a**-lako malhay-pwa
'say *pa*' 'say *p^{h}a*' 'say *p'a*'

In a pioneering study of the prosodic system of Korean, Jun (1993) argues that this segmental effect has been phonologized to a H tone in Korean. Were this correct, however, the situation in Korean would be unusual. While the phonologization of F_0 *depression* is cross-linguistically common, there are very few cases where *boosting* of F_0 under the influence of preceding consonants has been analyzed as a phonologized effect (cf. Bradshaw 1999). We should therefore be wary of accepting Jun's theory, as it posits for Korean a typologically marked sort of phonology. A more direct problem is that Jun's way of interpreting the F_0 boosting has difficulty in adequately explaining the accentual H tone (H*) assignment in the realization of the calling contour in Korean. I will argue, on both phonetic and phonological grounds, that the boosted F_0 as a consequence of the laryngeal effect in Korean should be interpreted as a phonetic effect.

This paper does not intend to provide an articulatory explanation of the segmental effect that causes variable manifestation of the F_0 perturbation in different languages. Rather, it will focus on clarifying the phonetic or phonological status of the F_0 enhancement induced by non-lenis consonants in Korean. In the remainder of this paper, I will first examine Jun's analysis of this phenomenon in detail (Section 2). I will then describe the phenomena and relevant problems in the realization of the calling contour in Seoul and Chonnam dialects of Korean (Section 3). The results of an experiment on vocative chant[2] will be reported (Section 4) with discussion and analysis of the phenomenon. Section 5 concludes.

2. Previous studies and problems

2.1 Phonologization of the laryngeal effect: Jun (1993, 1996, 1997)

In a study of the intonational pattern in Korean, Jun (1993) argues that an Intonational Phrase in Korean consists of smaller units, viz. Accentual Phrases (APs), which are tonally marked. Noting that the F_0 of a vowel preceded by a laryngeal consonant (i.e., aspirate or tense consonant) is substantially high and stable, Jun (1993) states that the segmental effect has been phonologized in Korean. Consequently, she contends that, if an AP begins with an aspirate or tense consonant, the tonal pattern of the phrase begins with a H tone, and otherwise a L tone. Thus, she suggests that the AP in Seoul has a tonal pattern of either LHLH or HHLH and that in Chonnam either LHL or HHL, depending on the laryngeal specification of the AP-initial segment.

In her analysis, the Tone Bearing Unit (TBU) for the Seoul dialect is the syllable, while that of the Chonnam dialect is the mora. This is because Seoul is generally known to have lost, or is undergoing a complete loss of phonologically distinctive vowel length, which Chonnam still maintains. The loss of vowel length in Seoul is a characteristic of the speech of younger generation (Magen & Blumstein 1993).[3]

(2) and (3) illustrate how Jun's pitch accent assignment works:

```
(2)   L    H  L  H                LH    L  L  L
      |    |  |  |                ||    |  |  |
    [y ə ŋ s u c ɨ ŋ i]   vs.   [y ə ə ŋ s u c ɨ ŋ i][4]
     'receipt-NOM'               'receipt-NOM'
        Seoul                       Chonnam
(3)    H  H    L  H                 HH  L     L  L
       |  |    |  |                 ||  |     |  |
    [pʰ a r a ŋ s æ k i]   vs.   [pʰ a a r a ŋ s æ k i]
     'blue color-NOM'             'blue color-NOM'
        Seoul                        Chonnam
```

Jun's proposal is interesting in that segmentally induced F_0 perturbation plays an important role in the intonation pattern of Korean; but it is not entirely clear whether the segmentally triggered phrase-initial H tone is phonetic, due to the undershoot of a L tone, or is phonological, i.e., part of an underlying phrase tone, as Jun argues. In other words, although it is possible to consider the high pitch after laryngeal consonants as part of an underlying tonal pattern, it would be also possible to assume that a phrase-initial F_0 perturbation created by whatever mechanism that is responsible for the F_0 boosting after voiceless consonants stays relatively high and stable in Korean.

In Jun (1996), an experiment is reported which focuses on the effects of consonants on the F_0 of a following vowel cross-linguistically. The goal of the experiment is to determine the status of the AP-initial H tone of Korean as either phonetic or phonological. The assumption is that if the initial H tone is a laryngeal effect that stays high due to the following H tone, we can test this hypothesis by examining how the segmental effect is realized when it is followed by a L tone instead of a H tone. The results of her experiment show that the F_0 pattern after Korean consonants is substantially different from that of English and French. For Korean, F_0 after an *aspirated* or a *tense* consonant is significantly higher (in average 50–80 Hz) than that after a lenis or a sonorant consonant, and these F_0 differences persist until the end of the vowel. In English and French, however, the F_0-boosting effect of consonants is not as significant: in both languages, the rise in F_0 persists for only 20–40 ms after consonant onset.[5]

Jun states that if the phrase-initial raised pitch in Korean resulted from a L tone undershoot due to the following H tone, we would expect a similar pattern of F_0 values both in English and French when the phrase-initial syllable is followed by a H tone. However, her results show that the F_0 values of English and French, even in these cases, differ only at phrase-initial position and the difference does not persist longer than 40–60 ms into the vowel. On the other hand, the phrase-initial high F_0 in Korean triggered by a laryngeal consonant remains high regardless of the following tone type. Based on these results, she argues that the phrase-initial H tone in Korean is not due to phonetic undershoot but is part of the underlying representation of intonation.

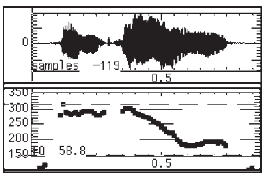
However, Jun's reasoning for determining the phonological or phonetic status of the phrase-initial high F_0 in Korean is questionable. It may be *phonetically* true that the effect of the Korean laryngeal consonants shows a significant difference from that of English and French. However, this in itself does not constitute a strong argument regarding the phonological or the phonetic status of the laryngeal effect in Korean. What her experiment shows is that the laryngeal effect in Korean is remarkably strong compared with the F_0 perturbation phenomena found in other languages, but, strictly speaking, does not clarify the source of the high pitch, i.e., whether it is due to the phonological status of the AP-initial tone or simply due to an unusually strong phonetic effect. If it were the latter case, the unusually strong segmental effect in Korean should be explained from the fact that the production of Korean aspirate and tense consonants involves different phonetic mechanisms[6] from the production of their nearest counterparts in English and French.

A more detailed review and discussion of Jun's argument will be given in the following section.

2.2 Problems with Jun's analysis

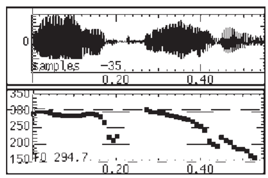
Jun's analysis of the laryngeal effect in Korean as a phonological H tone seems to be valid as far as declarative utterances are concerned. For example, let us look at the following data, which are citation forms of the name 'Hyun-Cheol [hyənčəl]' in Seoul and Chonnam.

(4) a. Seoul



Hyun-Cheol-i
'Hyun-Cheol-citation suffix'

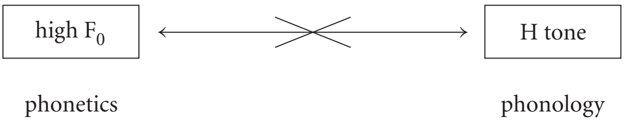
b. Chonnam



Hyun-Cheol-i
'Hyun-Cheol-citation suffix'

In the above pictures, it appears true that each phrase begins with a high pitch in both dialects. However, this in itself does not constitute a sufficient condition for its status as a phonological H tone. It is usually true that phonological H tones are realized with a high pitch, and a high pitch reflects a H tone. But a H tone can be realized with a lower-than-normal pitch (due to downdrift or an undershoot in fast speech, for example), and, likewise, a high pitch might arise in the absence of an underlying H tone. The posited relationship between the tone and pitch can be illustrated as follows:

(5)



In Jun's framework, each AP is realized with one of the two tonal patterns (LHLH or HHLH in Seoul, and LHL or HHL in Chonnam). Note that all and only the instances of the initial H tone in both Seoul and Chonnam occur if and only if the initial consonant is laryngeal. Therefore, there is no independent evidence in the phrasal tonology of Korean that there is an inventory with an initial H tone apart from the cases of the laryngeal-initial AP. To argue for a phonological inventory of tonal patterns such as HHLH for Seoul and HHL for Chonnam, one would want examples of such tonal pattern independent of the segmental effect. If we could find a tonal pattern of an AP with no phrase-initial laryngeal consonant realized similarly to such examples, then we could argue more convincingly for a *phonologization* of the segmental effect.

Another problem with treating the laryngeal effect as a phonological rule arises from the unique property of the phoneme /s/ in Korean. Unlike other obstruents, this fricative does not have a three-way distinction, but only a two-way one between lenis (/s/) and fortis (/s'/). In the following, I will show properties of /s/ which show a 'lenis'-like behavior with regard to a *phonological* rule, but an 'aspirated'-like patterning regarding a *phonetic* phenomenon.[7]

Although /s/ phonetically involves a strong aspiration in production, thus patterns with other aspirate consonants in terms of F_0 boosting, phonologically it is classified as one of the series of lenis consonants. Evidence can be found from the morphophonology of compounding, where /s/ patterns with lenis instead of aspirated consonants. The following data illustrate:

(6) Morphological gemination in compounding

a.	/i + mom/	→	[immom]	'tooth + body'	→	'gum'
b.	/pom + palam/	→	[pomppalam]	'spring + wind'	→	'warm wind'
c.	/mal + sori/	→	[malssori]	'words + sound'	→	'speech'
d.	/p^{h}ul + p^{h}ili/	→	[p^{h}ulp^{h}ili] (*[p^{h}ulp^{h}p^{h}ili])	'grass + whistle'	→	'grass whistle'

In co-compounding, the second constituent of a compound undergoes gemination[8] in Korean if it starts with a sonorant or a lenis consonant. Thus, the sonorant in (6a) and the lenis in (6b) are geminated, but the aspirated consonant in (6d) is not. We see here that /s/ phonologically patterns with the lenis consonant, instead of the aspirated consonant.

On the other hand, there is also a strong tendency for /s/ to pattern with aspirated consonants when the phenomenon is phonetic in nature. Let's take an intervocalic voicing rule in Korean, for example. Korean lenis consonants undergo voicing when in intervocalic position (7a). However, aspirate consonants and /s/, as well as fortis consonants, do not undergo voicing in the same environment (7b–d). The following examples illustrate:

(7)

a.	/aki/	→	[agi]	'baby'
b.	/isa/	→	[isa] *[iza]	'moving'
c.	/kit^{h}a/	→	[kit^{h}a] *[kid^{h}a]	'etc.'
d.	/op'a/	→	[op'a] *[ob'a]	'elder brother'

Silva (1992) has shown that this intervocalic voicing rule in Korean is phonetic in nature. The following example illustrates that the lenis stop voicing is sensitive to the phrasal domain:

(8) φ[ω[**p**ata] ω[**p**ala**p**wasse]] → [**p**ata **b**ala**b**wasse]
sea looked at
'looked at the sea'

He demonstrates that the voicing of lenis consonants in Korean shows a different degree of voicing depending on its position in the phrase. When located within a prosodic word (ω), it undergoes a complete voicing; but when it occurs between two prosodic words, it is only partially voiced. The following table illustrates:

(9) Positional effect on the lenis stop voicing in Korean (Silva 1992: 166)

	φ–Edge	ω–Edge	ω–Internal
Vocing during closure	10 ms	17 ms	33 ms
% of closure that is voiced	23%	36%	77%
Post-release VOT	60 ms	22 ms	3 ms

If the laryngeal effect were truly a phonologized phenomenon, as Jun argues, we would expect /s/ to pattern with the lenis series in terms of laryngeal effect. However, if it were phonetic, it would not be surprising that /s/ once again patterns with aspirate consonants instead of the lenis. In fact, /s/ is one of the most common segments that show such a segmental effect on the F_0 boosting, along with other aspirated consonants. Thus, its patterning with aspirated consonants instead of lenis supports the argument that the segmental effect is phonetic.

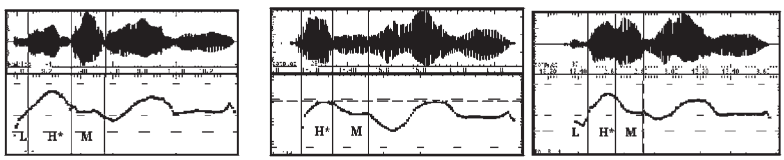
Having examined the previous account of the laryngeal effect in Korean, I contend that a criterion for determining the phonological or phonetic status of a certain phenomenon should be found where the question of categorization is more clearly involved. The assignment of the H* tone in calling contour of Seoul and Chonnam dialects of Korean serves as a good test case for this purpose. A detailed discussion of this will follow in the next section.

3. Calling contour

In the present section, the phenomenon of calling contour is examined to clarify the nature of the laryngeal effect in Korean. It is known that each language has one or more fixed tunes used for calling contours (Liberman 1975). For example, in English and German, the calling contour is made of a H tone followed by a M tone.[9] The H tone must be associated with the nucleus or the most prominent lexically stressed syllable, thus identified as an accentual tone, H* (Ladd 1997).

In English, the canonical tonal pattern for calling contour is known as LH*M, where only the H* and M tones are obligatory. Thus, in names like *Amánda*, where the stress falls on the second syllable, the H* is realized on the second syllable, followed by a M tone on the third. Since there is a place to dock the L tone, namely the initial syllable, all three tones are realized. In names like *Jóhnny*, however, the L tone is not realized since the H* is aligned with the stressed initial syllable, and there is no place for it to dock on. On the other hand, in names like *Suzánne*, although it is also a two-syllable name like *Jóhnny*, all three tones of LH*M are realized. This is achieved by lengthening the stressed second syllable to accommodate both the H* and M tones. The following pictures illustrate:

(10) a. Amanda b. Johnny c. Suzanne



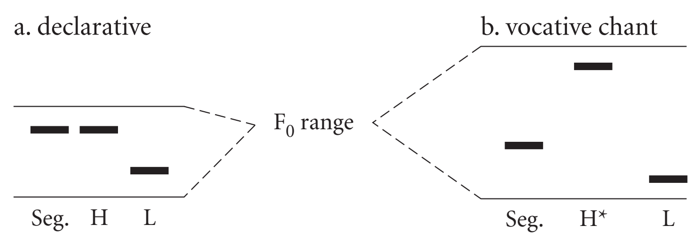
Amanda, where are you? Johnny, where are you? Suzanne, where are you?

No previous phonetic or phonological research has paid attention to the realization of calling contours in Korean. However, vocative chant provides an important test case for the word-level prosodic system of Korean. If the prosodic system of Korean were a lexical stress system similar to English, we would expect the same sort of tonal patterns as English with regard to the alignment of the H* assignment; I will actually argue this for Chonnam in the next section. On the other hand, if the system were better analyzed with phrasal tones as in Jun (1993), we would expect that the H* aligns with a phrasal H tone, since the syllable/mora with a H tone would be the most prominent syllable/mora in the phrase. In other words, if the AP-initial H tone in Seoul or Chonnam were truly phonological as Jun argues, we would expect that the H* tone would align with the AP-initial H tone. If for some reason the AP-initial H tone did not count for the purpose of aligning the accentual H tone, perhaps due to its origin as a segmental effect, we would expect at least the same calling contour pattern among the AP's of the same tonal pattern.

For concreteness, let us take some examples. Names such as *Sang-Won* and *Hyun-Cheol* all start with a laryngeal consonant, and are thus realized with an initial HH tonal pattern in Seoul and Chonnam in Jun's framework. On the other hand, names such as *Young-Seon* and *Eon-Suk* will have an initial LH pattern since they do not begin with a laryngeal consonant. Thus, we would expect the calling contours of the names like *Sang-Won* and *Hyun-Cheol* to show the same tonal pattern, on one hand, and those of the names such as *Young-Seon* and *Eon-Suk* same on the other. As will be discussed in the next section, however, the actual tonal pattern for the calling contour in Chonnam turns out to be the same for *Sang-Won* and *Eon-Suk* on one hand, with the H* on the second syllable, and *Hyun-Cheol* and *Young-Seon*, on the other, with the H* on the initial syllable. In Seoul, all the names, including the examples given here, are realized with the H* on the second syllable, regardless of the existence of the laryngeal onset consonant.

Of interest here is that the accentual H* tone in a calling contour is realized at a substantially higher pitch level than the F_0 range of a H tone in a declarative since vocative chant utilizes a greater degree of pitch range in expressing H and L tones than a declarative. Thus, any perturbed F_0 as a result of segmental effect is expected to be distinguishable from a true H* tone in a calling contour since the latter would be realized with a much higher F_0 than the boosted F_0 due to the segmental effect. The following schematically illustrates this idea:

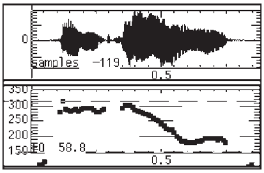
(11)



In the picture above, *seg.* represents the F_0 of an AP-initial syllable with a laryngeal consonant, which Jun has interepreted as a H tone. H and L represent the F_0 of the H and L tone, respectively.

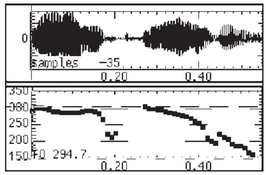
Let us take an example and see if the above prediction is borne out. In the previous section, we have seen that the name *Hyun-Cheol* is realized with a high initial pitch (initial HH tonal pattern according to Jun's theory) in both Seoul and Chonnam. The pitch contour for these names in a citation form is repeated here:

(12) a. Seoul



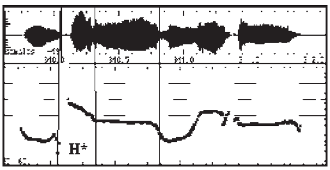
Hyun-Cheol-i
'Hyun-Cheol-citation suffix'

b. Chonnam



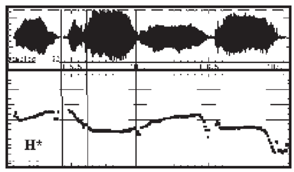
Hyun-Cheol-i
'Hyun-Cheol-citation suffix'

(13) a. Seoul



Hyun-Cheol-a nol-ca
'Hyun-Cheol, let's play!'

b. Chonnam

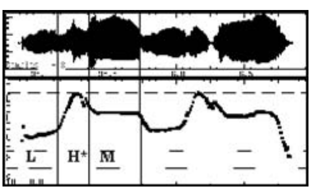


Hyun-Cheol-a nol-ca
'Hyun-Cheol, let's play!'

Contrary to our expectation, we see that the location of H* tone is different in the two dialects although they had a similar pitch contour in declaratives.

One might wonder then whether the phonologization of the laryngeal effect is valid only in Chonnam in calling contour. However, there are numerous counterexamples to such a speculation. That is, names such as *Sang-Won*, although it begins with /s/, does not begin with an initial H* in Chonnam, as in the following example shows:

(14) Pitch track of 'Sang-Won-a (nol-ca)' in Chonnam



In the next section, I will present the results of an experiment which examined acoustic aspects of the calling contours of Korean. It will be shown that the F_0 of the initial syllable is correlated with the existence of a laryngeal consonant, but the F_0 of a non-initial syllable is not. It will be also shown that there is a correlation between the H tone and vowel length in the vocative chant of Korean, but that the high pitch caused by the laryngeal consonant is not correlated with vowel length.

4. Calling contour experiment

4.1 Method

An experiment was conducted on the performance of children's vocative chant in Seoul and Chonnam dialects in order to test the assumptions made in the previous section regarding the alignment of the H* tone in vocative chant. The basic function of the vocative chant used in this experiment is children calling a friend to come out and play.

Two female speakers, one from each dialect, were solicited to read and then sing the vocative chant for 60 different names, each twice in random order. Korean names are mostly composed of two syllables, where each syllable corresponds to a sino-Korean morpheme. The frame phrases used are the following:

(15) Frames used for declarative and vocative
  a. *Name*-(i) ‘name-citation suffix’
  b. *Name*-(y)a[10] nol-ca ‘name-vocative suffix play-commitative’
  =‘*Name*, let's play’

All names used in the experiment were composed of two syllables.

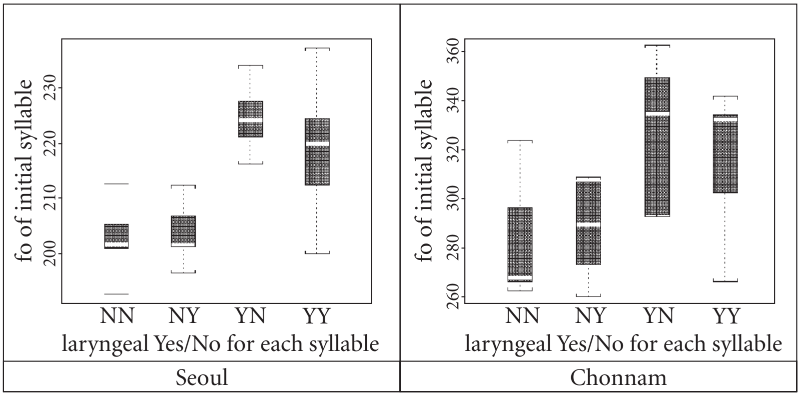
The data were digitized at 16,000 Hz, and acoustic analyses were conducted using a speech analysis program. The F_0 and the length of each syllable of the names were measured in relation to the variables as follows: (a) underlying and surface tonal pattern, (b) existence of a laryngeal onset consonant, and (c) the location of the syllable in the phrase.

4.2 Results and discussions of the calling contour experiment

4.2.1 *Segmental effect*

In names beginning with a laryngeal onset consonant such as *Hyun-Cheol* and *Sang-Won*, it was found that the F_0 of the initial syllable is consistently higher than in a name lacking a word-initial laryngeal onset, confirming the laryngeal effect at the phonetic level at least. For this analysis, only the names with the H* on the second syllable were examined, excluding the ones with the H* on the initial syllable in Chonnam. The following illustrate:

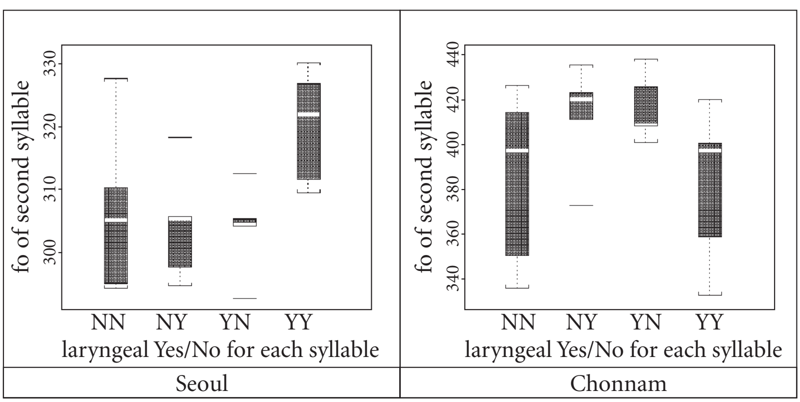
(16) Laryngeal effect in the initial syllable



In the above box plot, the Y axis represents the F_0 value of the initial syllable for each name of four different types. On the X axis, the data are labeled *Y* and *N* for each of the two syllables, where *Y* indicates the existence of the laryngeal onset and *N* the lack of one. Thus, a name such as *Sang-Won* is labeled as *YN* where as *Jin-Hyun* is labeled as *NY*. Then the F_0 of the initial syllable of the name types NN and NY on the one hand, and YN and YY on the other were compared for each dialect. The results show that the syllables with laryngeal onsets show a consistently higher F_0 than the ones with a non-laryngeal onset, and it was significant in both dialects ($T(15) = -4.71$, $p < 0.001$ in Seoul, and $T(6) = 3.86$, $p < 0.05$ in Chonnam).

However, such effect appears to be absent in non-initial position. The following illustrate:

(17) Laryngeal effect in the non-initial syllable in Seoul and Chonnam



Here the Y axis represents the F_0 values of the second syllable in each name. The interpretation of the X axis works the same way as in the graphs in (16). We observe that the F_0 value of the syllables with a laryngeal onset consonant is not necessarily higher than that of the initial syllable when the target syllable is in a non-initial position. The result of the *t*-test shows that the laryngeal effect in the second syllable is not significant in either dialect ($T(18) = -1.30$, $p > 1.0$ in Seoul, and $T(18) = 0.23$, $p > 0.4$ in Chonnam).

The question is why the high F_0 in the beginning of an AP is realized with a L tone in calling contour in some names but not in others in Chonnam. For example, both the names *Sang-Won* and *Hyun-Cheol* begin with a high pitch in declarative because of the AP-initial consonant /s/ and /h/, but *Sang-Won* is realized with an initial L tone in calling contour while *Hyun-Cheol* is realized with a H tone. If the phrase-initial H in the declarative were truly a phonological H tone as Jun argues, the non-homogeneous behavior of names beginning with a laryngeal consonant in Chonnam would be unexplained.

The tonal patterns of various names in calling contour will be discussed in detail in the following section.

4.2.2 *Tonal patterns and the Tone Bearing Unit of calling contour*

An examination of more data indicates that the canonical calling contour pattern of Korean is also a sequence of a H* tone and a M tone, similar to the LH*M of English. In Seoul, the location of the H* tone is always on the second syllable. In Chonnam, however, its location varies between the initial and the second syllable. Therefore, the initial L tone is realized only when the H* is on the second syllable in Chonnam. The M tone is always realized on the vocative suffix '-(y)a' in both dialects. The data examined in (18) and (19) will illustrate the argument made in this paper that the phrase-initial H tone as a result of segmental F_0 perturbation is not a phonological H tone, but is a phonetic effect.

The following illustrates some of the tonal patterns of various names in calling contour:

(18) Tonal patterns of various names in the calling contour in Seoul and Chonnam

	Names	Seoul	Chonnam
a.	Eon-Suk, Myung-Joon, Eun-Ah (initial N)	H* on the second σ (LH*M)[11]	H* on the second σ (LH*M)
b.	Hyun-Cheol, Seon-Suk, Ho-Jun (initial Y)	H* on the second σ (LH*M)	H* on the initial σ (H*M)
c.	Young-Sun, Jae-Hun, Pyung-Chul (initial N)	H* on the second σ (LH*M)	H* on the initial σ (H*M)
d.	Sang-Won, P^hyung-Geun, Hi-Myung (initial Y)	H* on the second σ (LH*M)	H* on the second σ (LH*M)

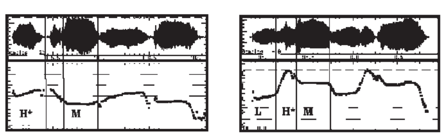
As far as the data in (18a) and (18b) are concerned, the 'phonologized segmental effect' theory seems to be applicable to the Chonnam tonal pattern at least: names in (18a) with no laryngeal onset begin with a L tone, but those in (18b) with a laryngeal AP-initial consonant begin with a H tone. However, the data in (18c) and (18d) provide counterexamples and eliminate the possibility of explaining the tonal pattern of calling contour by segmental effect, for the names in (18c) all begin with a H* tone in the absence of a laryngeal onset, while those in (18d) start with a L tone despite the presence of an AP-initial laryngeal consonant.

Interestingly, it appears to be more reasonable to regard the syllable as the TBU in both dialects. If we follow Jun's analysis and consider the mora as the TBU of the Chonnam dialect, it is a puzzle why *Hyu:n*[12]*-Cheol* (HH.L) and *Sang-Won* (H.H) are realized differently in calling contour as *Hyu:n-Cheol* (H* on the initial σ) and *Sang-Won* (H* on the second σ), respectively, despite the fact that both of them begin with HH in declarative.

(19) Jun's analysis of Chonnam AP tonal pattern vs. their calling contour

a. Declarative (Jun): Hyun-Cheol-a [h y ə ə n č ə l a] — HH L L; Sang-Won-a [s a ŋ w ə n a] — H L L
TBU: μ

b. Calling contour: Hyun-Cheol-a — H* M; Sang-Won-a — L H* M
TBU: σ



In Jun's analysis, the initial syllable of *Hyu:n-Cheol* has two TBU's since the vowel is realized long. However, the realization of the tone in vocative chant does not seem to show evidence that the TBU is mora; rather, the H* and M tone are realized on the whole syllable.

Now the most promising solution to explain the alignment of the H* tone in the calling contour of Chonnam seems to be bringing in the notion of metrical saliency. If we assume that Chonnam is a lexical stress language, and the stress is on the initial syllable in *Hyun-Cheol* but the second in *Sang-Won*, the assignment of the H tone in the calling contour can be explained.[13] For Seoul, I assume that the default location of the stress is the second syllable. The following illustrates the proposed analysis of the assignment of tone in the calling contour of Seoul and Chonnam:

(20) Tonal assignment in the calling contour of Seoul and Chonnam

a. Seoul: H* on the second syllable, M on the vocative suffix

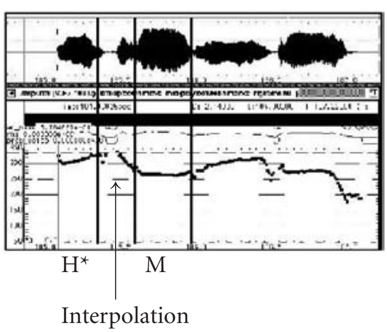
```
Eon-Súk-a   Hyun-Chéol-a   Young-Sún-a   Sang-Wón-a
 |    | |      |     |  |     |    | |     |    | |
 L   H* M      L    H*  M     L   H* M     L   H* M
```

b. Chonnam: H* on the stressed syllable, M on the vocative suffix

```
Eon-Súk-a   Hyún-Cheol-a   Yóung-Sun-a   Sang-Wón-a
 |    | |      |         |    |        |   |    | |
 L   H* M     H*         M   H*        M   L   H* M
```

Notice that in Chonnam, names with an initial stress such as *Hyun-Cheol* and *Young-Sun* are realized with only the obligatory tones, i.e., H* and M, and their second syllable is unspecified for any tonal realization. A default assumption would be that its pitch is realized as an interpolation of the surrounding tones, which is borne out as the following picture illustrates:

(21) a. Hyun-Cheol-a (nol-ca)

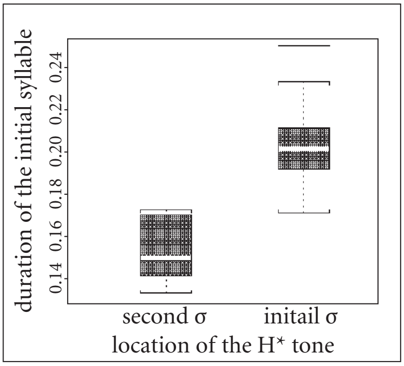


In this section, I have explained the H* alignment of Chonnam based on a lexical stress system like English. In the following section, I will show how the high pitch as a result of the segmental effect differs from a true H* tone in terms of the correlation between pitch and vowel length.

4.2.3 *Correlation between a H* tone and vowel duration in Chonnam*

In Chonnam, there is additional convincing evidence in support of the claim that the high pitch associated with the accentual H tone is different from the high pitch caused by the laryngeal effect:[14] namely, the duration of the syllable associated with the H* tone is greater than that of the L tone, whereas the duration of a syllable associated with a laryngeal onset consonant appears to be arbitrary. In this experiment, a speaker was asked to sing a name 'Kyung-Sook' twenty times: ten times with the H* on the initial syllable, and ten times with the H* on the second syllable. The experiment was done as such so that the inherent difference of the length can be controlled among vowels and consonants of different quality. The result is illustrated in (22).

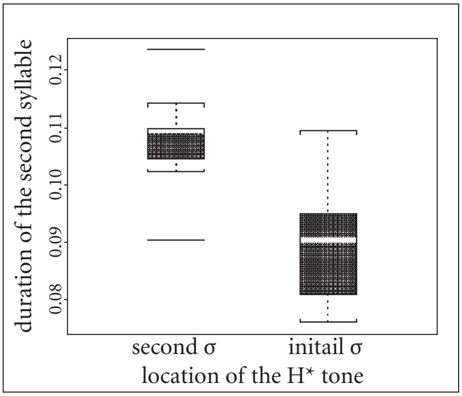
(22) Correlation between the surface H* tone and the duration in the initial syllable in Chonnam



In the above, the Y axis represents the duration of the syllable, and each bar is labeled on the X axis as to the location of the H*. These graphs show that there is a correlation between the tone and the duration of the syllable in Chonnam, i.e., syllables with a H tone have longer duration than those with a L tone. The result appears to be significant ($T(15) = -5.98$, $p < 0.001$).

Also note that the vowel lengthening was obvious in the second syllable as well, as shown in (23).

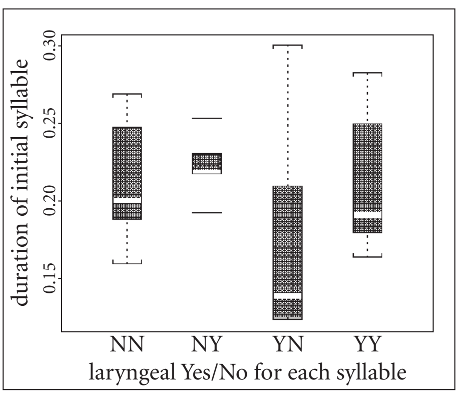
(23) Correlation between a surface H* tone and duration in the non-initial syllable in Chonnam



The duration of the second vowel increased when it is associated with a H* tone, and the result was significant (T(16) = 4.09, $p < 0.001$).

Now, interestingly, the correlation between the laryngeal effect and the duration seems dubious. The following graph illustrates:

(24) Laryngeal effect and the duration of the syllable



The result of a *t*-test shows that the correlation between a tonal type and the duration of a syllable is not significant (T(14) = 0.95, $p > 0.18$).

The results of the experiment examined in this section illustrate the following two points: First, the nature of the high pitch caused by the H* tone is different from the high pitch caused by the laryngeal effect. Second, and more interestingly, the high pitch as a reflect of the H* tone in Chonnam is a manifestation of underlying stress one of whose acoustic manifestations appears to be duration.

5. Conclusion

In this paper, I have discussed the phonological or phonetic status of the segmental effect associated with laryngeal consonants in Korean. Contrary to the arguments made by Jun (1993, 1996, 1997), I have argued that the effect is phonetic, although stronger than in other languages. Evidence was drawn from the assignment of the H* tone in calling contour of Seoul and Chonnam dialects of Korean. I have also argued that the realization of tonal pattern in calling contour has a close relationship with the phonological prosodic prominence system of a language.

This paper examines evidence from Sino-Korean morphemes only, mostly personal names. To give a complete picture of the prosodic system of Korean, more investigation, including that of native Korean vocabulary, is necessary.

Notes

* I thank Mark Liberman, Gene Buckley, and John Kingston for helpful comments. All remaining errors are my own. Readers are referred to Ko (2002) for a more comprehensive analysis of the Korean word level prosody that does not employ AP. The main argument of the present paper is not affected by the somewhat updated analysis.

1. The fortis consonant is phonetically realized as identical as geminated lenis consonants. Therefore, it has been debated whether the Korean fortis is a geminated lenis or a singleton. Since the argument is not directly related to the issues raised in this paper, I will not discuss the nature of the fortis consonants in this paper. However, I have argued elsewhere (Ko 1999a) that the fortis series are geminated lenis consonants.

2. The terms 'vocative chant' and 'calling contour' are used interchangably throughout this paper.

3. I have, however, suggested elsewhere that the long vowel in Chonnam is an expression of accent instead of being a phonemic long vowel, and that, therefore, the TBU in both dialects is the syllable (Ko 1999b; Ko 2002).

4. A long vowel is represented as a geminate vowel sequence.

5. Compare, however, Hombert's (1978) observations:

> Although the greatest difference in the F_0 curves [in Figure 1] exist at vowel onset, statistical analysis (analysis of variance followed by Duncan's test) reveals that they are still significantly different *100 msec* after vowel onset.
>
> (Hombert 1978: 80, emphasis added)

6. The explanations proposed for such segmental effects can be summarized into two categories (Hombert 1978: 81). The first attributes the F_0 perturbations to aerodynamic effects, and the second to differences in vocal cord tension. According to Hombert, researchers following the aerodynamic theory would explain the phenomenon in the following terms: after the closure of a voiced consonant, voicing continues, but since the oral pressure increases (because of the closure), the pressure drop decreases, leading to a lower frequency. In the case of voiceless consonants, since the rate of airflow is supposed to be high, a strong Bernoulli effect will draw the vocal folds together very rapidly; they will be pushed apart very rapidly as well because the subglottal pressure is high. Consequently, the rate of vibration of the vocal folds will be high at the onset of the vowel and will return gradually to the intrinsic value of the vowel being realized. On the other hand, proponents of vocal fold tension theory claim that this perturbatory effect is too long to be attributed to aerodynamic factors. Halle and Stevens (1971) suggest that these intrinsic variations are the result of horizontal vocal cord tension, and they propose the features [stiff] and [slack] vocal cords to capture the relationship between low tone and voiced consonants (where the vocal cords are supposed to be slack in order to facilitate voicing) on the one hand, and high tone and voiceless consonants on the other hand. Since Korean aspirate and tense consonants, both of which show an F_0 boosting effect, do not share a [voice] feature, but are both characterized by a [stiff] vocal fold (Kim 1965), it seems that the second position is more plausible as an explanation of the Korean data. Besides, it is known that the influence of the subglottal pressure to pitch is ignorable compared to the range of pitch discussed in tonogenesis.

7. John Kingston (p. c.) has pointed out to me that one possible exception to this behavior of /s/ is the neutralization of manner in coda position. Although the coda neutralization in Korean is known to be phonological, it applies to /s/ and all laryngeal consonants alike, neutralizing them to /t/. However, whether the laryngeal gesture also neutralizes between /s/ and /t/ would need to be examined before we can conclude the neutralization of /s/ to /t/ to be phonological.

8. Or tensification in the case of obstruents, depending on one's view. See Note 1. Regardless, the point holds that /s/ patterns with other lenis consonants, i.e., it becomes phonetically fortis whether via gemination or tensification.

9. Or a downstepped H tone, depending on the interpretation. It is not crucial for the present discussion.

10. 'y' is inserted to avoid hiatus when the name ends in a vowel.

11. The tonal pattern in parenthesis reflects the M tone that is obligatorily realized on the vocative suffix, although it was not spelled-out in the table for simplicity of representation.

12. Jun argues that vowel length is distinctive in Chonnam, and assigns two moras for a long vowel. Although later I argue the vowel length difference as an attribute of stress, thus not phonological, I marked the initial vowel as long here to show how her analysis would work in such cases.

13. There is independent evidence that Chonnam has a lexical stress system. In Ko (2000), I discuss this in detail with data that show morphologically conditioned accent shift phenomena.

14. In Seoul, this experiment cannot be performed since all names begin with a L tone and there is no comparable data that begin with a H tone.

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Time, tone and other things

The diphthong dynamics distinction in Swabian

How much timing is there in phonology?

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1. Introduction[1]

Phonological theory is usually conceived of as largely abstracting from timing – representing only a two way distinction in quantity (moras) and linear ordering between values for the same features (i.e. within each autosegmental tier) plus, arguably, overlap (the "weak" concept of autosegmental association proposed by Sagey 1986). Nontrivial timing enters the picture only at the interface to phonetics (cf. e.g. Clements, Hertz, and Lauret 1995 for such an approach in speech synthesis), where significant differences are found between languages in the realization of material represented alike in the output of phonology, cf. e.g. Peeters's (1991) work on diphthong dynamics. This abstraction away from timing appears to be seriously challenged by the instrumental phonetic demonstration of a minimal contrast in diphthong dynamics occurring within a single language, Swabian (Geumann & Hiller 1996; Geumann 1997), between[2] [ɑ̆i̯] and [ɑĭ̯]. This contrast is phonemically distinctive and must therefore be specified even in lexical representations (and *a fortiori* in the output of phonology).

The issue at hand will be whether it is desirable – or even only conceivably possible – to represent this contrast without adding to the power of the framework of autosegmental representation. While it will be argued that the contrast between these two diphthongs (as well as one or two parallel contrasts) must be a suprasegmental one, or rather, that what the two diphthongs contrast in is a prominence of some kind among the diphthong "halves", it will be demonstrated that the phonological properties can be accounted for representing them as unitary complex segments. As turns out, this representation must presume an even more powerful component of phonetic interpretation than is commonly assumed – in particular, and perhaps surprisingly, it involves an even somewhat greater degree abstraction from timing, even though, taken at face value, it seemed to call for representation of more, rather than less detail.

Part I
Phenomena to be considered

Data are from Swabian, which belongs to the West Upper German[3] family of German dialects. There will be some bias towards the variety spoken in the city of Stuttgart (which is the author's native language), but results and generalizations hold for most or very probably all of Central Swabian. An exception from this will be made for vowel nasalization, which as a simplification is transcribed like found in rural basic dialect. Incidentally, the Stuttgart variety has lost distinctive nasalization altogether but (also synchronically) retains according changes in vowel quality, which would have made description of the phonology considerably more abstract and more complex.

Swabian does not have the status of a literary language; rather, that role is taken by standard German. More precisely, the literary language for speakers of Swabian is within what is tolerated by the prescriptive standard as far as vocabulary, syntax and morphology are concerned; as for phonetics and phonology, it gets as close as it can[4] without completely restructuring the phonological system and the organization of the lexicon used for the vernacular (s. Ruoff 1983 for such a characterization). This near-standard variety will subsequently be referred to by the sociolinguistic term *acrolect* (sc. of Swabian), in this paper. Speakers generally identify the acrolect with written standard German[5] and, at least in urban areas, it serves as the formal register of the Swabian dialect to the extent that code switching between the two is the rule, rather than the exception; since the vernacular and the acrolect are that closely correlated, certain arguments in this paper will be drawn from the relationship between them. Transcriptions of items, forms or variants restricted to the acrolect have been indicated by a preceding ❖ throughout this paper. The terms "colloquial Swabian" and "(Swabian) vernacular" will be used interchangeably.

The set of contrasting closing diphthongs of Swabian can be classified by direction of movement in vowel space into three classes (Table 1(a)), which in turn consists of pairs, except of the fronting-unrounding class, which is singleton. The property that distinguishes between the two members of each class is

	rounding	frtg.-unrounding	fronting
type 1	ɑ̆u̯	❖ ɔ̆i̯	ɑ̆i̯
type 2	ɑŭ̯	ɔi̯	ɑi̯

(a) closing diphthongs

[+ATR] only	i(ː)	❖ y(ː)	u(ː)
[±ATR] minimally contrastive	e(ː)	❖ ø(ː)	o(ː)
	ɛ(ː)	ə	
[−ATR] only			ɑ(ː) ɒ(ː)

(b) monophthongs

Table 1. Phonemic monophthongs and phonemic diphthongs of Swabian. Phonemes marked with ❖ only occur in the acrolect. /ɒ/ and /ɒː/ do not occur in the acrolect; neither do the diphthongs /ui̯ iə̯ uə̯ ɛə̯/ not shown in the tables.

the main topic of this paper; in order to not preempt any of the conceivable representation alternatives, relative durations (see Section 2) have been indicated by breve signs. For simplicity, the V̆V̯ diphthongs will be referred to as “type 1” or “set 1” here in this paper, while the VV̯̆ diphthongs will be dubbed “type 2” or “set 2”. The single fronting-unrounding diphthong patterns with set 2, as to be discussed below. The actual inventory of this diphthongal subsystem of the phonemic inventory already constitutes evidence for the representation of the individual diphthongs (in particular, the gap at ∗/ɔ̆i̯/); however, it must for that purpose also be viewed in relation to the total inventory: The monophthongal system (Table 1(b); Frey 1975: 63f.; Russ 1990) is of the canonical triangular four height type, plus schwa, although the “triangle” is somewhat distorted. Unlike standard German, Swabian has a genuine quantity distinction in all vowels[6] except schwa, without any accompanying change in quality (Frey 1975: 37). The fourth height can be shown to be represented as a distinctive contrast in tongue root position (feature [±ATR]) between /e(ː)/ and /ɛ(ː)/ (Hiller 1995: 48, 57; 1998: 41), therefore the height system can be expressed by the three licit combinations of the canonical height features [±high] and [±low].

The 5 closing diphthongs and 7 long and 8 short monophthongs do not exhaust the phonemic vowel inventory of Swabian. In addition, there are three centralizing diphthongs /ɛə̯ iə̯ uə̯/, the latter two with nasalized allophones [ẽə̯ õə̯], all of which contrast with the corresponding long and short monophthongs. Eventually, a number of more conservative varieties still preserve a phoneme /ui̯/, which, however, does not quite fit into the system synchronically; in particular, it does *not* act as a type 1 counterpart of /ɔĭ̯/, as to be discussed below. Correspondingly, /ui̯/ has diachronically become more and more marginal, and has been lost altogether by many modern varieties of Swabian.

As for the consonant inventory, there is not much to be said that would have been of interest here. For the transcriptions, it has to be noted that although the consonant system is basically the same as that of standard German, it has been restructured so it contains no voiced obstruents: In stops, the contrast is voiceless aspirated vs. voiceless unaspirated, /pʰ tʰ/ do not occur in native monomorphemes; the standard German voiced fricatives correspond to approximants /ʋ j/, voiceless fricatives /f s/, or sometimes even a stop /p/. There is some regional variation with the rhotic [ɾ]~[r]~[ʁ̞], but where this is relevant, focus is here on the varieties in which it is uvular /ʁ̞/. In these varieties, this phoneme is integrated with the approximant series. As for the other approximants, the palatal glide /j/ possibly alternates with a vowel under some circumstances (under some analyses), but the labiodental glide /ʋ/ never does. Since Swabian does not have a labial-velar glide */w/, the Swabian closing diphthongs cannot conceivably be analyzed as composed from a vowel plus an (otherwise) phonemic glide.

In how far Swabian should count as having lexical stress remains to be worked out – just like in standard German, most native stems only have one stressable vowel. Weight insensitive initial stress is found as a result of loanword adaptation, where stress in those words is different from that in the source language, cf. (1), (2), (3) where the model had the second syllable stressed, in each of these words, supporting the hypothesis that the lexical strata whose items have root initial stress are closer to the native core.

(1) [ˈpi.ʁ̞oː] ‘office’ < Fr. <bureaux>

(2) [ˈʁ̞e.ˌnɑː.te] ‘(f. first name)’

(3) [ˈtʁot.ʋɑːʕ̞] ‘sidewalk’ < Fr. <trottoir>

The rare cases of minimal pairs by stress most clearly involve pairs of different lexical strata (4), (5), again, with noninitial stresses more faithful to the source of the loan, so initial stress in the items of the left column of (4) and (5) must have resulted from nativization.

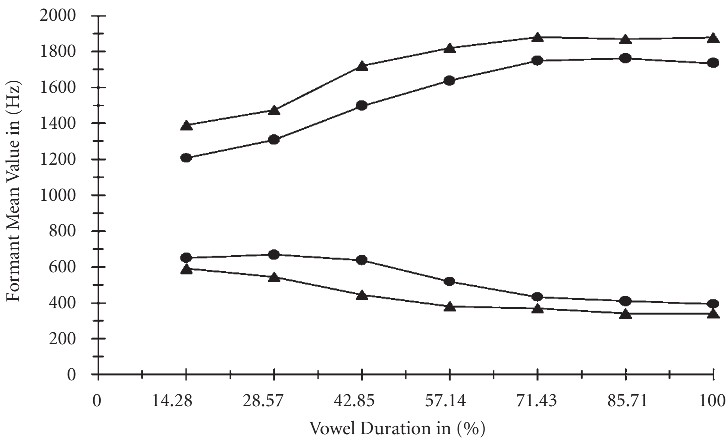
(4) [ˈkʰɑ.feː] ‘coffee’ – [kʰɑ.ˈfeː] ‘café’

(5) [ˈɑŭ̯.kuʃt] ‘(m. first name)’ – [ɑŭ̯.ˈkuʃt] ‘(month of) August’

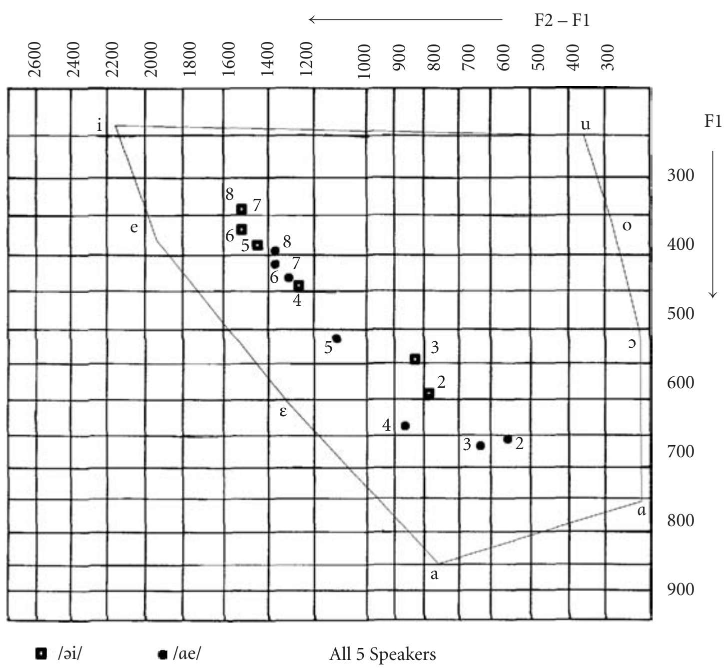
2. Diphthong phonetics

Instrumental acoustic studies of the contrast between [ɑ̆i̯] and [ɑĭ̯] (I am not aware of any before[7] Geumann & Hiller 1996; Geumann 1997) show trajectories in F1/F2 formant space that appear to be closer together for the two contrasting diphthongs than for inter-speaker variation. The only demonstrable consistent contrast was one of diphthong dynamics: The velocity peaks of F1 and of F2 occur noticeably earlier in [ɑ̆i̯] than the corresponding velocity peaks in [ɑĭ̯] (Figure 2;[8] if the plots of formants against time during the diphthongs are conceived of as S-shaped, the velocity peaks can most easily be understood as the point where the two arcs of each "S" meet). For the two subjects evaluated by Geumann (1997: 36), peak velocity of F2 occurred after 94 ms, or 40%, of [ɑĭ̯], on average, and after 69 ms, or 31%, for [ɑ̆i̯]. According values for F1 peak velocity seem to be around 50% for [ɑĭ̯] and 30% for [ɑ̆i̯], as far as can be estimated from Figure 2(a). No other diphthongs have been analyzed in those studies, but pending that, relations between [ɑ̆u̯] and [ɑŭ̯] (as well as between ❖[ɔ̆i̯] and [ɔĭ̯] in the acrolect) can most plausibly be hypothesized to be roughly analogous (at least as far the F1 trajectory is concerned). Taken at face value, this is bad news for theories of phonological representation, which have so far been able to abstract from that kind of timing detail and e.g. represent the diphthongs [aɪ̯] of standard German, Dutch, and English (which are different from each other in a quite comparable way; Peeters 1991) all alike, respectively, in the output of phonology, viz. by starting point and terminal point of the respective diphthong.

Other than directly representing timing, the contrast between type 1 and type 2 diphthongs of Swabian can be conceived of as a contrast in a *prominence* relation of some sort among the same two diphthong components. Determining what particular notion of prominence is relevant for that contrast is part of the goals in Part II of this paper. The other part is arguing *that* the contrast is one of which of the two diphthong components is more prominent, as opposed to contrasts along other conceivable dimensions. "Prominence" is here meant to be understood as a pretheoretic cover term for any appropriate kind of asymmetric relation that characterizes the contrast in dynamics. Interchangeably with "more prominent component" vs. "less prominent component", the terms "head" vs. "dependent" are used. At this point, these terms are not intended to specifically refer to any of the various technical terms of the same names, unless explicitly indicated, i.e. are here used to characterize the search space rather than preempt the solution. For instance, supposing that in type 1 diphthongs, the second part is more prominent, and in type 2 ones,



(a) Plot of formants against time. Circles: [ɑĭ̯], triangles: [ăi̯].



(b) Plot of F1 against F2–F1 difference at equidistant intervals. Circles: [ɑĭ̯], squares with dot: [ăi̯].

Figure 2. Results of study of [ɑĭ̯] vs. [ăi̯] (Geumann 1997), mean across five subjects.

the first part, in order to get the dynamics that have been observed, the kind of prominence involved must be one like stress that tends to lengthen the more prominent part.

2.1 Prolongability

By the same kind of reasoning, which part is more prominent is something that determines which of the parts is prolongable:

- In type 1 diphthongs, very clearly only the final part is prolongable. Speakers are unable to sustain in any controlled manner (and, in that sense: to "determine") the quality of diphthong onset.
- In type 2 diphthongs, speakers readily sustain either of diphthong onset and offset[9] when instructed to do so. Which one is preferred under what condition (spontaneous hesitation in dialogue, singing or stylized recitation etc.) remains open to be determined by future studies.

To illustrate what this is evidence for: if in a foot, the most natural parts to sustain are its head syllable or its final segment, then, here again, stress is a candidate for what is sought here.

3. Pattern to be explained – alternation among diphthongs

The structure of the Swabian system of closing diphthongs as presented in Table 1(a) can be justified by the pattern of relations that hold between them in phonological and morphological alternations (Table 3(a)). A similar pattern is found in the acrolect (Table 3(b)), which will be discussed at some more length in Section 5. A generalization that establishes the division into "set 1" and "set 2" is that set 1 never occurs when nasalized by a nasal following within the same word ∗[ɑ̆͠u̯], ∗[ɑ̆͠i̯] (and, in the acrolect, ∗❖[ɔ̆͠i̯]), while set 2

set 1:	ɑ̆u̯	$\overset{umlaut}{\Longrightarrow}$	ɑ̆i̯	(ɑ̆i̯)
	n.↓		*n.*↓	⇓*ablaut*
set 2:	ɑŭ̯	$\overset{umlaut}{\Longrightarrow}$	ɑĭ̯	ɔĭ̯

(a) Relations between closing diphthongs in Swabian. "*n.*" is for "neutralization before nasals".

set 1:	ɑ̆u̯	$\overset{umlaut}{\Longrightarrow}$	ɔ̆i̯	ɑ̆i̯
	n.↓		*n.*↓	*n.*↓⇓*abl.*
set 2:	ɑŭ̯	$\overset{umlaut}{\Longrightarrow}$	ɔĭ̯	ɑĭ̯

(b) According relations in the acrolect

Table 3. Relations in phonological and morphological alternations.

freely occurs in such positions [ɑ̃ŭ̯ ɔ̃ĭ̯ ɑ̃ĭ̯]. In cases in which *ceteris paribus* a nasalized type 1 diphthong would have been expected, the according type 2 diphthong occurs instead. This can at least be observed for the pair /ɑ̆i̯ ɑĭ̯/

(6) /sɑ̆i̯/ + ∅ – /sɑ̆i̯/ + /n/
[sɑ̆i̯] [sɑ̃ĭ̯]
'be-IMP' 'to be-INF'

(6), (8), (10). For verb stems whose vowel is the diphthong /ɑ̆i̯/, the strong verb paradigm in (7) is rather dominant.[10] (8) simply belongs to the same paradigm.

(7) a. [ˈʃnɑ̆i̯ə] 'to snow' – [ˈkʃniːə] (PAST.PRT)
b. [ˈplɑ̆i̯pə] 'to stay' – [ˈpliːpə] (PAST.PRT)

(8) [ˈʃɑ̃ĭ̯nə] 'to shine (sun)' – [ˈkʃĩːnə] (PAST.PRT)
/ʃɑ̆i̯n/ + μ

As exemplified in (9), vowel length is neutralized by shortening in (a certain subclass of) the lexical class of prepositions, while the underlying contrastive length is preserved in the prepositional pronoun derived from it by prefixing /tʁ̞̩/-. The one in (10) is further subject to an alternation briefly addressed in Section 4.3 that normally yields [ɑ̆i̯] for expected [iː]. However, because of nasalization, [ɑ̃ĭ̯] occurs in place of it in (10).

(9) a. [nɒχ] 'after' – [tʕ̞̩ˈnɒːχ] 'thereafter'
SHRT[11](/nɒːχ/) /tʁ̞̩/ + /nɒːχ/
b. [ˈipʕ̞̩] 'above' – [ˈtʁiːpʕ̞̩] 'above it'
SHRT(/iːpʁ̞̩/) /tʁ̞̩/ + /iːpʁ̞̩/

(10) [ẽn] 'into' – [tʁɑ̃ĭ̯] 'into there'
SHRT(/iːn/) /tʁ̞̩/ + /iːn/ (+ 'i→ɑ̆i̯')

For the acrolect, also the according relation between ❖/ɔ̆i̯ ɔĭ̯/ can possibly be found in the synonyms ❖[ˈʃɔ̆i̯.ʕ̞̩] and ❖[ˈʃɔ̃ĭ̯ne] 'barn', if they are both derived by suffixation from the same stem ❖/ʃɔ̆i̯/- (which does not occur independently). Finally, note that type 1 diphthongs can tautosyllabically precede a nasal[12] tautosyllabically across a word boundary (11).

(11) /pɑ̆i̯#m/ [pɑ̆i̯m] 'near the-M/N.SG.DAT'

Like standard German, Swabian has a nonconcatenative morph that generally takes back vowels to front (leaving front vowels unaffected), which is known as[13] *umlaut*. Umlaut occurs in various parts of morphology, e.g. with (12), (13) (in conjunction with the suffix /ɐ̯/) in agentive noun formation. When applied to closing diphthongs, umlaut leaves /ɔ̆͡i̯ ă͡i̯ ɑ͡ĭ̯/ (as well as ❖/ɔ̆͡i̯/) unaffected and takes /ă͡u̯/ to /ă͡i̯/ (12) and /ɑ͡ŭ̯/ to /ɑ͡ĭ̯/ (13), i.e. to corresponding type 1 vs. type 2 counterparts, respectively.

(12) [ˈsă͡u̯fə] 'to drink' – [ˈsă͡i̯fɐ̯] 'drunkard'
(acrolect: ❖[ˈsɔ̆͡i̯fɐ̯])

(13) [fɐ̯ˈkɑ͡ŭ̯fə] 'to sell' – [fɐ̯ˈkɑ͡ĭ̯fɐ̯] 'salesclerk'
(acrolect: ❖[fɐ̯ˈkɔ͡ĭ̯fɐ̯])

Another nonconcatenative morph of Swabian (as of standard German) that is realized as paradigmatic vowel alternation, however one that cannot necessarily very simply be expressed in terms of feature specification, is called *ablaut*. Generally, it can involve backing of high front vowels, like in the nominalization in (14), or lowering like in the causativization in (16). Corresponding relations involving diphthongs exhibit the pair /ă͡i̯/–/ɔ͡ĭ̯/, (15), (17).

(14) [ˈli͡ə̯kə] 'to tell lies' – [ˈlu͡ə̯kəˌpă͡i̯tl̩] 'liar (lit. 'lying-bag')'

(15) a. [ˈʃɐ̯ă͡i̯ə] 'to shout' – [ʃɐ̯ɔ͡ĭ̯] 'a yell'
[kʃɐ̯ɔ͡ĭ̯] 'clamor, shouting'
b. [ˈlă͡i̯tə] 'to suffer' – [lɔ͡ĭ̯t] 'suffering'
c. [ˈʃtă͡i̯kə] 'to climb' – [ʃtɔ͡ĭ̯k] 'steep road'

(16) [ˈliːkə] 'to lie (down)' – [ˈleːkə] 'to lay'

(17) [ˈʃlă͡i̯fə] 'to grind, to polish' – [ˈʃlɔ͡ĭ̯fə] 'to drag on the ground'

Observe in particular, how in this relation /ă͡i̯/ substitues for the "missing" counterpart of /ɔ͡ĭ̯/ (In the acrolect, ablaut pairs /ă͡i̯/ with /ɑ͡ĭ̯/, the equivalent of the right hand column of (15) reading ❖[ʃɐ̯ɑ͡ĭ̯], ❖[keˈʃɐ̯ɑ͡ĭ̯], ❖[lɑ͡ĭ̯t], ❖[ˈʃtɑ͡ĭ̯ke], and that of (17) ❖[ˈʃlɑ͡ĭ̯fn̩]∼❖[ˈʃlɑ͡ĭ̯fə] – corresponding to absence of an alternation at all in prescriptive standard German.) Incidentally, the marginal phoneme /u͡i̯/ cannot be found in any of these relationships to any of the closing diphthongs in any of the modern varieties that still retain that phoneme at all. Yet some more evidence for the organization of the Swabian system of closing diphthongs will be drawn from the relationship with the system of the acrolect in Section 5.

4. Properties directly established

4.1 Suprasegmentals

Given the suggestively structured 5 way contrast addressed in the previous section, it almost comes as a surprise that the closing diphthongs behave all the same with respect to evidence of suprasegmentals. One suprasegmental of interest is moraicity, since Swabian has contrastive vowel length (see Section 1). However, it turns out all five of the closing diphthongs are bimoraic.[14] Though Swabian does not conceivably have any weight sensitive stress assignment of relevance, it does have a weight sensitive allomorphy (unpublished research by R. van de Vijver and M. Hiller): When attached to stems ending in a short vowel or in a centralizing diphthong (schwa doesn't license a mora of its own), the plural finite verb ending as well as the second part of the "partitive infinitive" circumfix are -[nt] (18), otherwise (i.e. with bimoraic-plus stems[15]) they are -[ət] (19). After stems ending in any of the closing diphthongs, these morphemes are -[ət] (20), showing that all of these diphthongs[16] are bimoraic.

(18)	a.	/hɑ/- : [t͡shẽnt]	'(nothing/much/…) to have'
	b.	/tuə̯/- : [t͡stõə̯̃nt]	'(nothing/much/…) to do'
(19)	a.	/mɛː/- : [ˈt͡smɛː.ət]	'(nothing/much/…) to mow'
	b.	/ʋɛʁ̞/- : [ˈt͡sʋɛʁ̞ət]	'(nothing/much/…) to become'
	c.	/fɑːʁ̞/- : [ˈt͡sfɑː.ʁ̞ət]	'(nothing/much/…) to drive, to ride'
(20)	a.	/pɑ̆u̯/- : [ˈt͡spɑ̆u̯.ət]	'(nothing/much/…) to build'
	b.	/hɑŭ̯/- : [ˈt͡shɑŭ̯.ət]	'(nothing/much/…) to beat'
	c.	/ʃnɑ̆i̯/- : [ˈt͡ʃnɑ̆i̯.ət]	'(nothing/much/…) to snow'
	d.	/ʃtʁ̞ɑĭ̯/- : [ˈt͡ʃtʁɑĭ̯.ət]	'(nothing/much/…) to sprinkle, to strew'

Vijver and Hiller draw the generalization that the -[ət] allomorph is taken by those stems whose last consonant can be ambisyllabic[17] (19b) or which for any other reason form a heavy syllable by normal syllabification before -[ət] (19a), (20). In rough paraphrase, they argue as follows: Input for -[ət]∼-[nt] is either of[18] /ət/ or /nt/. Constraints are ranked such as to make sure this kind of suffix has a mora, if possible without epenthesis.[19] With an input /hɑ+ət/, ∗[ˈhɑ.ət] is ruled out for its monomoraic full-voweled syllable. With a (potentially) bimoraic stem as in (19b) /ʋɛʁ̞+nt/, the suffix is forced into a syllable of its own to avoid a trimoraic syllable ∗[ʋɛ$^{\mu}$ʕ̞$^{\mu}$n$^{\mu}$t] while still having a mora itself [ˈʋɛʁ̞̣ət] (the underdot marks the syllable boundary that the [ʁ̞] straddles). That a diphthong does not break apart, as with (20a) /pɑ̆$^{\mu}$u̯$^{\mu}$+nt/, follows from its inability to contribute an onset, which includes the inability to contribute an ambisyllabic consonant, ∗[ˈpɑ$^{\mu}$w̞$^{\mu}$ət] and that a hiatus in the middle of the stem ∗[ˈpɑ.õnt] would be ruled out for its monomoraic full-vowelled first syllable, both of those ruled out in favor of hiatus *after* the diphthong [ˈpɑ̆u̯.ət]. Van de Vijver and Hiller must crucially presume diphthongs are bimoraic at most in Swabian: Unless specifically stipulated otherwise, a hypothetical trimoraic diphthong as in (∗)[ʃtʁɑ$^{\mu\mu}$i$^{\mu}$+nt] would be expected to break apart to ∗[ˈʃtʁɑː$^{\mu\mu}$.ẽ$^{\mu}$n$^{\mu}$t], better satisfying the constraint against trimoraic syllables and having additional violations only for constraints that we know from (19a), (19c), (20a) the one against trimoraic syllables has priority over. In sum, the -[ət]~-[nt] allophony not only provides an argument that all the closing diphthongs of Swabian are at least bimoraic but *also that they are no more than bimoraic.*

One of the hypotheses mentioned above was that the differences between corresponding type 1 and type 2 diphthongs was that they had the same pairs of components but the first component was more prominent (in a sense to be worked out below) in type 2 and the second more prominent in type 1 diphthongs. Now, the paradigm case for this kind of opposition in diphthongs is that between rising (𝕍̯𝕍, semivowel-to-vowel) and falling (𝕍𝕍̯, vowel-to-semivowel) diphthongs, cf. Catford (1977: 215ff.). A relevant test is syllabification of a following approximant. The only phoneme of the Swabian approximant series that can be syllabified in a syllable coda, or even in a nucleus for that matter, is[20] /ʁ̞/, which in these positions turns up as a backed allophone, viz. an epiglottal approximant [ʕ̞]. Due to the Sonority Sequencing Principle,[21] [ʕ̞] can appear in syllable coda after the second mora of a long vowel but never after any consonant, because a consonant can at most be as sonorous as a glide (e.g. [ʕ̞]). Therefore, (21a) is monosyllabic, whereas the fact that (21b) and (21c) have two syllables each shows that both type 1 and type 2 diphthongs alike pattern as 𝕍ℂ (not 𝕍𝕍, for that matter).

(21) a. /fʁ̞iːʁ̞/ + /ʃ/
[fʁ̞iːʕ̞ʃ]
'be cold-2sg.ind.pres'

b. /fɑ̆i̯ʁ̞/ + /ʃ/
[ˈfɑ̆i̯.ʕ̞̩ʃ]
'celebrate-2sg.ind.pres'

c. /pɑĭ̯ʁ̞/ – cf. /pɑĭ̯ʁ̞/ + /əʃ/
[ˈpɑĭ̯.ʕ̞̩] [ˈpɑĭ̯.ʁ̞iʃ], ∗[ˈpɑĭ̯.ʕ̞̩.iʃ]
'(a) Bavarian' 'Bavarian-adj'

So, for one thing, there is no contrast in syllabification between type 1 and type 2 diphthongs; and in particular, both of them, including set 1, pattern as falling diphthongs, none of them as rising diphthongs.

It should be noted that some (older) varieties that have diachronically developed some /ɑʊ̯̆ ɑɪ̯̆/ from former /oː eː/ in certain positions *can* have these two diphthongs before coda /ʁ̞/ (22).

(22) a. [hɑɪ̯̆ɐ̯ʃ(t)] 'hear-2SG.IND.PRES' – cf. Stuttg. variety: [heːɐ̯ʃ]
b. [ɑʊ̯̆ɐ̯] 'ear' – cf. Stuttg. variety: [oːɐ̯]

But for most modern varieties, the generalization explained in the previous paragraph holds (Hall 1992: 143ff. makes a similar observation about the prescriptive standard variety of German). It holds all the more for the acrolect, where the sonority contrast between the second mora of a long vowel and that of any of the closing diphthongs can not only be reflected in syllable count but (in other positions) also in different allophones of the following /ʁ̞/, reflecting its position within the syllable (23).

(23) a. ❖[ˈfʁ̞iː.ʁ̞n̩] 'to be cold'
b. ❖[ˈfɑ̆ɪ̯.ɐ̯n̩] 'to celebrate'

Notably, preposition shortening is another piece of evidence that shows even type 1 diphthongs (25) behave like short vowel–consonant sequences (24), not like long vowels (9), in that they are not changed by the vowel shortening forming prepositions (s. (9), (10) in Section 3).

(24) [uf] 'onto' – cf. [tʁuf] 'onto it'
SHRT(/uf/) /tʁ̞/ + /uf/

(25) [pɑ̆ɪ̯] 'near, with' – cf. [tɐ̯̩.ˈpɑ̆ɪ̯] 'near it, with it'
SHRT(/pɑ̆ɪ̯/) /tʁ̞/ + /pɑ̆ɪ̯/

This cannot be due to mora count, because as shown at the beginning of this section, all the closing diphthongs are bimoraic, just like long vowels (and tautosyllabic 𝕍ℂ sequences). In sum, all the closing diphthongs of Swabian behave alike in being bimoraic and in counting as vowel–consonant sequences for purposes of syllable structure assignment. This exhausts the supragsegmentals that one might want to adduce in order to account for the distinction between set 1 and set 2.

A point worth noting about the varieties that do have [ɑʊ̯̆ ɑɪ̯̆] before [ɐ̯] in the same syllable is that these diphthongs do not change in that environment – like long vowels and unlike short vowels. For the long vowels, Hiller (1995: 52f., referring to literature on geminate inalterability) attributes inalterability to the association of their segmental melody to two skeletal positions. How to extend this to the diphthongs mentioned will also be a minor point to consider in Section 9.

4.2 Segmental properties

To directly establish at least some of the segmental properties of the individual closing diphthongs, it is mainly three pieces of evidence that seem to be helpful:

– Vowel quality changes under nasalization
– Distribution of the allophones [ç]~[χ] (~[x]) according to the preceding segment
– Alternations with monophthongs (Section 4.3 below)

Though conditions for the vowel quality changes under nasalization turn out to be rather diverse (Table 4), there is a notable generalization to be made about the outcome: If there is any change, the vowel becomes non-high or it becomes [+ATR], or both. Note that the change of [–ATR] to [+ATR] even creates a redundant allophone [ɐ̃], which by itself is a quite marked segment, being a [+ATR] low vowel (cf. Archangeli & Pulleyblank 1994). Type 1 diphthongs turn into type 2 diphthongs under nasalization, which most conceivably means set 1 is treated like high vowels and set 2 like nonhigh vowels.

Distribution of the allophones [ç]~[χ] of the dorsal fricative is determined by the immediately preceding segment: [ç] after front vowels, [χ] (or [x], marginally) otherwise. Note that with centralizing diphthongs, it appears to be the schwa part that is relevant (26b).

(26) a. [pɑχ] 'stream, river-SG' – [pɛç] (PL)
b. [ˈkʰiçəˌtiə̯χle] 'dishcloth-DIM.SG'
c. [hoːχ] 'high, tall' – [ˈheːçʕ̞̩] 'higher, taller'

(27) a. [ˈmɐ̃n(t̠)çe] 'some, a few'
b. [mil(t̠)ç] 'milk'
c. [kʰɨʕ̞χ] 'church'
d. [tʊʕ̞χ] 'through'

(28) a. [ʁ̞ɑŭ̯χ] 'smoke' – [ˈʁ̞ɑĭ̯çʁ̞ə] 'to smoke-TR'
b. [pɑ̆u̯χ] 'belly-SG' – [pɑ̆i̯ç] (PL)
c. [sɔĭ̯ç] 'piss'

	Conditions: Blocked if nasalization was across…	①	②	③	④	**Remarks**
/ĩ/→[ẽ]	word boundary? syllable boundary?	✔	✔			
/ũ/→[õ]	word boundary? syllable boundary?	✔	(?)			
/ɛ̃(ː)/→[ẽ(ː)]	morpheme boundary				✔	
/ɑ̃/→[ɐ̃]	syllable boundary (?) (nasal must be present!)	✔		✔	✔	
/ɑ̃(ː)/→[ɑ̃ː]	morpheme boundary (nasal must be deleted)		(✔)		n.a.	("[ɑ̃ː]" is [ɒ̃ː] in a number of varieties)
∗[ɒ̃]	—	✔			n.a.	(except: see previous)
/ĩə̯/→[ẽə̯]	word boundary? syllable boundary?	n.a.	✔?	✔	n.a.	
/ũə̯/→[õə̯]	word boundary? syllable boundary?	n.a.		✔	n.a.	
∗[ɑ̆̃u̯]	??	n.a.			✔	
/ɑ̃i̯/→[ɑĭ̯̃]	word boundary (?)	n.a.			✔	
❖/ɔ̃i̯/→[ɔĭ̯]	word boundary (?)	n.a.			✔	Only applicable in the acrolect
∗[ũi̯]	??	n.a.			n.a.	

Table 4. Neutralization and other allophonic changes of basic vowel quality in regressively nasalized vowels in Swabian (① = quantity sensitive? ② = (lexical) exceptions? ③ = creates redundant allophone? ④ = also in acrolect?).

Unlike with standard German (Hall 1992), the dorsal fricative phoneme never occurs word initially; also, the allophone is not [ç] after /ʁ̞/, except for the Stuttgart variety, for which the words in (27c), (27d) are [kʰɵʕ̞ç], [tʊʕ̞ç], respectively, instead (however (28) is unchanged). Acrolect generally agrees on this with the colloquial dialect of the same speakers. In any case, for distribution of [ç]∼[χ], it is the second component of the diphthong that is relevant (28), indiscriminately alike for type 1 (28b) and type 2 diphthongs (28a), (28c).

4.3 Alternations with monophthongs

Evidence for inventory constraints can be expected from cases in which any of the closing diphthongs appear in place of vowel sequences that would otherwise have been expected. From other alternations between diphthongs and monophthongs, direct evidence for their segmental specification may be glanced. A relevant inventory restriction is the nonoccurrence of ∗[ei̯], ∗[ɛi̯],

-∅	[tʁɑːk]	(1SG)	-∅	[lik]	(1SG)
-$^{[–bk]}$/ʃ/	[tʁɑ̆i̯ʃ]	(2SG)	-/ʃ/	[lɑ̆i̯ʃ]	(2SG)
-$^{[–bk]}$/t/	[tʁɑ̆i̯t]	(3SG)	-/t/	[lɑ̆i̯t]	(3SG)
-/ət/	[ˈtʁɑːkət]	(1–3PL)	-/ət/	[ˈliːkət]	(1–3PL)
(a) /tʁ̥ɑ(ː)k/– 'carry, tote'			(b) /li(ː)k/– 'lie (down)'		

Table 5. Example of strong verb paradigms that (exceptionally) involve vocalization of /k/ (and /p/) to [i] in clusters and thereby supply evidence for alternations of closing diphthongs with other segments. Raised "[–bk]" is for a nonconcatenative (part of a) morph that normally takes [ɑ(ː)] to [e(ː)], in these paradigms.[22]

which even holds in the acrolect (except possibly for some unassimilated loans from English for certain speakers). In a number of varieties, this can even be observed in a synchronic alternation, showing [ɑ̆i̯] for expected ∗[ei̯] or ∗[ɛi̯]. This is found in the paradigms of a certain closed class of strong verbs that vocalize coda stops in clusters (Table 5(a)).

This same class of verb paradigms also shows cases of synchronic "replacement" with [ɑ̆i̯] for underlying or expected [iː] (Table 5(b)), an alternation that has also been argued to be involved in (10) in Section 4.1, and similarly, with /si(ː)/-, one of the suppletive stems of the verb 'be' (29).

(29) -/nt/ [sẽnt] (1–3PL), -/n/ [sɑ̃̆ĩ̯] (INF), -∅ [sɑ̆i̯] (IPV)

It must be cautioned that synchronic cases of [ɑ̆i̯] for expected [iː] are limited to these few examples,[23] so it is hard to draw any generalizations from this alternation; note at least, all of these cases also involve equally exceptional alternation or instability in vowel quantity, creating the impression this was to increase the "distance" from short [i] (perhaps paralleling the diachronic push chain [i] → [iː] → /ɑ̆i̯/ – cf. Russ (1990) for references on the latter).

Incidentally, these few cases of [ɑ̆i̯] for expected ∗[ei̯] or ∗[ɛi̯] and of [ɑ̆i̯] (or, when nasalized, [ɑ̃̆ĩ̯]) for expected [iː] exhaust the synchronic alternations in Swabian of any of the closing diphthongs with anything else than other closing diphthongs.

5. Evidence from the acrolect

At the beginning of Part I (p. 2; and, in passing, also subsequently), the acrolect has been addressed, i.e. the standard language as produced with a certain set of non-standard characteristics by speakers of Swabian. It differs from colloquial Swabian, importantly by certain aspects of its vowel inventory, but at the same time is very closely correlated with it; thereby it sheds further light on the systematic relationships among the closing diphthongs (and between closing diphthongs and other segments) in the dialect. In the vowel inventory of the acrolect, the ban on front rounded vowels has been relaxed (cf. again Table 1(b)); at the same time, a type 1 fronting-unrounding diphthong ❖[ɔ̆i̯] appears. In the lexicon, fronting-unrounding closing diphthongs and merely fronting closing diphthongs switch their roles in the majority of cases, as to better approximate the prescriptive and the written standard. For that reason, umlaut in the acrolect is between rounding and fronting-unrounding diphthongs, ablaut is within the fronting series (cf. Table 3(b)).

If the acrolect is conceived of as an approximation to the standard language while retaining most of the phonological system of the vernacular, its relation to the vernacular shows two things:

- Since distribution of the three classes of rounding vs. fronting-unrounding vs. fronting closing diphthongs is changed while distribution of set 1 vs. set 2 is retained, from the vernacular – thereby even creating a novel additional phoneme neither found in the vernacular nor in the prescriptive standard – it supports the idea that these two kinds of distinctions constitute two independent dimensions of diphthong quality.
- With appearance of ❖[ɔ̆i̯] at the same time as that of front rounded vowels, they must be banned from the vernacular by the same constraint, relaxed in the acrolect (in the relevant sense, ❖[ɔ̆i̯] "is" a front rounded vowel).
- In addition to these two observations, the disappearance of all other diphthongs in the acrolect (viz. the centralizing diphthongs as well as /ui̯/) shows that the constraint ruling them out from the acrolect does not apply to the closing diphthongs – which are apparently closer to the monophthongs, in that respect.

Part II
Representations to be considered

These are the empirical observations that a phonological representation to be assumed should help explain. At the very least, representation of the phonemes involved must not impose unfulfillable demands on an account for these observations. Basically all of below proposals for representations pay attention to the appropriate grouping established in Section 3 of the closing diphthongs –

viz. rendering the type-1–type-2 distinction orthogonal to the other contrasts between any two of these diphthongs. Similarly, bimoraicity of all those diphthongs is handled more or less equally well.

6. The phonetically obvious

In so far as phonology deals with the phonetically observable pattern (or rather, the grammar that generates an idealized version of this pattern), the first consideration should be given to potential representations that directly capture the phonetically observed timing. In the case of the closing diphthongs of Swabian, doing so would have to amount to representing the diphthong dynamics. This, in turn, might in principle be accomplished as shown in Figure 6: The first mora of /ɑ̆i̯/ dominates two specifications for segmental melody, which has been proposed as a representation for "short", i.e. monomoraic, diphthongs. Unlike in those, however, the second melodic specification in /ɑ̆i̯/ is also associated to a second mora. On contrast, /ɑĭ̯/ is give the canonical representation for a (bimoraic) diphthong, which is to capture that even in this diphthong, none of the formant velocity peaks (of F1 and of F2) occurs after the middle of the diphthong (see Section 2. Alternatively, /ɑĭ̯/ could be given a representation symmetrical to that of /ɑ̆i̯/, i.e. with the first melodic specification doubly linked).

Not only would this representation be crosslinguistically unique, giving up the restriction of arbitrary melodic contours to short diphthongs would also predict a host of other possibilities never attested in any language – e.g. a *three* way contrast in diphthong dynamics between a representation like discussed above for /ɑ̆i̯/ and *each* of the two discussed above as possibilities for /ɑĭ̯/. And second, this choice of representation doesn't allow for more than stipulating any of the properties reviewed in Part I but number of moras and prolongability facts. The only remarkable exception is that they make plausible

(a) representation for /ɑ̆i̯/ (b) representation for /ɑĭ̯/

Figure 6. One way of directly representing the phonetical observations.

why, with [ɑ̆i̯] turning up for expected [iː] and [ɑĭ̯] for expected ∗[ei̯], these two members of each of those pairs count as especially closely related.

7. Type 1 vs. type 2 as height contrast

Even though pairs of corresponding type 1 and type 2 diphthongs may not be distinct by the vowel qualities of their starting points and end points, phonetically, the corresponding diphthongs of set 2 are more open during most of their duration, as the transition from the lower to the higher vowel quality only occurs at a later point in the duration of the diphthong. That is, representation of the contrast as one in height should also be considered. In terms of canonical height features, at least /ɑ̆u̯ ɑŭ̯ ɑ̆i̯ ɑĭ̯/ move from a [+low, –high] quality to a [–low, +high] quality. The height specification of either component of any of these diphthongs may be subject to debate, but neither of these features can conceivably represent the minimal contrast between set 1 and set 2 if applied to the whole diphthong.

However, the feature [±ATR] has been argued to act as a "height diacritic" feature that encodes height distinctions smaller than captured by the features [±low, ±high]; and Swabian has been argued to use [±ATR] that way in monophthongs (see the remarks on /e eː ɛ ɛː/ in Section 1). Since type 2 diphthongs, if any, are the ones that qualify for being the "more open" species, they should, by that reasoning, be [–ATR] and the type 1 ones, [+ATR].[24] However this would run counter head on to the generalization established in Section 3 for the monophthongs of Swabian that whenever an [±ATR] related effect is observed under nasalization, it is avoidance of [–ATR] in favor of [+ATR]. Since under precisely that condition, type 1 diphthongs are avoided in favor of type 2 ones, the representation just proposed for the set 1 vs. set 2 contrast is not conceivably tenable.

Another possibility for representing the distinction in terms of height consists in representing the contrast only in the second component. By that reasoning, [ɑĭ̯] is represented as /ɑe/, [ɑ̆i̯] as /ɑi/, [ɑŭ̯] as /ɑo/ etc.[25] This excellently captures the effects observed under nasalization, where high monophthongs and type 1 diphthongs are dispreferred or banned. Under this view, the structure of the diphthong system established by the pattern of morphophonological relations (Section 3) and by the changes observed in the acrolect (Section 5) comes about by independence of the two dimensions of height of the second component and of backness/rounding melody of the whole diphthong on the other hand. This representation does not allow accounting for

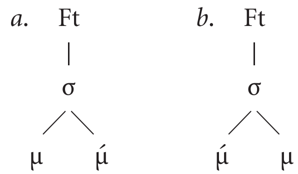
– the contrast in diphthong dynamics (A link of this kind suggested by A. Geumann, p.c., between openness and dynamics is intrinsic duration, a factor known to increase with openness. But this would predict that the second component should occupy a larger, rather than a smaller, fraction of the whole duration in type 2 than in type 1 diphthongs, which is exactly the converse of what has actually been observed.[26])
– the inventory of closing diphthongs, in particular for the absence of ❖/ɔ̆i̯/, which is added in the acrolect, along with front rounded vowels.

A minor disadvantage is that under this approach, the contrast between set 1 and set 2 no longer is a property of the diphthong as a whole. More relevantly, this representation makes a patently wrong prediction about the syllabification of the closing diphthongs of Swabian, namely that they should be vowel–vowel sequences, whereas in fact they behave as vowel–consonant sequences (Section 4.1). But representing the second halves as semivowels, those the second halves together would add up to an inventory /i̯/ vs. /e̯/ vs. /u̯/ vs. /o̯/. Out of this most unusual inventory, only /i̯/ = [j] independently occurs in Swabian, other than in those diphthongs.

A variant that avoids this complication is representing the contrast by [±low] in the first component and representing the second half as [+high] invariably. Together with the problem just addressed, however, such a representation[27] disposes of the capability of accounting for the alternations under nasalization.

8. Representation as a suprasegmental contrast

The observed independence of the type 1 vs. type 2 distinction would most easily be made sense of if the contrast could be established to be suprasegmental in nature. Unfortunately, it can be shown (as in Section 4.1) that there is no contrast in length (moraicity), nor is there one in syllabification, between any two of the closing diphthongs of Swabian. A contrast of vowel vs. semivowel as the second component is out of the picture as well, as all of the closing diphthongs pattern as vowel–consonant sequences. To conclude this, there is no conceivable evidence of lexical tone in Swabian, either. In Sections 2 and 2.1, it was pointed out that the dynamic as well as the prolongability facts show a pattern typical for a contrast in prominence, i.e. like the first component is more prominent than the second one in type 2 diphthongs and the second one more prominent in type 1 diphthongs. The kind of contrast best known to produce such a pattern (more prominent part has a longer duration, more prominent is prolongable) is metrical stress. Under that analysis, the first part of type 2 diphthongs is stressed,[28] resulting in a metrical structure like (30b), and the second part in type 1 diphthongs (30a). This would, then, be a contrast between a left headed moraic foot (moraic trochee) and a right headed moraic foot (moraic iamb) (Kager 1991: 293).

(30)


Such a representation in an ideal way reflects the organization of the diphthong inventory as discussed in Section 3; the alternation under nasalization could now be described as avoiding nasalized high vowels coextensive with a *stressed mora*. Problematic for this representation are the "missing" counterpart of [ɔ̆i̯] and the syllabification facts. In the first place, however, this representation is implausible because Swabian does not (otherwise) have contrastive stress. Stress assignment may be different for different lexical strata, but there is plenty of contrast between type 1 and type 2 diphthongs within each lexical stratum. Besides, (30) requires moraic feet that have been proposed to account for quantity sensitive stress assignment, whereas analysis of quantity insensitive stress assignment, like found with primary as well as secondary stress in Swabian[29] must crucially rely on feet that are binary in terms of syllables rather than moras.

9. Unitary complex segments

One notion of relative prominence among the diphthong halves that might successfully represent the contrast between diphthongs of set 1 and of set 2, has so far been left unexplored: Which is, the head component could be vocalic, the dependent half consonantal, in each of these diphthongs. E.g. the prolongability facts, then, follow because vowels are prolongable but semivowels are inherently momentary (Catford 1977: 131, 134). To be sure, this immediately raises the issue that in a type 1 diphthong, say [ɑ̆i̯], the consonantal /ɑ/ component phonetically precedes the vocalic /i/ component; so syllabification as 𝕍ℂ constitutes an *antiedge effect:* The relevant property (non-vocalicity) of the first component appears to be accessed – hence must be accessible – from the second mora, and the according property (vocalicity) of the second component from the first mora. For this to be possible, the specifications of both components must be dominated by a single node that in turn is dominated by both moras. In effect, the diphthongs of set 1, and for reasons of symmetry (to be established below) all the closing diphthongs of Swabian, must be unitary complex segments. Dealing with antiedge effects in phonetic contours by representing them as complex unit is by no means novel (cf. Lombardi 1990 as well as van de Weijer 1996: Chapters 7 and 8). The closing diphthongs of Swabian can be represented that way in the feature geometry proposed by Clements and Hume (1995: 277f., 292–297 for a summary) in which places of articulation of consonants and of vowels involve representations by autosegments on the same four tiers [labial], [coronal], [dorsal] and [radical] (Clements 1993: 105). If directly associated to [Place], these denote the active major articulator in consonants; if associated through [V – Place], they roughly correspond to the feature specifications conventionally assumed for vowels (Keating 1987 for further references): [V – Place | labial] is what has more commonly been termed [+round], [V – Place | coronal] is [–back], [V – Place | dorsal] is[30] [+back], [V – Place | radical] is [–ATR]. Note that the meaning of these autosegments may differ somewhat with their double function: E.g. [Place | labial] represents labiality *without* lip protrusion, while [V – Place | labial] represents lip protrusion. Secondary articulations are represented by features associated through [V – Place] in consonants (making e.g. the correct prediction that labialization in consonants is generally lip protrusion).

One issue raised by this representation is, can these features also occur in vowels with their "consonantal" meaning (the denotation they have when directly associated to [Place])? Conceivably, yes: In some, though not too many, languages, vowels may contrast for a superimposed articulation that is clearly outside vowel space and therefore only moderately affects recognition of basic vowel quality: Retroflexed vowels, thus, are [Place | coronal], and pharyngealized vowels are [Place | radical] (Hiller 1998: 17f., 46–48 for some discussion). That vowel place is more prominent in these segments than consonantal place features is implicit in descriptions that treat the vowel features as the defining property, e.g.[31] "moderately rhoticized o" rather than "rounded uvularized apicopostalveolar vowel". Clements (1993: 140f.) interprets the contrastively "lip-compressed" (rather than rounded) long front and back vowels of Swedish this way: The contrasting front vowels with lip protrusion are [V – Place | labial], lip-compressed ones are [Place | labial]. In fact, Clements symmetrically proposes the lip-compressed front vowels to be [Place | labial] and [V – Place | coronal], and the normally rounded front vowels to be

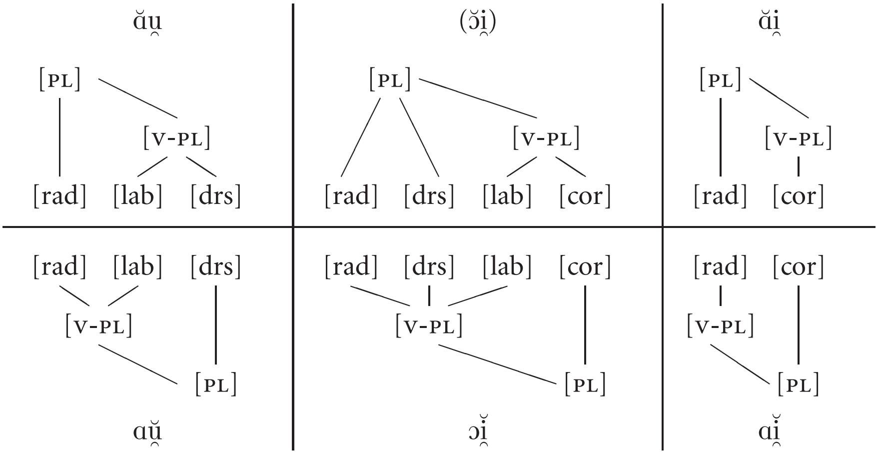


Figure 7. Representation of the contrast between set 1 (top) and set 2 (bottom), involving "almost" a suprasegmental for the contrast. Only [labial] causes asymmetry, being always associated with [V – Place]. ❖/ɔ̆i̯/ is correctly represented as a front rounded vowel.

[V – Place | labial] but [Place | coronal], on the grounds that both kinds are in fact diphthongs (a point noted by various descriptions, e.g. Traunmueller 1979), and in both cases the "consonantal" feature indicates the direction of movement from the "more vowellike" part of the phoneme. In this context, it is important to note that those two features in each phoneme are not realized exactly simultaneously, in each case, and their order is only determined at the point of phonetic interpretation, two issues we will return to (with the Swabian closing diphthongs) in Section 10.

The same kind of symmetrical pairs of representation[32] seems to be what is needed to represent the contrast between set 1 and set 2 of closing diphthongs in Swabian (Figure 7):

– The contrast between "vocalic" and "consonantal" function of the same features in pairs of corresponding type 1 and type 2 vowels accounts for the contrast in their dynamical contributions. Vowel features can most plausibly be taken to specify aspects of a state of the vocal tract, whereas consonant features specify dynamic gestures superimposed on movement between such states (Öhman 1966: 165). As a result, semivowels are notoriously variable wrt. their vowel height and are inherently momentary (Catford 1977: 131). This accounts for the prolongability effects observed.
– A (nondisjuctive) generalization can be stated that captures the observed inventory depicted in Figure 7 (without ❖/ɔ̆i̯/):

- Each of the four tiers discussed is occupied only once within each phoneme; there must be some "vocalic" component.
- [labial] is invariably "vocalic", redundant (strictly correlated with [dorsal]) and does not make a licit "vocalic" component on its own.
- [coronal] excludes [dorsal] or [radical] in the same component.
- [radical] must be present.

Together with the constraint that [V – Place | labial] presupposes [V – Place | dorsal] or [V – Place | radical], this yields the five diphthongs observed (cf. the cases of structure preservation discussed in Section 4.3). It also explains why in the acrolect, where this constraint is inactive, ❖/ɔ̆i̯/ comes in along with the front rounded vowels.

- Given this representation, neutralization of closing diphthongs under nasalization, which results in the corresponding type 2 diphthong, is most plausibly driven by avoidance of high vowels in that environment.
- Umlaut can uniformly be represented as addition of a [coronal] autosegment. This results in loss of a [dorsal] autosegment in Swabian, but not in its acrolect, which allows reassociation of the [dorsal] feature (and, in addition, permits ❖[ɔ̆i̯]).
- The antiedge effect in syllabification discussed above can successfully be stated, however with some amount of complication.
- Representation as bimoraic unitary segments explains why they parallel long vowels in inalterability before coda /ʁ̞/, in varieties where they can occur in that position.
- Alternation between [iː] and [ɑ̆i̯] involve addition of a [radical] feature directly to consonantal [Place] and leaves the specification unchanged otherwise.

It must be added that with these representations, appearance of [ɑĭ̯] for expected ∗[ei̯] does not have a comparably elegant representation.

To sum up, the more prominent component of each of these diphthongs is represented as vocalic place of articulation features of Clements and Hume's (1995) framework and the other as major (i.e. "consonantal") place of articulation features in a single melodic specification, and this has made possible accounting for the phonological properties of the closing diphthongs of Swabian much better than any conceivable sequential representation. A possible problem may be posed by the Stuttgart variety, realizing the dorsal fricative [ç]∼[χ] as palatal [ç] after consonants but not after the closing diphthongs /ɑ̆u̯/ and /ɑŭ̯/, but otherwise it seems to be straightforward to see how an account for each of the phenomena discussed should look like, using these representations. It has not been addressed yet what vowel height features these representations are specified for: Most plausibly, they reflect the vowel height of the vocalic (head) component, which would incidentally also be the most unmarked height given the specification for the other [V – Place] features, respectively.

10. Consequences for the relation between representation and timing

The solution arrived at, at this point, must necessarily presuppose that autosegmental phonological representations, even in the output of phonology, do not very firmly constrain phonetical timing among the articulations they represent: If two subspecifications are dominated by the same node within a single melodic specification and are not ordered with respect to each other on any single tier, they need not necessarily be realized simultaneously (this is in line with Sagey 1986), but may be in sequence instead. But since in each of the closing diphthongs of Swabian, phonetic sequencing does not vary, a rather powerful module of phonetic interpretation has to be assumed as part of the grammar that may language-specifically introduce temporal order between realization of features, when the output of the phonological module specifies them as simultaneous. The behavior of the feature [labial] illustrates the complexity involved: Since it is realized as lip rounding, it must be dominated by [V – Place] in all the closing diphthongs in which it occurs, irrespective of which diphthong component it is realized together with. This is also necessary in order for some of the generalizations made in the previous section to be stated successfully. This means that it is not even necessarily the case that the "consonantal" and the "vocalic" place of articulation features of the diphthong are each realized together as a group: [V – Place | labial] is realized together with the "consonantal" features in [ɑŭ̯] (and in ❖[ɔ̆i̯] in the acrolect).

A first attempt at working out how else phonetic interpretation should possibly determine the order of articulations not ordered in phonological representation suggests that phonetic interpretation employs many of the same criteria that also constitute constraints in the phonological module of grammar: As for the timing of liprounding, this is especially salient for the difference found with the acrolect: The same preference for liprounding not to cooccur with vowel frontness that excludes ❖[ɔ̆i̯] from occurring in Swabian proper seems to have liprounding realized with the "consonantal" portion rather than the (front) vocalic portion in this phoneme of the acrolect. Similarly, realization of vowel height, of each individual component of these diphthongs corresponds to universal tendencies present in the phonology in the form of constraints: [radical] goes with low (or in [ɔĭ̯], lower mid) height, while [coronal] and (in the absence of [radical]) [dorsal] go with high vowel height. This outline sketch notwithstanding, determining the workings of phonetic interpretation in the case of the closing diphthongs of Swabian is left for future research. In particular, further investigation should include phonetic experiments designed to confirm or refute the role here crucially attributed to diphthong dynamics in the phonology of Swabian, such as perceptual experiments involving resynthetic manipulation of diphthong dynamics (like were done by Peeters 1991 for languages in which diphthong dynamics don't contrast) for comparison to factors such as vowel duration and height.

Notes

1. For comments and discussion on an earlier draft of this paper I would like to thank James Scobbie, Anja Geumann and an anonymous reviewer for this volume. Remaining errors are exclusively mine.

2. Breve diacritics indicate the phonetically observed contrast, so as to not preempt a particular one out of several more abstract solutions to be discussed below.

3. The term "Alemannic" is avoided, because this word is colloquially used as a designation for the West Upper German dialects (and ethnicities) *except* Swabian.

4. Most notably, phonation in obstruents is neutralized much more readily, whereas distinctions not supported by the prescription are retained in vowels: [ə] vs. [e] in "reduced" syllables, and short [e] vs. [ɛ], to mention two of them, as well as the diphthong contrast focused on in this article. These differences, speakers tend to perceive a matter of regional "accent".

5. Whence the common term "Schriftdeutsch", which is ambiguous between the literal meanings "[Holy] Writ's German" and "the German [used] in writing".

6. But none in consonants.

7. The bulk of dialectological literature seems to have been content using different symbols at all, most often <əu ao oe əi ae> for [ău̯ ɑŭ̯ ɔĭ̯ ăi̯ ɑĭ̯].

8. Figure 2 appears by courtesy of A. Geumann, Munich.

9. Whether speakers sustain the quality *at* diphthong offset or instead only one *close to* diphthong offset is an open question, considering that they produce a more *open* quality than found at the average offset in connected speech in the studies cited in the previous section.

10. Of the three exceptions that Frey (1975) enumerates, one is (8) (discussed in the text), another, [ˈklɑĭ̯tə] 'to slide', is an obvious loan from standard German (to wit, no sound shift to /ɔĭ̯/ !), and the third has [iə̯] rather than [iː] in the participle [ˌõntʕ̞̍ˈʃiə̯tə] ‘distinguish-PAST.PRT’ in many varieties.

11. “SHRT” is intended to represent the abstract shortening morpheme mentioned without preempting whether it is a prefix, suffix or a process etc.

12. Whether the diphthong in (11) is nasalized is left open to empirical study without providing any prediction. Recall from Section 1 that many varieties show a different pattern of nasalization (viz. predictable from *surface* nasals), but otherwise the same vowel qualities as transcribed here (i.e. quality changes and surface nasalization may not coincide).

13. The technical term *umlaut* more usually refers to a distance assimilation between vowels that, unlike *vowel harmony* only changes one vowel (hence, not harmony). Such an alternation was triggered by /i/ and /j/ in Old High German. Since in most or all modern dialects, the triggering vowel has been lost but the alternation has been preserved, the reflex of former umlaut is that nonconcatenative morph, which is therefore still referred to using the term *umlaut*.

14. Cf. this to Scottish (both the Scots dialect proper and its acrolect), where a pair phonetically similar to [ăi̯] vs. [ɑĭ̯] patterns as short vs. long (Scobbie, Turk, & Hewlett 1999: 1618f.; Scobbie, Hewlett, & Turk 1999: 241). Description of Fijian (Schuetz 1985: 545) short vs. long /ai̯/ resembles some descriptions of Swabian [ăi̯] vs. [ɑĭ̯], but it is not clear from that how close that resemblance is.

15. Read: stems that are bimoraic or more *unless* they are attached a vowel initial suffix.

16. I am not aware of any relevant example involving /ɔĭ̯/. Also, the allomorphy is not found in the acrolect.

17. In the coda of the preceding syllable and onset of the next syllable at the same time.

18. That suffix contrasts with 3SG -[t]. In verb suffixes, [ə] and [n] never contrast (discounting invariable gerund forming -[nt]). Optimality Theory (Prince & Smolensky 1993: 191) must admit either input in order to account for the absence of contrast, i.e. an analysis must be able to handle whatever is the “worst case” for it.

19. And without making an obstruent a sonorant or having a syllabic obstruent. The restriction against moraic schwa has to be relaxed in a way so a syllable [ət] has one (not two!) moras.

20. This test is not possible with those varieties that have an apicoalveolar rhotic instead, which is less sonorous, so they can not have an approximant in coda at all.

21. Just like in standard German, syllabification of obstruents in Swabian apparently freely violates the Sonority Sequencing Principle (so they never occur as nuclei but don’t trigger epenthesis, either) but syllabification of sonorants strictly observes it.

22. Cf. e.g. /hɑlt/- ‘hold’ with [hɑlt] (1SG), [helt͡ʃ] (2SG), in other words, this is the “umlaut” referred to in Section 3, or rather, “umlaut” plus raising.

23. One might add as a related phenomenon the rather pervasive strong verb paradigm mentioned in Section 3 that alternates [ăi̯] in present tense and [i] or [iː] in the past participle.

24. Some South-East Asian languages have been reported to show a "register" (arguably [±ATR]) distinction also in some diphthongs. It might be worth exploring whether those contrasts bear any resemblance to the Swabian system of closing diphthongs.

25. This can also be motivated by the circumstance that the phonetic description of phonological /ae/ vs. /ai/, etc. of Hawaiian (Elbert & Pukui 1979) resembles some existing descriptions (disputed in Section 2) of the Swabian diphthongs.

26. Nevertheless, this looks promising for bringing light into the *diachronic* origin of the present-day set 1 vs. set 2 distinction. In particular, it might help reconstruct the original role of /ui̯/, which is no longer integrated with the system constituted by the closing diphthongs and has started disappearing from Swabian altogether.

27. That would be /ɛi ɑi ou ɑu ɔi/ or /əi ɑi əu ɑu ɔi/ etc.

28. The notion of stress on one but not the other half of a diphthong, I know of no phonetic explication of, but it seems to be not too unusual in the descriptive literature.

29. All other things being equal, stress in Swabian avoids "reduced" syllables (schwa or syllabic cononants). But vowel quantity or closed syllables don't make a difference, as most obvious with consonants like [ʋ] that are never ambisyllabic in Swabian (i).

(i) [ˈʋe.ʋeː.ˌlə] 'aches, injuries-DIM.PL', ∗[ˈʋe.ˌʋeː.lə], ∗[ʋe.ˈʋeː.lə]

30. Absence of both [coronal] and [dorsal] from [Place] characterizes central vowels (Clements 1993: 107).

31. With consonants, to be sure, these roles are reversed in the same kinds of descriptions.

32. It does not seem accidental that both Swedish and Swabian have vowel systems fairly rich in contrasting basic vowel qualities (basic v.q. is, not counting additional contrasts – or lack of contrast – in nasalization, phonation etc.), as smaller systems can be expected to first exploit for contrast the less marked possible qualities. What may or may not be accidental is that the segments discussed for both languages are all bimoraic (after all, the Swedish ones do not involve antiedge effects).

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Depression in Zulu

Tonal effects of segmental features*

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Zulu, a Bantu/Nguni tone language spoken in South Africa, exhibits a curious interaction between tone and consonants, in which a specific set of onset consonants is correlated with extreme lowering of an immediately following high (H) or low (L) tone. This extreme lowering often causes realignment of tones and has been called 'tonal depression'. The triggering consonants are traditionally referred to as 'depressors'.

While the phenomenon of tonal depression has been found and studied in several Bantu languages, neither the set of depressor consonants nor the mechanism of depression have been satisfactorily characterized. Early attempts to define depressors as a natural class based on a feature like [+breathy voice] are contradicted by the facts (cf. Traill, Khumalo, & Fridjhon 1987; henceforth TKF; Giannini, Pettorino, & Toscano 1988, henceforth GPT). The hypothesis that tonal depression is caused by a L tone associated with an obstruent (Laughren 1981) is inconsistent with standard assumptions about the sonority of tone bearing units (TBUs). Proposals for a tone insertion rule that places an extra L tone on the 'regular' tonal tier cannot explain why tonal depression consistently occurs very late in the derivation: H tone distribution initially follows its regular patterns regardless of the presence of depressor consonants, while depressor induced H tone shift is blocked by depressor consonants.

In this paper, I will argue that tonal depression in Zulu warrants the introduction of a new feature pair into the feature geometry. This enhanced feature geometry is not only phonetically motivated, but also provides a straightforward explanation of otherwise puzzling characteristics of tonal depression and its effects in the phonology.

1. Description of tonal depression

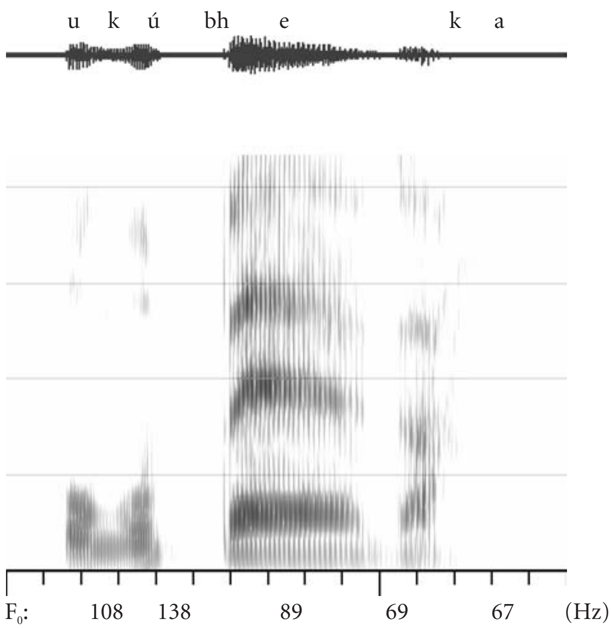
The term “tonal depression” refers to a distinct lowering of the fundamental frequency (F_0). The set of Zulu consonants that consistently cooccur with F_0 lowering on the immediately following vowel is shown in (1):

(1) *bh, d, g, v, z, h, dl, j, gc, gq, gx* [p, t, k, v, z, ɦ, ɮ, ʤ, $|_D$, $!_D$, $||_D$]

The continuants and affricates *v, z, h, dl, j* are clearly voiced. The stops *bh, d, g* are voiceless unless they are prenasalized (TKF 1987; GPT 1988). The depressor clicks *gc*, *gq*, *gx* are marked as post-breathy voiced (Rycroft & Ngcobo 1979; henceforth R/N 1979), which really only means that they are depressors. In terms of surface phonation, “pitch lowering is the primary and only reliable manifestation of depression in Zulu” (TKF 1987: 271).

Example (2) shows a waveform and spectrogram of the word *ukúbheka* ‘to look at’, as pronounced by a KwaZulu speaker from the instructional tapes accompanying R/N 1979.

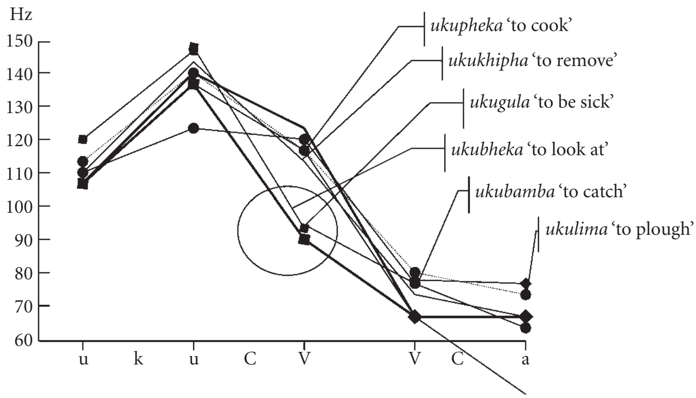
(2)



As indicated by the accent mark, the F_0 rise on the second vowel is perceived as a H tone by native speakers. In contrast to the “lenis voiced” (R/N 1979) *k* [g], the depressor consonant *bh* is clearly voiceless, but nevertheless induces a noticeable dip in the fundamental frequency of the following vowel. I took one F_0 measurement from the peak of each vowel and two from *e*, since it is bimoraic due to penultimate lengthening. The tone bearing unit in Zulu is arguably the mora, since only lengthened vowels may carry full phonological contour tones.

To illustrate the degree of F_0 lowering induced by depressor consonants, example (3) juxtaposes similar F_0 measurements for different words with the same moraic structure (VCVCVVCV, w/V = moraic V-slot) and the same basic H tone pattern (H on the second vowel).

(3)



While the pitch contours of the words with aspirated or lenis voiced stops pattern together, it is rather clear that the depressor consonants (here: *g* in *ukugula* and *bh* in *ukubheka*) cause a deviation towards a significantly lower pitch level.

As in other Bantu languages, H tones are mobile and do not necessarily surface on the donator morpheme, i.e. the morpheme that carries an underlying specification for a H tone. Depending on the morphosyntactic structure of the word and the tonal patterns associated with it, it can thus happen that a H tone targets a V-slot (or mora) that is also subject to tonal depression due to the segmental context. Since the pitch raising gesture of the H tone is antagonistic to the lowering gesture involved in depression, a conflict arises which is usually avoided by associating the H tone with the next available V-slot on the right. This resolution algorithm has been referred to as 'depressor induced H tone shift', and it is blocked if another depressor consonant intervenes between the initial target vowel and the next available one. In this case, H association largely overrides the depression gesture, and the target vowel surfaces with a rising onglide leading into a H tone, i.e. with a depression-induced monomoraic phonetic contour. The pitch level of such a 'depressed H tone' remains lower than that of a regular H tone. The following examples serve to illustrate this behavior (data from R/N 1979). Consider (4) first:

(4)	underlying form	u	+	ya	+	leth	+	el	+	a	donators: *u-*, *leth*
		SUBJ 3SG		T PRES		'bring'		BENEF		ASP	
	surface form	ú y a l e t^h é l a									
		's/he is bringing for'									

With Khumalo (1987) and Clark (1988), I assume that only H tones (indicated by accents) are manipulated to yield the basic H tone melodies, whereas mid tone levels are supplied by default to TBUs without tonal specification. I tentatively follow Clark (1988) and Downing (1990) in assuming that H tone melodies are accentual, which means that morphemes can serve as "donators" and introduce H tones into a metrical structure. This structure may then be manipulated by a particular set of rules (which are not relevant here) with the result that the H tone appears to be mobile, i.e. it can surface away from its donator. In (4) above, the prefix *u-* as well as the root *leth* are donators, but the root's tone is attracted to the penultimate syllable, which yields the characteristic surface pattern.

The mobility of H tones is further exemplified in (5), where the prefix H tone surfaces on the antepenultimate syllable for metrical reasons:

(5)	underlying form	u	+	ya	+	łakul	+	a	donator: *u-*
		SUBJ 3SG		T PRES		'weed'		ASP	
	surface form	u y a ł á k u l a							
		's/he is weeding'							

(6) illustrates the effect of a depressor consonant on the tonal melody. The morphological material matches that of (4) with the exception of the subject prefix *zi-* containing a depressor. The H tone donated by this prefix would be expected to surface in situ, as it does in (4). However, the presence of the depressor consonant causes an adjustment in the tonal melody that results in the H tone surfacing on the next syllable to the right.

(6)	underlying form	zi	+	ya	+	leth	+	el	+	a	donators: *zi-, leth*
		SUBJ 3PL		T PRES		'bring'		BENEF		ASP	
	form predicted by metrical patterns	*zí y a l e t^h é l a									
	surface form	zi y á l e t^h é l a 'they are bringing for'									

The morphological material in (7) parallels that of (5) insofar as the subject prefix represents the only donator morpheme. As in (5), the metrical pattern targets the antepenultimate syllable for the H tone. However, the root initial depressor *v* causes an adjustment similar to the one in (6), i.e. the H tone appears to be shifted to the next syllable on the right.

(7)	underlying form	u	+	ya	+	v u m	+	e l	+	a	donator: *u-*
		SUBJ 3SG		T PRES		'agree'		BENEF		ASP	
	predicted form by metrical patterns	*u y a v ú m e l a									
	surface form	u y a v ù m ê l a 's/he is allowing'									

The morphological material in (8) would lead one to expect the same surface tonal pattern as that of (6), since the subject prefix in both cases starts with a depressor consonant, which should shift the H tone to the right. However, the initial depressor consonant of the tense prefix in (8) seems to block this shift.

(8)	underlying form	$\underline{z}$ i	+	$\underline{z}$ o	+	bosh	+	w	+	a	donator: *zi-, bosh-*
		SUBJ 3SG		T FUT		'arrest'		PASS		ASP	
	predicted form by metrical patterns	*z í z o b ô sh w a[1]									
	expected form by depressor shift	*z i z ó b ô sh w a[2]									
	surface form	z í z o b ô sh w a 'they will be arrested'									

Without going into details, I do not think that any of the existing analyses can account for these descriptive facts with sufficient explanatory adequacy. Traditional autosegmental accounts manipulating H tone patterns via spreading and delinking have to make *ad hoc* assumptions about the timing of L tone introduction through the depressor consonants. Without such assumptions, it remains unclear why depressors seem transparent for the purposes of initial H tone displacement (cf. (7)), but opaque for depressor induced H shift (cf. (8)). A metrical analysis of H tone patterns can accommodate the transparency facts, since the relevant TBUs are units on the metrical grid are unaffected by specifications dependent on the skeletal tier. The opacity effects in the context of depressor induced H shift, however, pose a problem and, in my opinion, require additional assumptions about interface conditions between metrically relevant units and the segmental structure, which I hope to provide in the remainder of this paper.

2. A phonetically grounded featural basis

Tonal depression in Zulu is a highly localized phenomenon: if associated with a depressor consonant, the depression gesture is centered within that consonant (TKF: 263). The resulting F_0 lowering reaches into the following vowel and may also affect the preceding one. The feature responsible for depression does show some important autosegmental characteristics (see below), but these are highly restricted.

F_0 lowering can be achieved via adjustments of (a) the vocal folds (overall and/or longitudinal slacking), (b) the larynx as a whole (lowering), and (c) the subglottal airpressure (reduction) (cf. Roubeau, Chevrie-Muller, & Lacau Saint Guly 1997). The latter is typically used for global pitch control, i.e. in establishing the main pitch ranges in intonational contours and stress patterns (cf. Strik & Boves 1995). Both (a) and (b) are regulated by laryngeal musculature, which appears to allow for more fine-tuned adjustment than the respiratory musculature. Thus, (a) and (b) are common adjustment strategies on the local level.

The local character of tonal depression suggests involvement of laryngeal musculature. Lowering of the whole larynx via the strap muscles is clearly employed in the exaggerated pitch adjustments required in operatic singing (Sundberg 1977) or glissando enunciation (cf. Roubeau, Chevrie-Muller, & Lacau Saint Guly 1997). As electromyographic (EMG) data show, it is also used by Mandarin speakers within contour tones (Hallé 1994). Based on fiberoptic investigation, TKF (265) claim that strap muscles are not involved in Zulu tonal depression, since the expected lowering of the larynx was not observable.

However, these visual observations alone may not be sufficient to rule out involvement of particular muscles, since the glottis was not always in plain view.

Since the vocal folds are not consistently slack in depressor consonants (/bh, d, g/ are voiceless when not prenasalized), TKF – by exclusion of all other possibilities – argue that some sort of vocal fold shortening is mainly responsible for the F_0 lowering in tonal depression. In some speakers, this shortening is achieved via "an anterior movement of the arytenoids and the posterior movement of the tubercle of the epiglottis" (TKF: 265). This latter mechanism is not observable in other speakers, so TKF (265) stipulate relaxation of the cricothyroid muscle to yield the same effect.

If it is true that vocal fold shortening is the primary cause of tonal depression, this phenomenon cannot be captured by existing proposals on feature geometry without some modification, since Sagey (1990), Halle (1995), and Clements and Hume (1995) incorporate only [slack/stiff vocal folds] and [spread/constricted glottis] into their models. The shortening of the vocal folds is usually accompanied by [constricted glottis], i.e. "the arytenoids [are] almost always adducted" (TKF: 267), but at least for depressor /h/ the constriction is incomplete. It seems to be compatible with [stiff vf] as well as with [slack vf] (TKF: 271), i.e. the causal articulatory gesture is independent of the ones responsible for the primary voicing features.

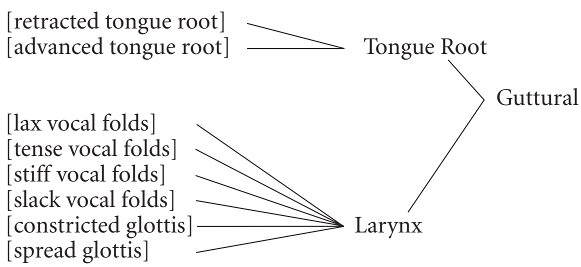
Of course, one may argue that tonal features are suprasegmental and thus do not need to be captured within the segmental feature geometry. In recent proposals, tonal features are dependent of the typical tone bearing units syllable (σ) or mora (μ) (cf. Yip 1995 for a relevant model and further references), and the tonal categories L, M, H may be taken to be shorthands for relevant articulatory gestures. Similarly, extra low $\underline{L}$ (cf. Cope 1970; Laughren 1981) may be introduced as a similar shorthand. Such a strategy is unsatisfactory for several reasons: (a) it remains at the descriptive level, but – ultimately – an explanatory adequate theory of feature geometry will have to fill its shorthands with articulatory content; (b) it cannot explain why tonal depression may be triggered by a non-TBU; (c) it wrongly predicts suprasegmental (i.e. non-local on the skeletal level) spreading characteristics of depressed tones.

Shryrock (1995: 6) describes consonantal interaction with tone in Musey, a Chadic language spoken in Cameroon. In this language, the opposite effect from the Zulu case can be observed: a particular set of consonants *raises* F_0 on the following vowel, and low tones seem to be pushed away. As in Zulu, the relevant set of consonants does not represent a natural class describable in terms of commonly assumed features, since it includes both voiced and voiceless obstruents. Like TKF, Shryrock (1995: 69–73) provides detailed phonetic evidence against casting the tonally relevant obstruents in a class based on e.g. [slack/stiff vf], [raised/lowered larynx], [fortis/lenis voice] etc. His analysis further parallels that of TKF in that he posits an increase in the longitudinal tension of the vocal folds as the primary cause of F_0 raising in Musey. It has independently been shown that tensioning of the cricothyroid muscle raises F_0 (cf. Hallé 1994).

Since evidence from two languages from different families (i.e. Bantu and Chadic) points to a similar articulatory gesture as an active component in the phonology of the particular language, it seems warranted to introduce a new feature into the descriptive apparatus. Since the relevant obstruents in these two languages are not tone bearing units as commonly understood, the new feature should be part of the segmental feature geometry.

Assuming the basic feature geometry from Halle (1995:2), I propose that [decreased longitudinal vocal fold tension] vs. [increased longitudinal vocal fold tension] be added under the laryngeal node, or [lax vf] vs. [tense vf] for short:

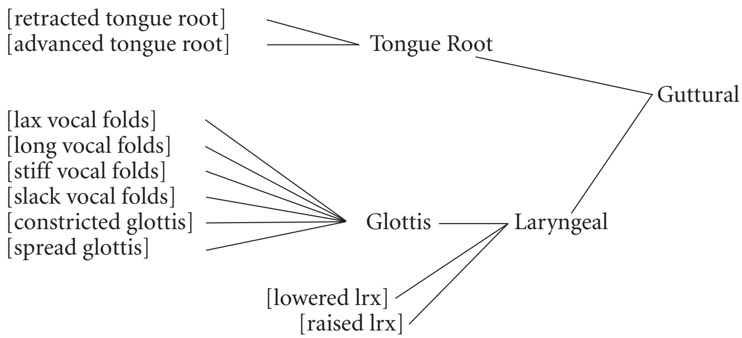
(9)



[tense vf] would be the active feature in Musey, whereas [lax vf] is active in Zulu.

To complete the picture, lowering and raising of the larynx should be encoded as well, since the strap muscles are available not only for conscious and voluntary formant control, but also for linguistic encoding of tone (see above). A feature [lowered/raised larynx] should, however, be distinguished from the glottalic features, since the two sets are independent from each other (cf. Trigo 1991). The following feature configuration is possible:

(10)



With this enhanced feature apparatus, tonal categories can be correlated with articulatory gestures and thus phonological features as follows:

(11)

tonal category		(articulation)		segmental feature
H	↔	cricothyroid tensing	↔	[tense vf]
		posterior arytenoid movement	↔	[stiff vf]
		suprahyoidal tensing	↔	[raised larynx]
L	↔	cricothyroid laxing	↔	[lax vf]
		anterior arytenoids movement	↔	[slack vf]
		strap muscle tensing	↔	[lowered larynx]

(arguments for particular correlations in TKF 1987; Hallé 1994)

The laryngeal area contains a large set of muscles, and – as far as I can gather from the literature – the exact function of each individual muscle is not completely understood. Correlating phonological laryngopharyngeal features with particular physiological mechanisms is also difficult, because many muscle groups have synergistic effects. The articulators in (11) thus only have suggestive value. However, even if views on the exact mechanisms of articulation may still change e.g. with better imaging techniques, it seems clear that tonal categories can and must be interpreted as cover terms for sets of articulatory gestures. These gestures may cooccur, but the presence of all of them at the same time does not seem to be required to achieve an F_0 lowering or raising effect.

The importance of providing articulatory specification for tonal categories lies in the fact that the points of interaction with segmental features are illuminated. If a language exhibits consistent correlations of H tone with voiceless and L tone with voiced consonants, one may suspect that [slack/stiff vf] is the dominant F_0 control feature in this particular language (e.g. Ngizim, cf. Purnell 1997: 29–31). Languages in which tone is largely independent of segmental specifications (e.g. Mandarin), one would expect [lowered/raised larynx] to control F_0, and ejectives/implosives to be absent. The correlation of segmental inventories with particular tonal patterns may thus be an area worth exploring. In Nguni languages, voiceless and ejective consonants are neutral with respect to tone, which leaves only [lax/tense vf] as an F_0 control feature that is relatively independent of segmental structure, with the notable exception of depressor consonants.

3. The depressor inventory

Now that relevant phonological features with explicit phonetic correlates have been introduced, it becomes possible to determine the phonological contrasts in the phonemic inventory of Zulu. Since stops exhibit the richest contrasts, I will limit my discussion to this set. I assume that the relevant distinctions in fricatives, affricates and clicks are equivalent.

(12) Inventory of stops, orthographic and phonetic notation

	labial		coronal		velar	
	orth	phon	orth	phon	orth	phon
ejective	p	[p’]	t	[t’]	k	[k’]
voiceless, aspirated	ph	[ph]	th	[th]	kh	[kh]
depressor*	bh	[p]	d	[t]	g	[k]
plain voiced	b	[b]			k	[g]

*voiceless in isolation, voiced after nasals
(adapted from Giannini, Pettorino, & Toscano 1988: 113)

I propose the following featural distinctions:

(13)

	ejective	voiceless aspirated	depressor	lenis voiced
lax vocal folds			+	
stiff vocal folds	+	+		
slack vocal folds			(+)	+
spread glottis		+		
constricted glottis	+		(+)	
raised larynx	+			

If one assumes that only distinctive features are underlyingly marked (following e.g. Steriade 1995), the feature matrix in (13) is reducible to the one in (14):

(14)

	ejective	voiceless aspirated	depressor	lenis voiced
lax vocal folds			+	
slack vocal folds				+
spread glottis		+		
constricted glottis	+			

This would imply the following default rules:

(15) a. [constricted glottis] → [stiff vocal folds, raised larynx] (ejective)
b. [spread glottis] → [stiff vocal folds] (vl. aspirated)
c. [lax vocal folds] → [constricted glottis] (depressor)

4. Phonological evidence for the featural characterization

Khumalo (1987) makes two interesting observations: Zulu exhibits limited forms of both consonant and vowel harmony, and depressor consonants participate in both. For previous accounts that identified depressor consonants either via a tonal specification for L (cf. Laughren 1981) or via an abstract laryngeal feature [depressed] (cf. Khumalo 1987), the different aspects of depressor behavior remain unintegrated. Given the above feature specifications, however, the interactions between depressor consonants and particular autosegments are not only explainable, but are even expected.

Following Khumalo (1987: 74), Zulu has 7 surface vowels: [i, e, ɛ, u, o, ɔ, a]. The pairs [e/ɛ] and [o/ɔ] are in allophonic variation: [e] and [o] occur only when the following syllable contains a high vowel, i.e. they are conditioned surface variants.

Khumalo (1987:75) provides the following examples with several alternative pronunciations (those marked with "?" sound strange to Khumalo, "✓" indicates acceptable forms, while the ones marked with "→" are claimed to be most common):

(16) a. u- ya- sebenz -a → [uyásɛbɛnza]
3sg t 'work' asp
'he works'

b. aka- sebenz -i
neg/3sg- 'work' asp
'he doesn't work...'

1. ✓ [akasɛbénzi]
2. → [akasebénzi]
3. * [akasɛbɛ́nzi]

c. isi- sebenz -i — 1. ✓ [isísɛbénzi]
nc7 'work' deriv — 2. → [isísebénzi]
'worker'

d. aka- thekelez -i — 1. ✓ [akáthɛkɛlézi]
neg/3sg- 'tie up' asp — 2. → [akáthekelézi]
'he doesn't tie up...'

Since, according to Archangeli and Pulleyblank (1994: 176), [high] is predictable from underlying [ATR], the following feature matrix suffices for the characterization of Zulu vowels:

(17)

	i	u	ɛ	ɔ	a
ATR	+	+			
low					+

Given these underlying specifications, the data in (16) can be explained as ATR harmony, where the autosegment ATR spreads from right to left. Speakers may apparently differ with respect to whether or not ATR spreading applies iteratively, which would explain the variation between (16b-1&2, c-1&2, d-1&2). In the absence of an ATR trigger, [ɛ/ɔ] surface unchanged (16a).

As Khumalo (1987: 76) indicates, depressor consonants block ATR spreading to vowels in their domain:

(18) a. ngokudla → ✓ [ŋgɔkûdlá]
'by eating' but: *[ŋgokûdlá]
b. ngelikabani → ✓ [ŋgɛlíkabaní]
'whose is it?' but: *[ŋgelíkabaní]

It thus seems that, at least for some speakers, depressor consonants involve an articulatory gesture that is phonologically describable as [RTR] (or [–ATR], depending on the theory), which would explain an interaction with ATR harmony. For present purposes, it seems sufficient to point out that the articulatory gestures associated with depressor consonants are not limited to F_0 control, but have predictable consequences in the segmental phonology.

Notice that even though depressors and L tones correlate with [RTR]/[–ATR], H tones do not correlate with [ATR], i.e. [–ATR] vowels are compatible with H tone:

(19) nga- ngi- sebenz -a → [ŋga:ŋgisɛbɛ́:nza]
1sg/t 1sg 'work' asp
'I was working' (Khumalo 1987: 79)

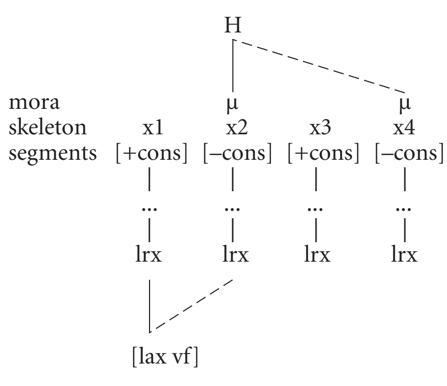
The fact that H tone assignment does not cause a [–ATR] vowel to be raised suggests that F_0 control is independent of [RTR/ATR] per se. This provides phonological evidence *for* the assumption of an additional laryngeal feature (i.e. [lax vf]) as the trigger of tonal depression and *against* any assumptions of an exclusively *tonal* specification on depressor consonants. Instead, segmental features are the underlying cause for tonal effects of these consonants, and interaction with other segmental features thus does not come as a surprise.[3]

It may be possible that the consonantal features [tense/lax vf] stipulated here are, in fact, the same as the traditional vowel features tense and lax, i.e. the old question of whether and how tongue root phenomena are related to tense/lax is reopened. While it may well be the case that the tense/lax distinction is overshadowed by height/backness settings in Germanic languages on the one hand and tongue root settings in e.g. Igbo and Akan on the other hand (cf. Ladefoged & Maddieson 1996: 302–306), Zulu seems to suggest that there are languages where tense/lax is not only an active but possibly even a dominating feature. As a laryngeal setting, it is, of course, independent of vowel/consonant distinctions.

5. Interactions of H tone and depression

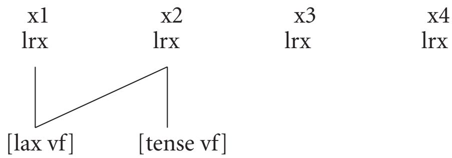
In the previous section, I have provided evidence for assuming a segmental feature as the defining characteristic of depressor consonants. The initial independence of H tones and depression thus finds a simple explanation: phonological tones are abstract elements that are manipulated with respect to abstract host units (TBUs, most likely moras in Zulu). The depressor feature, an abstract element of different categorial status, is manipulated with respect to a different set of host units (namely the laryngeal nodes), as indicated in (20).

(20)



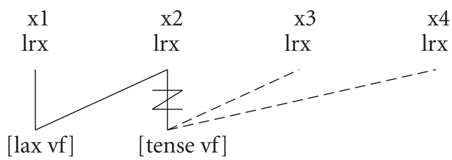
In categorial terms, H and [lax vf] are completely independent and may ultimately target host units that correspond to the same skeletal slot (like x2 in 20). A conflict may arise when H is translated down into segmental features for articulation, e.g. [tense vf] as suggested above. (20) would then yield (21) in its relevant aspects:

(21)



At x2, two antagonistic articulatory features are now linked to the same node. H tone shift, in the form of delinking and spreading [tense vf], could therefore be regarded as a conflict resolution mechanism:

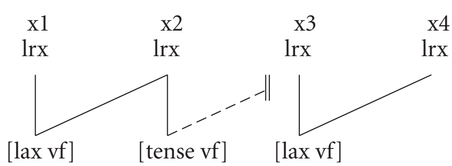
(22)



I assume that the spreading behavior of [tense vf] is the same as the one of [lax vf], since both operate on the same tier. Thus, [tense vf] will establish a rather localized spreading domain, where it provides the necessary acoustic cues to be reinterpreted as a H tone.

If x3 carries relevant laryngeal specification, i.e. if x3 is a depressor consonant, spreading of [tense vf] would be blocked. A lowered H tone with an onglide results at x2, as the contour representation in (23) indicates.

(23)



If the proposed representation is correct, an otherwise puzzling characteristic of depressor induced tone patterns finds a straightforward explanation: while Bantu H tones typically are highly mobile and can surface far from their origin, depressor induced H shift is a strictly local phenomenon. The reason for this change in behavior lies in the fact that H shift occurs not within the tonal module but within the segmental feature geometry. The Zulu constraint against contour representations on the tonal level does not hold in the segmental geometry, which explains why depression may lead to monomoraic surface contours even if underlying tonal contours typically require bimoraic manifestation.

6. Conclusion

I thus claim that tonal depression is essentially a nontonal process, i.e. it does not work on a categorial level commonly thought of as tonal. The observed interaction between consonants and H tone melodies is not due to an underlying tonal (i.e. H/L) specification on the relevant consonants, and consonantal features do not have direct access to tonal tiers either. Rather, the interaction takes place when the (in terms of abstractness) higher-level tonal categories are translated into lower-level segmental features in order to become pronounceable.

Previous proposals for integrating tonal categories and segmental feature geometry were inadequate, because categories of different type were mixed: segmental features are articulator-based, while tonal features are function-based. My suggested translating algorithm is a way to overcome this weakness: in the feature geometry, tone is to be represented in articulator-based terms. Once this is achieved, consonant-tone interactions are not only allowed but expected. The reason why depression is crosslinguistically rare is due to the fact that tonal specifications may make use of a set of exchangeable features, and I assume that languages tend to choose features for suprasegmental purposes that are least likely to disrupt the segmental geometry (and vice versa). Zulu exhibits depression because of its wide range of consonantal distinctions, i.e. all features that may be used for the manifestation of tone (i.e. [slack/stiff], [lowerd/raised lx], [tense/lax vf]) are distinctive on the segmental level. The likelihood of segment-tone interactions in a particular language is thus a function of the complexity of the phonemic inventory.

Notes

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1. The falling contour on *bôshwa* is due to a relevant underlying specification of this morpheme.

2. The falling contour on *bôshwa* is due to a relevant underlying specification of this morpheme.

3. Further evidence for the segmental rather than tonal nature of the depressor feature is provided by the fact that it seems to be active in root internal consonant harmony (cf. Khumalo 1987). Because of space limitations I cannot elaborate here.
In an extended version of this paper, I also hope to show that so-called 'erratic depression' is not a strong argument against the assumption of a natural class of depressor consonants. In short, most cases of 'erratic depression' can either be dismissed as lexical exceptions or derived from particular morphosyntactic constellations.

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Weakening processes in the Optimality Framework*

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0. Introduction

Processes of weakening may be subsumed under two heads namely, the loss of marked feature specifications such as voicing, aspiration, place specification or even the loss of an entire segment, and lenition, exemplifying processes such as voicing, spirantization and sonorization. This paper is an attempt at an analysis of both types of consonantal weakening in the framework of Optimality Theory (henceforth OT). In Section 1 we take up the phenomenon of weakening as the loss of feature specification and propose an analysis in terms of prosodic alignment and featural markedness. Section 2 examines lenition in Tamil and proposes a universal constraint 'Harmonic Sonorancy' which explains the process as an assimilatory tendency to increase the sonority of consonants in the neighbourhood of sonorants.

1. Weakening as loss of marked feature specification

The loss of marked feature specification is the converse of licensing of marked feature specification in prosodically strong positions. Extending the approach to licensing in Smolensky (1995) and Zoll (1998), we show that the distribution of marked feature specification can be accounted for in terms of alignment to prosodic categories. The loss of marked feature specification is widely attested in the following prosodically weak positions.

(1) Loss of marked feature specification in prosodically weak positions

a. syllable coda

well-known examples	coda devoicing in German, Dutch, Polish, Catalan
lesser known example	coda deaspiration in standard colloquial Bangla

Standard colloquial Bangla

i.	lab ˜ lab^{h}er	'profit ~ genetive'
ii.	g^{h}ɔr	'house'
iii.	ciʈ^{h}i	'letter'

b. onset of non-head syllables

well-known example	lack of aspiration of voiceless stops in English
lesser known examples	lack of aspiration in non-initial stops in the Adilabad dialect of Gondi (Subrahmanian 1968), the Hooghli dialect of Bangla (Ghosh 1995); in both cases aspiration is distinctive in voiceless and voiced stops.

	Standard Bangla	**Hooghli dialect**	**Gloss (Ghosh 1995)**
iv.	lab^{h}er	laber	'profit (gen.)'
v.	ciʈ^{h}i	ciʈi	'letter'
vi.	pat̲^{h}ieci	pat̲t̲ici	'I've sent'
vii.	g^{h}ɔr	g^{h}ɔr	'house'
viii.	d̲^{h}up d̲^{h}uno	d̲^{h}up d̲^{h}uno	'incense stick'(Ghosh, p.c.)

A uniform account of loss of marked feature specification is possible in terms of alignment to prosodic categories. This approach is a slight variant of the positional markedness approach argued for in Smolensky (1995) and Zoll (1998). Since the examples quoted are not restricted to syllable codas, we argue for alignment to genuine prosodic categories namely, left/right edges of syllables and left/right edges of stems/prosodic words. The analysis proposed is the following: A marked segment/feature *F is generally not parsed except when required by a higher ranking alignment requirement. The constraint hierarchies (henceforth CHs) for standard Bangla, the Hooghli dialect and the Noakhali dialect where aspiration is lost everywhere (Das 1996) below in (2) capture the difference in the pattern of aspirates as a consequence of the differential ranking of *[spread glottis] in the CHs of the three language varieties under consideration.

(2) **Constraint hierarchies of Standard Bangla, the Hooghli, and the Noakhali dialects**

Standard Bangla	Hooghli dialect	Noakhali dialect
Align {PrWd; left},	Align {PrWd; left}	*[spread glottis]
Align {syllable; left}	>>	>>
>>	*[spread glottis]	Align {PrWd; left},
*[spread glottis]	>>	Align {syllable; left},
>>	Align{syllable; left},	Align {syllable; right}
Align {syllable; right}	Align {syllable; right}	

Whereas aspiration is parsed in all syllable onsets in standard Bangla because of constraint domination, aspiration is parsed only at the left edge of the prosodic word in the Hooghli dialect. Finally, the undominated status of *[spread glottis] in the Noakhali dialect ensures the loss of aspiration in this language variety. A major advantage of the alignment approach to weakening is that it captures the path of weakening in related dialects in a dramatic way. A stronger argument for the alignment approach comes from the Jamshedpur variety of Hindi (Sandhu 1999) where medial aspirates in Hindi are re-located at the left edge of the stem e.g., /po:c^{h}a:/ 'wiping the floor with a wet cloth' becomes /p^{h}o:ca:/. Data like these are not amenable to a positional identity/faithfulness account as in Beckman (1997) (and the reference cited in Zoll 1998). In this case we are not dealing with the identity of a feature to a position but feature faithfulness (Max [spread glottis]) over-riding the faithfulness to a link of [spread glottis] i.e., MaxLink [spread glottis] to a particular position in the input representation. In addition, this is also an argument for prosodic categories other than the syllable licensing marked features. Further, if in a word there is no consonant on the left to which apiration could be anchored (for example, if it is a sonorant), even the align constraint can be violated as aspiration is faithfully preserved in a word like /a:ŋk^h/ 'eye'.[1] The CH in (3) below accounts for the re-location of aspiration in obstruent-initial words in Jamshedpur Hindi.

(3) **Constraint hierarchy for Jamshedpur Hindi**

Max [spread glottis], *[+sonorant, spread glottis]
>>
Align {PrWd; [spread glottis]; left}
>>
Max link [spread glottis]
>>
*[spread glottis]

The tableau in (4) below illustrates the computation of the CH for the inputs /po:c^ha:/ (for lack of space presented as /p.c^h./) and /a:ŋk^h/ (for lack of space presented as /v.c^h./). Notice that Align left is a violable constraint which is overridden by the undominated constraint *[son], [spr gl] (which bans voiceless sonorants in the language).

(4) **Evaluation tableau for re-location of aspiration in Jamshedpur Hindi**

	Max spr gl	Align	Max link	*spr gl
i a.→ p^h.c.			*	*
i b. p.c^h.		* !		*
i c. p.c.	* !		*	
ii a. →v.c^h.		*		*
ii b. v.c.	* !		*	*

We thus see how feature faithfulness ranked with alignment to prosodic categories explains weakening as non-parsing of marked featural specification in positions not required to be aligned. Playing the devil's advocate, one could, in principle, object that the alignment approach is intrinsically arbitrary in that it predicts types of languages that, in fact, are clearly impossible. For instance, one does not come across languages where marked features are aligned only to the right edge of the prosodic foot, syllable etc. And yet such a grammar is eminently possible if alignment constraints are taken to be universally unordered with respect to one another. Adopting the position in Dresher and van der Hulst (1998) and the references cited there, one must recognize the phenomenon of 'head-dependent' asymmetries that have often been noticed in the literature. We assume with Dresher and van der Hulst that every prosodic category has a specified head (whether it must be notationally specified or not is a matter of debate) and a dependent category. Be it the syllable or the foot, there is non-controversially, a unique head and a clearly defined dependent/nonhead element. Take the syllable, for instance. Clearly the left edge making up the onset-nucleus combine makes for the head (whether one accepts the mora as a constituent or not). Similarly at the level of the foot, we propose that the left edge is the designated head and therefore, the right edge is the dependent edge.[2] As Dresher and van der Hulst point out, universally, there are two and only two possibilities with respect to markedness and the dependent element. The dependent element can either be required to be less marked than the head (e.g.,aspiration only in stressed-initial position, reduced vowel inventory in unstressed syllables etc.) or it can accept elements of equal complexity as the head (e.g., aspirates everywhere as in Hindi). Keeping these facts in mind, we propose the partial universal sequencing requirement of alignment constraints pertainign to the PrWd and the syllable in (5) below.

(5) **Partial universal sequencing of alignment constraints (pertaining to the PrWd and the syllable)**

a. Align {PrWd; left}
b. Align {syllable; left}

Type I a >> b	aspiration in English, the Hooghli dialect of Bangla
Type II a, b (unordered)	aspiration in all onsets in standard colloquial Bangla
c. Align {PrWd; right}/d.	Align {syllable; right} (c and d are not sequenced with respect to one another)
Universal sequencing prohibits * c/d >> a/b	
Type III a >> c	the right edge is weaker than the left edge (see Tamil below)
Type IV {a, c}/{b, d} (unordered)	segments of equal complexity are allowed throughout the foot and the syllable e.g., aspiration in Hindi
Type V a, b, c, >> d	licensing in all onsets and the final coda e.g., voicing in Yiddish (Lombardi 1991)[3]
Type VI a, b, d, >> c	licensing in all onsets and non-final codas e.g., obstruents in modern Tamil[4]

(6) **Right edge of the foot as a weak licensor in Tamil (Vijayakrishnan 1999)**

Verb Roots

i.	[t̲ura]	'renounce'	ii.	[kud̲i]	'jump'	iii.	[puɭu] gu	'lie'
iv.	[t̲ira]	'open'	v.	[mid̲i]	'step on'	vi.	[iru]	'be'
vii.	[mara]	'forget'	viii.	[pari]	'pluck (fruit/flower)'	ix.	[aʐu]	'cry'
x.	———[5]		xi.	[koʐi]	'become rich'	xii.	[koɖu]	'give'
xiii.	———		xiv.	[eri]	'burn'	xv.	[peru]	'get'
xvi.	*[ma:r]a		xvii.	*[ku:ʐ]i		xviii.	[o:ɖ] u	'run'
xix	*[maŋg] a		xx.	*[koŋg] i		xxi.	[t̲oŋg] u	'hang'

Notice that the vowels /a/ and /i/ are not allowed outside the foot in Tamil verbs. The gradation of markedness as it emerges is the following: The head of the foot licenses all the vowels; the weak edge licenses /a/ and /i/ and the least marked of the vowels i.e., /u/ is allowed everywhere, even outside the foot. The CH in (7) below accounts for these facts.

(7) **Partial constraint hierarchy for strong and weak licensing within the foot**
Align {PrWd; left}
>>
*[mid vowels]
>>
Align {PrWd; right}
>>
*[low/high coronal]
>>
Max[–consonantal]
>>
*[high, dorsal]

While the order of the alignment constraints is controlled by the sequencing principle in (5) above, the ranking of the vowels is governed by universal markedness constraints.[6] Thus the theory can predict that there cannot be grammars where the ranking of the alignment constraints and/or the ranking of the vowel features is reversed.

We saw in this section how an alignment approach to feature markedness captures weakening as the converse of licensing and very, importantly, it also demonstrates the paths that weakening could take through the alignment possibilities given the universal sequencing of alignment constraints in (5). Further, only an analysis making use of alignment can explain re-location of marked features at the left edge of prosodic categories.

2. Lenition

Lenition, the process of increasing the sonority of consonants, is attested in syllable onsets – more widely in the intervocalic position, but also initially (cf. Lass 1984). Assuming the sonority scale for consonants from most to least sonorous in terms of features/feature combinations in (8) below, lenition can be characterized as an upward shift on the sonority scale.

(8) **Sonority scale for consonantal features**

[+sonorant, –consonantal]	/j, w/
[“ , +consonantal, +continuant] (frictionless continuant)	/ʋ, ʐ/
[“ , “ , ±lateral]	/l, r/
[“ , “ , spread glottis, ±lateral]	/l^h, r^h/
[“ , “ , nasal]	/m/
[“ , “ , spread glottis, nasal]	/m^h/
[–sonorant, +consonantal, +continuant]	/h/

[" , " , " , slack vocal cords, oral place]	/v/
[" , " , " , stiff vocal cords, oral place]	/f/
[" , " , slack vocal cords]	/b/
[" , " , spread glottis, slack vocal cords]	/b^h/
[" , " , stiff vocal cords]	/p/
[" , " , spread glottis, stiff vocal cords]	/p^h/
[–sonorant, " , constricted glottis]	/ʔ, $p^ʔ$/

Lenition may be argued to be a universal tendency grounded in articulation being an assimilatory process which increases the sonority of the prototypical consonant – the obstruent, in the neighbourhood of the prototypical sonorant – the vowel.[7,8] Adopting the 'harmonic' approach to constraint formulation in Prince and Smolensky (1993), we can formulate lenition as 'Harmonic Sonorancy' (henceforth Hson). Like Hnuc in Prince Smolensky, this constraint takes the entire range of featural specifications determined by the grammar of a language and evaluates them in tandem. It targets only onsets because the primary condition for lenition to take place is that the obstruent should be followed by a vowel and only onsets are possible in that environment. We formulate Hson as in (9) below.

(9) **Harmonic Sonorancy (preliminary version)**
V [obstruent] V ≻ V ↑ C V (where '↑' stands for the upward shift on the sonority scale in (8))[9]

We illustrate the operation of Hson with an instance of intervocalic lenition which is exceptionless in the verb phonology of contemporary Tamil. The data presented below pertains to labials, dentals and dorsals in the verbal paradigm in Tamil.

(10) **Tamil consonantal inventory**

Labial	Corornal	Dorsal
p, b, m, ʋ	t̲ , d̲, n	k, g, h, ŋ

(11)

	Suffixal alternations	**Input**	**Class I**	**Class II**
i.	present tense	kir	hir	kkir
ii.	past tense	t̲	d̲	t̲t̲
iii.	future tense	p	ʋ	pp
iv.	nominal suffix	kai	hai	kkai
v.	nominal suffix	t̲al	d̲al	t̲t̲al
vi.	nominal suffix	pɨ	ʋɨ	ppɨ

The verbal paradigm can be analysed by setting up two lexical classes (cf. Vijayakrishnan 1982). If we assume that gemination in Class II verbs is either triggered by a rule or is the result of stem-final root specification [–sonorant, +consonantal], and if so, then Class I verbs exemplify lenition across place distinctions as shown in data in (12) below.

(12) **Lenition in the verbal paradigm in Tamil**

Verb Class I			Verb Class II		
i.	paɳi	‘serve’	ii.	paɖi	‘read’
	paɳihir			paɖikkir	‘present tense’
	paɳiʋ			paɖipp	‘future tense’[10]
	paɳiʋɨ	‘humility’		paɖippɨ	‘study’

Taken individually, we find that /p/ undergoes sonorization to /ʋ/, /t̲/ gets voiced and /k/ fricativizes to /h/. However, seen in the context of the consonantal inventory of Tamil in (10), we find that the sonority of the consonants is maximized to the extent allowed by the language (excluding nasals). Since place features, nasal, lateral and [–consonantal] are not involved, we postulate an undominated Max/Dep place, nasal, lateral, [+consonantal] in the CH of Tamil. As we said earlier, Hson evaluates all the candidates in tandem grading them in order of increasing harmonicity. Therefore, for instance, if /p/ is matched with /b/, /m/, /ʋ/, /l/ and /u/, the harmonicity increases progressively shown as /p ≺ b ≺ m ≺ l ≺ ʋ ≺ u/ as the sonority of the segments on the right increases progressively. However, the higher ranking Max/Dep place, nasal, lateral and consonantal rule out /m/, /l/ and /u/ as possible candidates. Thus, /ʋ/ is the optimal candidate. We give the relevant CH in (13) and illustrate its operation in the tableau in (14) below with the input /VpV/.

(13) **Partial constraint hierarchy for lenition in Tamil**

Max/Dep place, nasal, lateral, +consonantal
>>
Hson V ↑CV
>>
Max continuant, sonorant, slack vocal cords

(14) **Evaluation tableau for Tamil lenition**

	Max/Dep	Hson	Max
a. → Vʋ V	–	p ≺ b ≺ ʋ	*, * * *
VbV	–	p ≺ b!	*
VmV	*! nasal	p≺ m	**
V uV	*!+cons	p ≺ u	****
V lV	*! place	p ≺ l	****
b. VpV		* !	

We see that the CH of Tamil allows us to maximize sonorization carefully preserving place, nasal, lateral and [+consonantal] distinctions. We consider two further issues which are pertinent in the context of lenition in Tamil. The issues are: (a) the relationship of Hson to the align constraints in Tamil, in particular, and the ranking possibilities of these two constraint schemas in general and (b) how exceptions to lenition should be dealt with.

Taking up the first issue, since productive lenition in Tamil affects only suffixal consonants, obviously, Align constraints do not interact with Hson. But if we look at instances of lenition in early borrowings from Sanskrit, we find evidence for the domination of Hson by Align {left; word}. For instance, initial /p/ never lenites; but medial /p/ does to /ʋ/ as in /pa:pa > pa:ʋam/ 'sin', /t̲apa > t̲aʋam/ 'penance' (also see below).

However, Hson stated the way it is, will never interact with Align left since there is an initial vowel/sonorant in the formulation of the constraint. But, perhaps, since initial onsets also are leniting contexts as mentioned earlier (cf. Lass 1984), in principle, there ought to be some interaction between Align left and Hson. We assume that in a language where initial onsets undergo lenition, medial onsets would too. So we re-formulate the Hson appropriately in (15) below.

(15) **Harmonic Sonorancy (revised version)**
(Son) C V ≻ (Son) ↑ C V ('↑' stands for the upward movement on the sonority scale)

We consider the case of Boro (Bhattacharya 1977) as an instance of initial and medial, exceptionless lenition. Boro is a tribal language belonging to the Boro sub-group of the Bodo-Naga section of the Tibeto-Burman languages spoken in Assam in the north-east of India. In this language, voiced, plain stops contrast with voiceless aspirated stops in onsets. This could be argued to be a case of input contrast between the presence and absence of the specification [spread glottis]. Logically, then, the voicing of stops in onsets, exemplified in the data in (16) below, would be a case of initial and medial lenition.

(16) **The distribution of stops in Boro (Bhattacharya 1977)**

i.	^{2}gɨ^{1}brap	'difficult'[11]
ii.	^{2}gi^{1}dit	'big'
iii.	^{2}ba^{2}t^{h}ra	'information'
iv.	^{2}t^{h}a^{1}dum	'a sort of rum'

Assuming that stops are specified only for [spread glottis] in the input representation, we propose the CH in (17) for Boro.

(17) **Partial constraint hierarchy for Boro**
Max/Dep sonorant, continuant, spread glottis, *[spread glottis, slack vocal cords], *[+continuant, slack vocal cords]
>>
Hson
>>
Align {word; left}, Align {syllable; left}
>>
Dep. slack vocal cords

Informally, the feature [slack vocal cords] is epenthesized for onset stops when not specified for [spread glottis], initially violating Align left. Thus we see the subordination of an alignment constraint in the case of initial lenition.[12]

Having sorted out the potential ranking of Hson with respect to alignment, we turn to the second problem, namely the problem of exceptions, partial or total. In the intervocalic context the pattern discussed for verbs is, as mentioned earlier, applicable, perhaps, only to early loans from Sanskrit. But some loans from Sanskrit undergo partial lenition and, finally, Sanskrit-based proper names and recent loans from English (at least in my dialect) do not undergo lenition at all. The pattern is illustrated in (18) below.

(18) **The three phases of lenition in Tamil**

Labials	Dental	Dorsal
Phase I		
i. ṯapa ~ ṯaʋam ‘penance’	ii. aṯi ~ aḏi ‘excessive’	iii. maka ~ maham ‘a star’
iv. sulab^{h}a ~ sulaʋam ‘easy’	v. raṯ^{h}a ~ raḏam ‘chariot’	vi. suk^{h}a ~ suham ‘happiness’
		vii. ra:ga ~ ra:ham ‘Raga’
		viii. me:g^{h}a ~ me:ham ‘cloud’
Phase II		
ix. ça:pa ~ ça:bam ‘curse’		
x. kap^{h}a ~ kabam ‘phlegm’		
xi. ɲa:paka ~ nja:baham ‘remembrance’		
xii. rupija: ~ ru:ba: ‘rupee (Hindi)’		

Phase III[13]

xiii.	ru:pa: 'a name'	xiv.	ra<u>t</u>an 'a name'	xv.	ra:ke:ʃ 'a name'
xvi.	ab^{h}ayam ~ abayam 'a name'			xvii.	nagara ~ nagar 'a locality in a town/city'
xviii.	kabi:r 'a name'				

Notice that in Phase two the lenition process stops at /p~b/ and does not go on all the way. In other words, phase two lenition does not violate the input specification [–sonorant]. Thus, to capture the transition from Phase I to Phase II all we have to do is postulate an undominated Dep[+/–sonorant] along with the other undominated constraints in (13). And finally, in Phase III, there is no lenition at all. Seen this way, perhaps, the diachronic evolution of the progressively weakened lenition process is reflected in the dominance of the constraint Hson by more and more Max constraints until it is too weak to be visible. However, when we are dealing with contemporary Tamil, it is not desirable to postulate separate compartments of Tamil vocabulary with different constraint rankings.

One possible approach, which we take here, is to assume a minimum of prespecification in the input representation and adding the undominated constraints Maxlinkroot (to include sonorant and consonantal) and Maxlinklaryngeal (to indicate stiff or slack vocal cords) to the CH in (13). In plain English, the input representations of the targetconsonants in the three phases are made to be significantly different so that CH can evaluate them appropriately. The input representations of the labial consonant in the leniting environment in the three phases are given below in (19) below. Ignoring place specification, which is always invariant and hence part of the input representation, the least specified Phase I contains specification only for the feature [+consonantal] and all the three segments (which are distinctive elsewhere) emerge as a labial, frictionless continuant sonorant. For the vocabulary items in Phase II, the specification for sonorancy is added and the sonorant/obstruent distinction is respected by Hson. Finally, in Phase III, the three labial consonants have distinct specifications and Hson has no power to change any specification. We give the suitably revised CH below in (20).

(19) **Input representations of the labial consonant in the three phases of lenition**

Phase I	/p, b, ʋ →ʋ/	Phase II	/p, b →b/	/ʋ →ʋ/
	[+cons.]		[+cons., –son.]	[+cons., +son.]
	|		|	|
root	•		•	•
lar.				
Phase III	/p→p/		/b→b/	/ʋ→ʋ/
	[+cons., –son.]		[+cons., –son.]	[+cons., +son]
	|		|	|
root	•		•	•
	|		|	|
lar.	[stiff vc]		[slack vc]	[slack vc]

(20) **Partial constraint hierarchy for lenition in Tamil (revised version)**

Max/Dep place, nasal, lateral, Max link root, Max link laryngeal
>>
Hson V ↑CV
>>
Max continuant, sonorant, slack vocal cords

If the link is not parsed in the output representation in an attempt to obey Hson, Phase II or III inputs would incur the fatal violation of Maxlinkroot and/or Maxlinklaryngeal. The obvious advantage of this solution is that the CH and the increasingly maximally specified inputs across Phases I–III reflect the evolution of voicing in Tamil phonology.

3. Conclusion

In this paper an attempt was made to account for processes of weakening in the OT framework. While the non-parsing of marked features in designated weak positions was accounted for in terms of align constraints making out weakening as the converse of positional markedness, a new constraint schema was proposed to account for lenition which, like the constraint schema Hnuc of Prince and Smolensky evaluates competing candidates for harmonicity. Lenition was argued to be primarily a process of assimilation which enhances the sonority of the proto-typical obstruent in the vicinity of the proto-typical sonorant – the vowel.

Notes

* I am grateful to an anonymous reviewer for helping me strengthen the argumentation and spell out the ranking possibilities of align constraints within the alignment schema and also with respect to the newly proposed constraint family- Hson. Of course I am solely responsible for the remaining unclarities and misunderstandings, if any.

1. Sandhu (p.c.) reports that this word is pronounced with a final, long vowel the function of which is not quite clear, as the Jamshedpur variety does not have suffixal plural marking.

2. If one accepts the claim in van de Vijver (1998), of course, since the iamb is not an independent foot type, nothing more need be said. However, even if the iamb is taken to be one of the universal building blocks of prosody, one does not, for some inexplicable reason, come across any example of an iambic typology where marked elements (especially features) occur only to the right edge of the foot. Thus, the constraint ranking proposed here in terms of a universal ranking typology of alignment constraints is independent of claims regarding foot typology and the formalism for denoting the head.

3. However, see Mascaró and Wetzels (1998).

4. Except retroflex sounds which are not licensed initially in literary Tamil. Perhaps this should be explained in terms of a negative alignment requirement (see Vijayakrishnan 1998).

5. The mid vowels can be followed only by high vowels underlyingly, though there is a rule of lowering of high vowels when followed by a low vowel (see Vijayakrishnan 2000 for details).

6. Though there must be some leeway in the ranking of the three basic vowels /a, i, and u/ across languages.

7. What counts as a leniting environment is fairly heterogenous. Whereas in some languages lenition is attested only intervocalically (ignoring nasals), other languages permit lenition after all sonorants e.g., Meitei (Manipuri) where obstruents are voiced after vowels, liquids and nasals. Tamil seems to exemplify a mixed typology, having overlapping lenition strategies for post-sonorant and post-vocalic contexts. For clarity of presentation, we assume that the verbal paradigm is a post-vocalic one. In the post-sonorant context, firstly there are exceptions in the verbal paradigms and secondly, whereas verb-final /ʐ, r/ follow the vowel pattern in softening /k, p/ to /h, ʋ/ respectively, /l, ɭ/ harden to /n, ɳ/ respectively, in the past tense forms but follow the post-vocalic pattern elsewhere. Furthermore, the intervocalic lenition strategy is also attested in earlier borrowings from Sanskrit. We take up the latter under "exceptions" below.

8. The converse of lenition is fortition which, according to Lass (1984) is attested in initial onset and pre-consonantal positions. Fortition may said to be perception-based, the need to strengthen margins, making them as different from the nucleus as possible.

9. Typically, if a language exhibits lenition after liquids, it also attests the process after vowels and nasals, and if after vowels then after nasals as well. The reason for this implicational hierarchy 'liquid ⊃ vowel ⊃ nasal' is not quite clear.

10. The past tense form takes a nasal augment. For the sake of clarity of presentation, the wrinkle caused by the past tense forms is ignored in this paper.

11. The transcription is as in Bhattacharya (1977) where superscript numerals indicate tone on decreasing levels of pitch with '0' denoting toneless syllables.

12. The initial onset can also be subject to fortition (cf. Lass 1984), in which case there is room for conflict between alignment, Hson and the constraint schema responsible for fortition. A discussion of this issue would take us too far afield.

13. It is not the case that the distinction between Phase II and Phase III is that of common nouns vs proper nouns. Take the case of the word /swa:ṯi/ 'a star' for instance. This word is pronounced /swa:ḏi ṯiruna:ɭ/ 'name of a music composer' as Phase II but when referring to the star, it is pronounced /swa:ṯi/ – Phase III. It is interesting to note that the first part of the composer's name is due to the star which is considered his 'birth star' in Indian astrological terms.

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Base joint configuration in Sign Language of the Netherlands

Phonetic variation and phonological specification*

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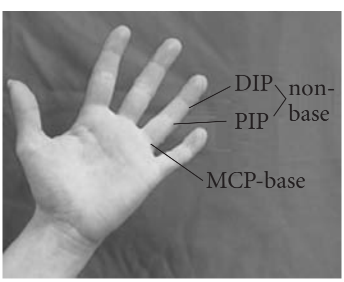
1. Introduction

Early phonological analyses of sign languages proposed that a sign consists of feature values for four parameters: handshape, orientation of the hand in space (e.g. palm up, fingers away from the body), place of articulation (or location), and movement (features such as shape, repeated, and alternating). This paper deals with what has traditionally been called handshape (Stokoe 1978). In refering to different handshapes, we will be using the terms "base joint(s)" and "non-base joint(s)". These are illustrated in (1).

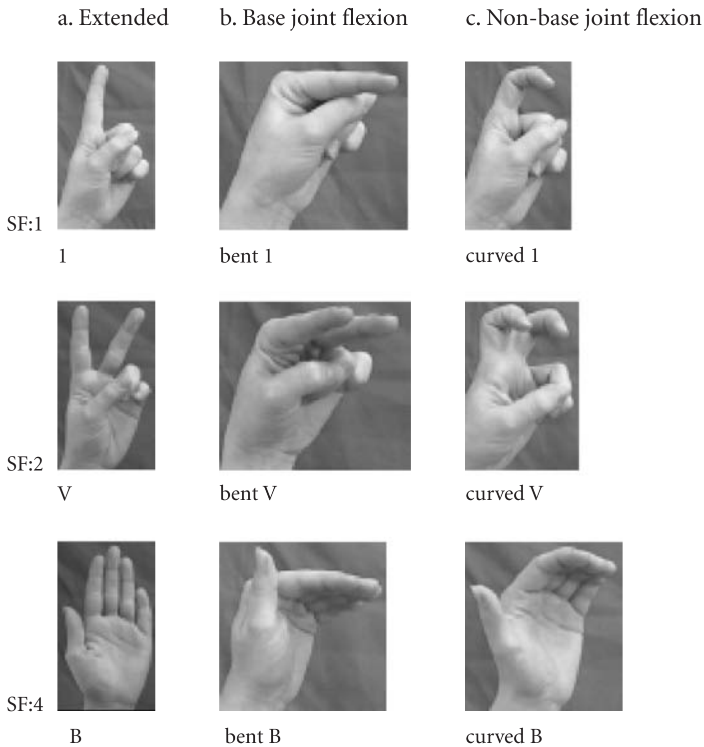
(1) Joints of the fingers

DIP = distal interphalangeal joint(s)
PIP = proximal interphalangeal joint(s)
MCP = metacarpophalangeal joint(s)



In the analyses of handshapes, features are proposed to distinguish different types of flexion of the fingers: base joint flexion (2b) and non-base joint flexion (2c). These are illustrated in (2) for the most common sets of selected fingers (1, 2, and 4).[1]

(2)



In Sign Language of the Netherlands (henceforth "NGT", Nederlandse Gebarentaal), these distinctions in finger position have been considered to be contrastive for handshapes with one and four selected fingers, either implicitly (NSDSK 1996, 1997a, b) or explicitly (Schermer et al. 1991). These distinctions have also been argued to play a role in other sign languages (e.g., Corina 1990 for American Sign Language, henceforth "ASL").

In this paper, we claim that the position of the base joints of the hand do not play a role in the phonological system of NGT. We argue that the phonological status of this joint in handshape models is not based on its contrastive function in the lexicon or its role in phonological processes, but rather is a historical relic of the phonemic analysis which started with Stokoe (1978), which considered handshape as a whole to be a phoneme. The position of the base joints, we argue, is not a part of a phonological entity "handshape", just as the position of the wrist is not a part of it. Because the position of this joint follows from other factors, such as the orientation of the hand with respect to the location, nobody has ever suggested features for wrist flexion.

There are two reasons for denying base joint position a phonological status. Our main argument is that the base joint position is not distinctive: we do not find minimal pairs based on base joint position. Our second argument concerns the abundant variation in flexion of the base joints in different realizations of a sign in different and similar contexts, within and across signers. The variation that we observed is gradual (from 0 to 90 degrees) and concerns not only lexical signs but also productive classifier constructions.

Although the idea that base joint flexion is not always contrastive is not completely new (see remarks on Norwegian Sign Language in Greftegreff 1993; Mandel 1981; and Boyes Braem 1981 on ASL), to our knowledge the factors that may determine base joint flexion (or extension) have never been examined systematically or studied in a large set of data. No feature system for handshapes has made the claim that only one flexion feature is needed and that we can do away with base joint flexion in the underlying representation.

If base joint flexion is not a distinctive feature of signs (a fact that still has to be established), what are the factors determining its position? That is another question we want to answer. We identified three factors that play a role in determining the actual position of the base joint in phonetic implementation. The analysis results in a proposal for the phonological representation of the position of the fingers that is simpler than other phonological analyses. In our model no special status is given to the notion "handshape", as we treat the base joint in the same manner as the wrist. Instead we propose the concept of "articulator", which does not entail exactly which part of the arm and hand is involved.

The paper is organized as follows. In Section 2 we review the literature on handshape, focusing on what other researchers have written about the base joint. In Section 3 we present our arguments for the non-phonological status of base joint features. In Section 4 we discuss the phonetic implementation of the base joint, that is, how does the state of the base joint end up the way it does in specific realizations of different signs? In Section 5 we sum up conclusions and highlight some areas for future research.

2. Previous research on finger configuration

Early descriptive works treated the handshape as a phonemic unit: each handshape received a name or a symbol (Stokoe 1978 for ASL; Harder & Schermer 1986 for NGT). It has been argued that the conception of handshapes as holistic phonemes is problematic. For instance, it remains unexplained why handshape changes cannot involve any random pair of handshape phonemes. Because these changes are restricted, Mandel (1981) proposed a distinction between *finger selection* and *finger configuration*, and this distinction has been used in handshape models ever since (e.g., Sandler 1989; Corina 1990). One or more fingers can be phonologically relevant, and features apply to these selected fingers to determine their bending at different joints and in different degrees. Mandel (1981) was also the first to state that the base joint can act distinctively in the phonology of ASL.

A feature referring specifically to the base joint is also invoked to describe movement at this joint . For example, Liddell (1990) and Liddell and Johnson (1989), who refer to this change in handshape as "flattening", have a feature to account for this movement in their model. Earlier, Friedman (1976) coined the term "bend-knuckles" for this movement. Similar use of a feature referring to the base joint has been made by Sandler (1989), Uyechi (1996), and Brentari et al. (1996), among others.

The description of finger configuration can be further subdivided into three categories (Brentari et al. 1996):

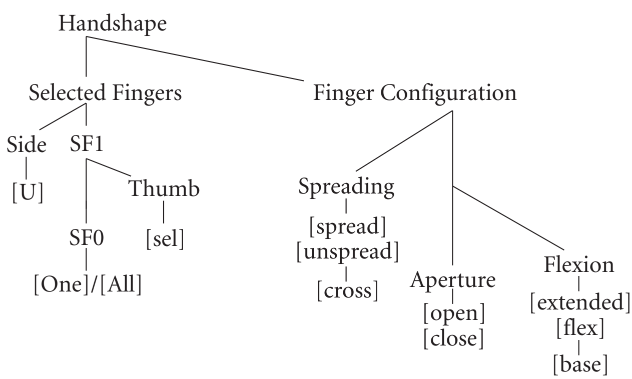
1. *spreading*: the abduction of two or more selected fingers at the base joint
2. *aperture*: the opening relation between the selected fingers and the opposed thumb[2]
3. *flexion of the fingers*: flexion at the base joints is distinguished from flexion at the non-base joints, and the degree of flexion has also been acknowledged as phonologically relevant

Spreading is a feature that can only be specified over sets of more than one selected finger, and it plays a limited role in contrasting different signs in the lexicon. Aperture has mainly been discussed in the context of hand internal movements (movements of the fingers and thumb). Flexion of the selected fingers seems to be more important in distinguishing different handshapes, as a further distinction has been made within this category: flexion of the base joints is distinguished from flexion at the non-base joints.

In the literature on ASL, the feature referring to the base joint position has always been assumed to account for the difference between the "B" and "bent B" handshapes.[3] No model accounts for the fact that this feature also predicts the occurrence of the non-existing "bent V" and "bent 1" (among others) as distinctive handshapes.[4] For NGT, however, the bent index finger is adopted in the set of handshapes (Schermer et al. 1991).

In this paper, we take the handshape model of Brentari et al. (1996), illustrated in (3), as our starting point. The model uses the framework of dependency phonology (Dresher & van der Hulst 1994). In this framework, phonological structures are binary branching, and the two nodes stand in a head-dependent relationship to each other. Each dependent node adds complexity to the representation of a head, thus expressing markedness. The main distinction in the model is between finger selection and its dependent finger configuration. We will ignore the finger selection node here. The finger configuration node dominates spreading, aperture and flexion. Under the flexion node, the dependent value [base] specifies the type of flexion and contributes to greater complexity of the sign. [flex, base] is realized as flexion at the base joints. However, in the motivation of this feature, no specific claim is made regarding its distinctivity. Our main aim here with respect to the phonological representation is to show that we do not need the feature [base].

(3) The model proposed by Brentari et al. (1996)



There has been some anecdotal discussion of allophonic variation between handshapes differing in base joint flexion only. Friedman (1976) suggests that bent B (90 degree base joint flexion) occurs as an allophone of B as the end position of a movement at the base joint, and also in "nonlexicalized gestures such as one indicating the surface and sides of a table" (p. 20). Alternation in base joint flexion also occurs in fingerspelling of M and N (3 and 2 fingers selected, respectively). Boyes Braem (1981) mentions that bent B seems to function as a free variant of the B hand. She links this observation to contact, either with the body or the weak hand. She also specifically mentions signs where the back of the hand contacts the face. Greftegreff (1992) argued that for indexical signs (signs in which the selected index finger points to a real or imaginary object), the orientation of the finger tip is the crucial perceptual target, and the flexing of the index finger joints is subordinate to this. Wallin (1996) notes that for some classifiers with 1, 2 or 4 fingers selected, alternate versions exist that have 90 degree base joint flexion. He states that these are "allomorph[s] which [are] articulatorily conditioned" (p. 108), but does not discuss what he means by this, nor when these alternates occur.

3. Two arguments

In this section we offer two arguments for the non-phonological status of the base joint position. Our first argument is the lack of minimal pairs. Secondly, we argue that we do not need a feature specifying base joint states to correctly describe the surface representations of citation forms of signs that either have 90 degree base joint flexion in their citation form, or that have movement at the base joint.

3.1 No minimal pairs

One of the reasons to assume the existence of a phonological feature is that it systematically distinguishes between minimal pairs in the lexicon in a particular language.[5] In the finger flexion node at least two types of flexion have been distinguished (see Section 2); flexion of base joints and flexion at the non-base joints. Non-base joint flexion is distinctive in signs containing all sets of selected fingers, as is illustrated by the following minimal pairs.

(4) Minimal pairs differing in flexion of the non-base joint

Selected fingers	flexed	non-flexed
1	HOER 'whore'	BEKWAAM 'able'
2	HUREN 'to rent'	AFHANKELIJK 'dependent'
4	KARAKTER 'character'	OPGELUCHT 'relieved'

(5) Example: HUREN – AFHANKELIJK[6]

For base joint flexion, however, there are no such minimal pairs. Of course it is impossible to conclusively demonstrate the non-existence of minimal pairs. There may be a pair of signs that we overlooked, or a new sign might be coined that is distinguished by base joint position only. In fact, finding minimal pairs is the task of those who claim base joint flexion to be phonologically relevant. As mentioned above, this has not been done in the literature that we know of. In (6), some conceivable minimal pairs of signs are given, one member being an actual citation form of the sign (the underlined form), the other being a conceivable but non-existing sign. In many cases this other member is a possible variant of the actual citation form.

(6) Actual citation forms and their minimally contrasting counterparts

in space:	ROEPEN 'to call' with bent B or B (latter feels awkward)
	KIJKEN 'to look' with V or bent V (actual free variants)
	INDEX (index) with 1 or bent 1 (depends on what is pointed at)
on the body:	OOK 'also' with B or bent B (latter feels awkward)
	BROER 'brother' with V or bent V (latter feels awkward)
	GEWOON 'plain, simply' with 1 or bent 1 (latter feels awkward)
on the head:	KENNEN 'to know' with B or bent B (actual free variants)
	PROBEREN 'to try' with H or bent H (actual free variants)
	VERLEGEN 'shy' with 1 or bent 1 (actual free variants)

Next to these constructed minimal pairs we found a few potential minimal pairs, examples of which are given in (7) and (8). We will argue in Section 4 that these pairs do not differ in handshape, but rather in their orientation and location specifications.

(7) Example: HOND vs. WACHTEN

Both signs in (7) consist of a repeated downward movement in front of the lower chest, palms facing downwards. HOND 'dog' has base joint flexion, WACHTEN is made with the base joints extended. Comparable pairs of signs are: STOPPEN 'to stop' vs. ROEPEN 'to call', BAKKEN 'to bake' vs. NEUKEN 'to fuck'.

(8) Example: AUTORIJDEN vs. ROEPEN

AUTORIJDEN 'ride a car' is a classifier predicate consisting of a B hand, palm facing downwards, base joints extended.[7] The fingertips refer to the front of the car, the palm side of the hand represents the bottom of the car. The sign ROEPEN 'to call' is a so-called "orientational verb" (Bos 1993) made with flexed base joints. The palm and fingertips point in the direction of the object of the verb. The handshape of the sign AUTORIJDEN differs from the sign ROEPEN in base joint flexion only.

The question is why we do not find minimal pairs as in (6), why some of these pairs are free variants, and how apparent minimal pairs such as HOND vs. WACHTEN and AUTORIJDEN vs. ROEPEN are to be phonologically specified. In Section 4 we will try to answer these questions by linking the occurrence of bent B to other formal aspects and to semantic-morphological or iconic motivation of the shape.

3.2 No role for a feature [base] in the description of surface forms

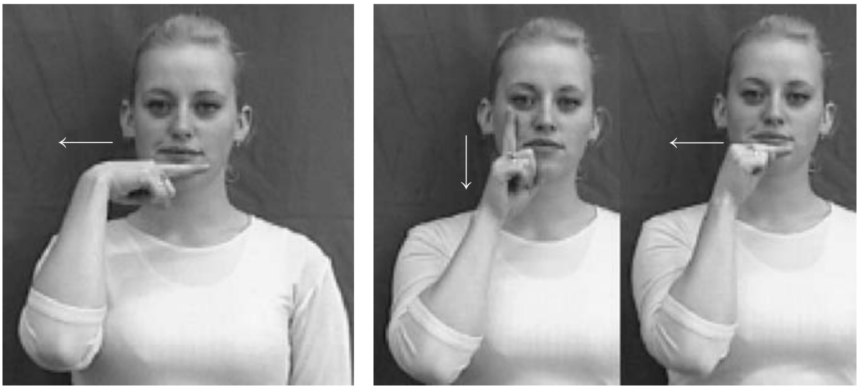
3.2.1 *Signs with base joint flexion in their citation form*

The data we used to investigate the potential contrast between signs with base joint flexion and signs without base joint flexion came from different sources. The main source was SignPhon, a phonetic-phonological database (Crasborn 1998; Crasborn et al. 1998). We also used dictionary CD-roms made for educational purposes (NSDSK 1996, 1997a, b). Both sources offered the opportunity to compare most of the signs in their citation form to a version of the same sign in context.[8] We found a great deal of variation in base joint position when comparing citation forms versus forms in sentence context. Because in most cases we could only compare the citation form to one instantiation of the sign in (a random) context, we cannot make any significant generalization as to the nature of the influence of context. However, the frequent occurrence of variation in base joint position across the lexicon, for both flexed and unflexed citation forms, demands an explanation.

Both for signs with extended fingers (that is, without base joint flexion) and for signs with (90 degree) base joint flexion in the citation forms, we find variation in the actual amount of base joint flexion in different realizations of the sign. In fact, the whole range of possible amount of flexion occurs, from –30 degrees (hyperextended), as in PINGUÏN 'penguin', to 90 degrees (flexed), as in ROEPEN 'to call' (see the illustration in (8) above). This contrasts with claims about other sign languages that there are two allophones of some handshapes, one with 0 and one with 90 degree flexion (Wallin 1996 for Swedish Sign Language).

Not only did we find variation in base joint position between signs in citation form versus sentence context, but we also found variation in the realization of the base joint in different morphological contexts. The NGT compound sign OUDERS 'parents' is composed of the signs VADER 'father' and MOEDER 'mother'. In citation form, both composing signs are generally articulated with an extended index finger. In the citation form of the compound, however, the sign MOEDER is found with the index finger flexed at the base joint, whereas the part VADER has the base joint of the index finger extended (see the illustrations in 10).

(10) MOEDER in isolation and as part of the compound
OUDERS (VADER+MOEDER)



Different morphosyntactic contexts can also give rise to different base joint positions. For instance, in the verb sign BEZOEKEN 'to visit', a B-hand moves from a location near the semantic source to a location near the semantic goal, the fingertips pointing in the direction of the goal. If the goal of BEZOEKEN is the first person, we always find base joint flexion, despite the fact that it *is* possible to touch the chest while bending the wrist, thus leaving the base joint position of the citation form unaltered.

(11) 1-BEZOEKEN-2 'I visit you' and 3-BEZOEKEN-1 's/he visits me'

In an earlier study, one of the authors looked at multiple instances of one single sign, ZEGGEN 'to say' (Crasborn 1997). In the citation form, this sign had an extended index finger for all three subjects, whereas in 15 out of 44 context forms there was some degree of base joint flexion. There, too, this flexion was not always 90 degrees. In that study, as in the present one, no generalizations were made about the phonological nature of the sentence context (in terms of the form of preceding and following sign, and the sentence prosody).

In order to find out what may determine this variation and the specific base joint state in the citation form we examined signs that contain handshapes with base joint flexion in their citation form (these shapes are illustrated in (2b). We assumed that especially these signs would be good candidates for an underlying specification of [base]. In total, we found 225 different signs that were specified with bent handshapes, in either the SignPhon database or the dictionary CD-roms, or in both. (We did not consider handshapes containing an aperture specification, although in Section 4.1 we will discuss the influence of aperture specification on base joint flexion.)

Examining these citation forms, we found that other formational aspects of the sign seemed to determine the actual state of the base joints: in none of them, a *phonological specification* of base joint flexion is needed to determine the phonetic surface form. We distinguish the three situations listed in (12).

(12) Factors explaining base joint flexion in citation forms
  a. aperture specification
  b. relative orientation and location specifications
  c. the presence of semantic motivation of the articulator shape

We will discuss these three aspects in the next section. We consider these three factors to be mainly responsible for the occurrence of base joint flexion in the

225 citation forms that we found. In establishing this set, we left out handshapes involving aperture specifications. The distribution of these signs over the two other factors (12b, 12c) is given in (13). The distinctions within the categories will be discussed in Section 4.

(13) Frequency of the different factors

Selected Fingers	Space	Body	Relative Orientation Total	Shape	Delimiter	Semantic Total	Rest
1 (n = 95)	47	48	95 (100%)	–	–		
2 (n = 15)	10	5	15 (100%)	–	–		
4 (n = 115)	37	28	65 (57%)	18	18	36 (31%)	14 (12%)

From this table, one can conclude that relative orientation is an important factor for all sets of selected fingers, whereas semantic motivation only seems to play a role in All-shapes (4 fingers selected). In the category of 4-hands, 14 signs (12%) are left. All of these signs containing a bent-B were either in free variation or a variant of C (the handshape illustrated in (2c), picture at the bottom).

Of the three factors, the role of relative orientation is most prominent in terms of frequency. Moreover, it is also important in that it plays a role in two other situations. First, we will argue that the potential minimal pairs mentioned in (7) and (8) above can be analyzed as having the same articulator specification, but different orientation and/or location specifications. Second, we will hypothesize that the same line of reasoning that we use to explain the bent citation forms can be applied to predict the base position state of *any* sign in different contexts, whether sentence context (coarticulation) or sociolinguistic context.

3.2.2 *Signs with base joint movement in their citation form*

A few signs have a change in base joint position in their citation forms. At first sight, these seem to behave parallel to signs with movement at the non-base joints, such as AFHANKELIJK ‘dependent’, WC ‘toilet’, or FOTO ‘photo’, which have a contour for the feature [flex]. We propose that contrary to these changes in the non-base joint, the changes in base joint position are not phonological, but are in fact a realization of a path movement (that is, a change in location), as was briefly suggested by van der Hulst (1995).[9] An example of such a change is the sign AANBIEDING ‘offer (n.)’.

(14) Base joint movement: AANBIEDING

Other examples are LIKKEN 'to lick', SEPTEMBER 'September', AUGUSTUS 'August', LAAT 'late', WARM-eten 'warm (of food)', WARM-weer 'warm (of weather)', VROEGER 'in the past, previously'.

Uyechi (1996) argues that in ASL, the sign PAST has three different forms: one with base joint flexion, one with wrist flexion, and one with elbow flexion. They seem to be in free variation. The same sign in NGT (glossed as VERLEDEN) does have different meanings signalled by the different articulations, referring to the recent, neutral, and more distant past, respectively. We do not consider these data to contradict our proposal. In many constructions in NGT, the size of the movement can modify the lexical meaning of the morphemes involved. In so-called classifier predicates, changing the size of the movement is used to express changes in size of the objects, movements, etc. that the signs refer to.

Uyechi suggests that these three forms have three different phonological representations. They are, respectively, a handshape change, an orientation change, and a location change. Our proposal makes it possible to see all of these movements as location changes, with constant location, relative orientation and finger selection specifications. What differs is not the phonological specification of the movement, but rather the size of the phonetic realization of this movement. (Actually, this can be expressed in different ways, as the size of the moving articulator varies, as well as the size of the path that the endpoint of the articulator traces through space.)

4. Factors involved in determining base joint position

In this section we will demonstrate how different aspects of the sign give rise to various configurations of the base joint. As we pointed out above, we consider this in principle analogous to determining the (prototypical) wrist state for a given sign in its citation form. Although the latter has never been done before, we consider it part of our task here to discuss the phonetic implementation of the base joint state. This is not just interesting in itself, but a necessary step in demonstrating that base joint flexion is not phonologically specified, but predictable from other factors.

4.1 Aperture

One set of handshapes that involve flexion at the base joint are handshapes with an aperture specification. In the handshape model in (3), two aperture features were introduced, [open] and [close]. Aperture, as we saw in Section 2, specifies the relation between an opposed thumb and the selected fingers. In combining these aperture features with the two features for finger flexion we end up with a four-way contrast, as is illustrated in (15) for handshapes with the index finger selected. The same contrast exists for handshapes with all fingers selected, and also, but less frequently, for signs with index and middle finger selected.[10]

(15) 4-way contrast in finger configuration

a. [open]

b. [close]

c. [close], [flex]

d. [open], [flex]

We propose that this four-way contrast can also be described by just one flexion feature: [flex]. If aperture consists of an opening relation between the thumb and the path of the selected finger(s), it is simply impossible to articulate this relation without flexing at the base joint. This redundant behaviour of the base joint suggests that in these cases we do not need a phonological feature to describe it. Moreover, in NGT the handshapes in (15a) and (15b), and the changes between them, are more frequent than the ones in (15c) and (15d), for any set of selected fingers.[11] This is correctly reflected by the relatively unmarked representation of the handshapes in (15a) and (15b) with one binary aperture feature only, and no flexion feature. The handshapes in (15c) and (15d), which occur less frequently, are representationally more complex in having a flexion feature as well as an aperture specification.

4.2 Relative orientation

The most important factor in determining base joint state is a combination of the specifications for relative orientation and location. To be able to make this point clear, we first have to explain what we mean by relative orientation; this is discussed in Section 4.2.1. Then, in the next Section 4.2.2 we will show how this aspect of the phonological representation of signs leads to different base joint states, and the impact this has on our conception of handshape. The phonetic motivation that underlies these phenomena is discussed in Section 4.2.3.

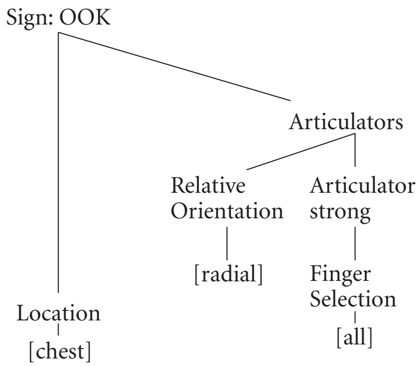
4.2.1 *The phonological representation of orientation*

Generally, the orientation of the hand has been thought of as the orientation of the hand in space. Independent of other parameters, the palm and fingers of the hand can point in any direction in space (palm up vs. palm down, for example). In some cases, this view of spatial orientation was supplemented by the specification of "facing" or "point of contact" features, specifying which side of the hand points in the direction of a location or contacts the location, respectively. In Crasborn and van der Kooij (1997), we suggested that all of these concepts could be subsumed under one feature for what we called "relative orientation": the relation between a side of the hand and the specified place of articulation. Features specified under the relative orientation node are relational and consist of a part of the hand (e.g. the finger tips, the palm, the thumb, or the pinky side of the hand). These parts, then, point in the direction of the specified location, a feature that has to be specified elsewhere in the model anyway (for example, van der Hulst 1993, van der Kooij 2002).[12]

Since only one part of the hand is specified, the remaining degree of freedom of the orientation of the hand is claimed to be predictable, and determined by the phonetic implementation of the phonological specification. We hypothesize that one will find articulatory constraints at work that favour a minimization of movement of the articulator to get to the target state (wrist flexion in the example below).

As an example, consider the sign OOK 'also', where the relative orientation value is [radial], that is, the thumb side of the articulator, and the location is on the chest. The relevant aspects of the phonological representation are given in (16).

(16) Partial representation of OOK



The actual implementation of this value in terms of orientation in space is predictable given the location specification of the sign: the simplest way of getting the articulator (the radial side of the hand) to the place of articulation involves no flexion of the wrist or base joints, leading to a fully stretched articulator, with the palm pointing diagonally down and the fingertips pointing diagonally upward. This is illustrated in (17).

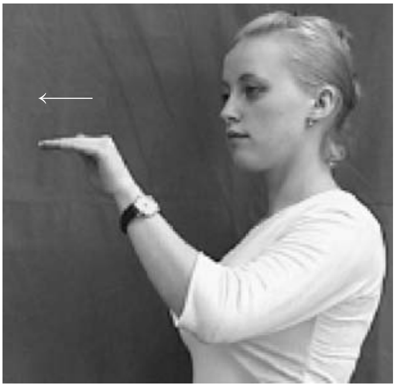
(17) Configuration of the articulator in OOK

4.2.2 *Combinations of relative orientation and location lead to different base joint states*

The proposal that we would like to make with respect to base joint flexion is that in all cases where it occurs (except for the cases of aperture specification and the exceptions mentioned below in Section 4.3), what is kept constant is the relative orientation of the *fingers* with respect to the location. The rest of the hand, or more precisely the part of the articulator proximal[13] to the base joints (the flat part of the hand, the forearm, the upper arm), does not form a part of the phonologically relevant articulator, but rather is a part of the arm that helps implementing the location and relative orientation of the articulator (the fingers).[14]

The apparent minimal pairs that were discussed above, such as STOPPEN vs. ROEPEN, actually differ in relative orientation, and not in articulator configuration (see the illustrations in (18) below). STOPPEN has a location somewhere in the signing space at shoulder height; the actual location varies depending on the morphosyntactic context. The relative orientation value is [palm]. The phonetic realization of the citation form of this sign has the base joints extended or even a little hyperextended, the palm pointing forward and the fingers pointing upward. ROEPEN has the same location, but instead of [palm] the orientation specification is [fingertips]. In order to make the fingertips point forward at that height in space, the articulator has to be flexed somewhere, and we find that in the citation form in neutral registers, it is flexed at the base joints.

(18) A difference in relative orientation: STOPPEN vs. ROEPEN



The same difference in relative orientation specification with the same location leads to the difference between WACHTEN 'to wait' vs. HOND 'dog' (see the illustrations in (7)). For WACHTEN, the relative orientation value is [palm], so the palm side of the fingers point to their location in neutral space, a horizontal plane at waist height. In most contexts (linguistic and extralinguistic), this is most simply done by keeping both the wrist and the base joints extended. In HOND, however, the relative orientation is [fingertips], which point to the same plane. In this case, if the shoulder and elbow are in the same position, this is most easily articulated with the base joints flexed. One could also imagine, however, contexts in which the flexion that leads to the downward pointing of the fingers occurs at the wrist, or by a combination of wrist and base joint flexion.

In other minimal pairs, such as AUTORIJDEN vs. ROEPEN (illustrations in (8) above), what differs is not the relative orientation specification, but rather the location. AUTORIJDEN is made at waist or stomach height, and ROEPEN is made at shoulder height. Both signs have [fingertips] specified as their orientation. We will come back to the example of AUTORIJDEN below.

In different morphosyntactic realizations of one underlying form, such as in the different forms of BEZOEKEN illustrated in (11) above, we see the same phenomenon. The relative orientation value [fingertips] is constant, but the phonologically specified location, the object or goal of the verb, changes depending on the context. In some forms, such as 2-BEZOEKEN-1, where the fingers have to point to the chest of the signer during the whole sign, this is almost impossible to articulate without also flexing the base joints in addition to flexing the wrist joints.

The same effect of relative orientation applying to the fingers only can be seen in a subset of the handshape changes, in which base joint flexion changes during the sign, whereas the relative orientation of the fingers is kept constant while the location of the articulator changes in height. We found examples of this phenomenon in some utterances of LIFT 'elevator', GROEIEN 'to grow (of children)', and HOOG 'high', for example; this last sign is illustrated in (19) below. Like the different morphosyntactic forms in BEZOEKEN, these examples illustrate the phenomenon under discussion particularly well: the relative orientation specification stays constant, namely [palm], but the physical location of the hand changes during the sign. The easiest way to maintain the correct orientation of the hand is by flexing the base joints, being the most distal joint in the articulator that is not phonologically relevant.

(19) Change in base joint state as a correlate of a change in location: HOOG

Next to locations in space, we find the same phenomenon in the citation forms of signs with body locations. For example, LIEF 'sweet, dear (personal characteristic)', which is illustrated in (20) below, has the location value [cheek] and the orientation value [back].

(20) Relative orientation is [back]: LIEF

Similar signs on the body are IK 'I' (orientation [fingertips], location [chest]), MOE 'tired' ([ulnar], [chest]), and GENOEG 'enough' ([back], [below chin]). The distribution of base joint flexion in citation forms over space vs. body locations can be seen in the table in (13) above.

In all the examples discussed, the flexion of the base joints is a phonetic phenomenon. There are no phonological features directly leading to a particular base joint state; instead the base joints together with more proximal joints work together to achieve a phonologically specified location and orientation specification. This predicts both that there is variation between different realizations of the same sign in the first place, as well as the fact that this variation seems to be gradual (there are not just two values, "0" and "90" degree flexion). The variation is predicted to occur because from realization to realization the combination of joints that articulate the same location and orientation may differ; the precise location may also differ slightly from one realization to the next. Both predictions were borne out by the preliminary data on variation that we discussed in Section 3.2. The underlying phonetic explanation for which articulation occurs when is discussed in the next subsection.

4.2.3 *The phonetic basis: Distalization is articulatorily easy*

Our main hypothesis is that flexion occurs as a result of the desire to minimize articulatory effort, by distalizing the articulation. Distalization is articulatorily easy because it reduces the energy expense of the movement, all else being equal: the mass of the articulator that needs to be moved is smaller in the case of finger movement than for movement of the whole hand at the wrist or at the elbow and shoulder joints (cf. Willerman 1994, for a discussion of articulatory effort in speech articulation and an overview of different aspects of articulatory complexity).

In many cases, flexion at the base joint seems an efficient way of minimizing wrist flexion, and in some cases also shoulder and elbow movement, while still realizing the target output form for relative orientation and location. We predict that the same effect determines different realizations of the same sign and the shape of different lexical items with respect to each other.

For example, consider differences in height. If the orientation target is palm down, we correctly predict that PINGUÏN 'penguin' is likely to be articulated with hyperextension at the base joints, whereas VERDIEPING 'level (of a building)' has close to 90 degree flexion at the base joints. In both cases, the same relative orientation target could be reached by keeping the base joints neutral (0 degree flexion), but by respectively hyperextending and flexing the wrist instead. Apart from the biomechanical cost of moving the fingers vs. the whole hand, to produce the same height (of the end part of the articulator) the whole arm needs to be respectively lowered and raised further as well. This makes the movement more costly as well.

Note that this distalization does not apply just to the wrist vs. base joint alternation. In the example of ROEPEN above, we remarked that the elbow is flexed for over 150 degrees to bring the hand at the specified (shoulder) height in space. However, this height of the fingers could just as well be accomplished by abducting the shoulder, flexing the elbow in the same manner as in the standard articulation, and extreme adduction of the wrist, as in the illustration in (21).

(21) Alternative articulation of ROEPEN

Here, too, we suggest that the aim of reducing articulatory effort predicts the actual articulation that we find, which is favoured over alternative articulations such as the one in (18). The same goes for the sign LIEF, illustrated in (20) above. To articulate this sign without base joint flexion would require extreme effort on the part of not only the wrist but also the shoulder joint: the wrist would have to be flexed maximally, and the shoulder abducted and extended to a fair degree to raise the forearm enough to let the back of the hand and fingers point to the cheek.

Two remarks should be made at this point. First, this notion of articulatory ease by distalization should be made more explicit (as Boersma 1998, for example, does for the movement of the speech articulators) and thereby testable. Second, we can only speculate what causes the distalization effect in a specific utterance of a specific sign. In other words, in the above examples, we do not know what the factors were that promoted or allowed distalization. Presumably, factors like the ones listed below play a role:

– signing style (register)
– personal preference/style
– discourse contexts such as role shifting
– morphosyntactic contexts such as verb inflection and aspect
– position of the sign in the sentence
– the size of the signing space (in turn partly influenced by the register)
– the immediate phonetic-phonological context (coarticulation)

We predict that distalization occurs in sentence context more frequently than in the careful production of citation forms, in more informal styles rather than in formal styles, etc. (cf. Lindblom 1990). Preliminary evidence indicates that distalization is one of the main characteristics of soft or "whispered" signing, whereas proximalization is found in loud or "shouted" signing (Crasborn 1999, 2001).

Finally, it is obvious that just as for spoken language articulation (e.g. Boersma 1998), the tendency to distalize the articulation can be formalized as an OT constraint system that determines the best articulatory realization of an underlying perceptual target. This implies that we need to think more of perceptual feature specifications, a major break from the articulatory definitions of handshape in the sign language literature.[15] We still need to account for the fact that in some cases there seems to be a tendency for the articulator to be realized with extended base joints. If for a sign the underlying specification is defined in perceptual terms such as "big flat surface", then in some (sociolinguistic or other) contexts, base joint extension may result in an articulatory "candidate" that leads to a perceivable form which is better than articulations with base joint flexion would produce. We leave this, too, for future research.

4.3 Semantic motivation

There are signs that we cannot explain by either an aperture specification or a combination of orientation and location specification, such as the ones listed in (22).

(22) BAL 'ball', WERELD 'world', GROEP 'group', BORSTEN 'breasts', BILLEN 'buttocks', AARDE 'earth', VOOR 'in front of', ACHTER 'behind'

These signs are predicted to be realized without base joint flexion in their citation form. However, we consistently find them articulated with 90 degrees of base joint flexion, both in citation and context forms.

We suggest that these signs are exceptions that can be understood by taking their semantics into account. We know that formal elements of the sign can be iconically motivated or meaning bearing, as was suggested, for example, by van der Hulst and van der Kooij (to appear). In this paper on iconicity in the phonetic implementation of location, it was argued that if a location is iconically motivated, an idiosyncratic unique form-meaning relation is established based on a resemblance relation with some referent object or action.

On the other hand, as has been noted for different sign languages, metaphorically motivated form-meaning pairings of formal elements are typically not unique but occur over and over again in a language (e.g. Taub 1997, for ASL). An example is the temple as the location associated to signs expressing mental states or activities in both NGT and ASL. In this case the formal element can be seen as a bound morpheme.

We want to propose that the same two types of motivation play a role in distinguishing signs with 90 degree flexed base joints from signs which do have the predicted extension at the base joints. In all cases that we found, the signs had four selected fingers; for ease of reference we will therefore refer to them as B vs. bent B. The distribution of semantically motivated signs with base joint flexion in their citation form over the two categories can be found in the table in (13).

The first category consists of signs in which the B or bent B is used to outline or depict the shape or surface of some referent object can be productive or lexical. Examples of the latter are given in (23).

(23) B or bent B is used to outline some surface (iconic use)

a. B-hand
BERG 'mountain', HUIS 'house', TAFEL 'table', TUIN 'garden', KAMER 'room'

b. bent B hand
BAL 'ball', WERELD 'world', CONGRES 'congress', GROEP 'group', BORSTEN 'breasts', BILLEN 'bottom', AARDE 'earth'

In the signs in (23b), the base joint flexion is motivated by the shape of the represented object, or the object metaphor that is used to represent the concept, such as in GROEP. In both cases, this object has a round three-dimensional shape.

When the signs in (23a) are made higher in the signing space or closer to the body, bent B can be used, conforming to the phonetic implementation process outlined in the previous section. In signs that are made higher in space by their very meaning, such as HOOG 'high' and GROEIEN 'to grow', bent B is standard.

The second category consists of signs in which the articulator is used as a delimiter (metaphorical/morphemic use). A possible metaphorical motivation for the bent B handshape was proposed for expressions of time and spatial relations in Italian Sign Language (LIS; Pizzuto et al. 1995). Time is expressed spatially in LIS, and in most other sign languages studied to date. According to Pizzuto et al., the bent B contrasts with the B-hand in that the B-hand has neutral meaning, symbolizing a non-specific event, whereas the bent B specifies a delimited event in time or space. Examples cited include A-LITTLE-BEFORE, BEHIND and AHEAD.[16]

Also in NGT, some time and space related signs are articulated with bent B shapes (e.g. VOOR 'before, in front of', NA 'after', ACHTER 'behind' (so in both temporal and spatial contexts)).

However, we have reason to doubt the meaning component associated to the bent B. Firstly, our informant could not confirm the meaning component of "delimiter" that was claimed to be associated to the bent B shape in LIS. Moreover, the Italian researchers found that just as in NGT, the bent B shape in LIS is used in expressions of time and spatial relation in only two dimensions: the front-back and the high-low dimension. In the lateral dimension (ipsi-contra or right-left), only B-hands occur. Further, in NGT there seems to be "free" variation between B and bent B in the signs referring to time and space made in the front-back (e.g., VOOR 'in front of') and high-low (e.g., GROOT 'big') dimension. However, we do not find variation in the lateral dimension, that is, these signs are never made with a bent B shape. Our hypothesis is that the same phonetic factors as discussed in Section 4 play a role for these signs, just as for other signs.[17] For instance, the sign KLEIN 'small' consisting of an approaching movement, palms facing each other, is only attested with B-hands. If bent B were to indicate a delimited event in time or space, as the sign KLEIN would require, we would have to assume that phonetic ease of articulation overrules this iconic realization of the 'delimiter' meaning.

Another indication that phonetics is stronger than the alleged semantic motivation can be observed in the use of car classifiers. The car classifier, illustrated in (8) above, consists of a flat hand with all fingers selected and extended. This shape of the articulator roughly resembles the spatial proportions of the prototypical car. The palm side of the hand refers to the bottom of the car, and the fingertip side of the hand refers to the front of the car. Because of its strong semantic motivation we expected this shape not to be sensitive to or more resistant to the phonetic forces we discussed. However, we do find the more or less lexicalized signs AUTO-BOTSING 'car crash' and FILE 'traffic jam' with both B and bent B shapes in our data. In the sign FILE, illustrated in (24) below, the strong hand is behind the weak hand, and moves towards the body, at chest or shoulder height. The closer the moving hand comes to the body, the harder it will be to maintain its relative orientation of the palm pointing to the ground surface. Flexion of the base joints contributes to making this possible, but at the same time makes the flat surface of the articulator that iconically represents the car smaller.

(24) Example: FILE

Concluding, it might be the case that realizing specific perceptual targets is more important in motivated signs than minimizing articulatory effort as compared to non-motivated signs, but this too might strongly depend on the specific discourse or sociolinguistic context. This is an interesting topic for future investigations.

4.4 A few remarks on other sign languages

A quick survey of dictionary data from German sign language (Microbooks 1998), Thai Sign Language (Suwanarat et al. 1990), and New Zealand Sign Language (Kennedy 1997) seems to support the claims made above: in most cases base joint flexion in the citation forms seems the articulatorily easiest implementation of a certain combination of orientation and location features, or is the result of an aperture specification. We do not consider it crucial for our argument to know whether or not there is a phonological role for the base joint in any other sign language: it is simply the null hypothesis that a given phonetic property does *not* play a role in the phonological system. In view of the factors determining the position of the base joint state described in this section, we predict that in other sign languages base joint position is not phonologically distinctive either.

5. Conclusion

We have argued that base joint flexion is not expressed directly by a phonological feature in NGT. The arguments that we have advanced for this claim were, first, that there are no minimal pairs that contrast only in this respect, and secondly, that for all signs that have base joint flexion or movement in their citation form, this effect can be generated in the phonetic implementation of those signs. Two phonological aspects were discussed that lead to some phonetic implementations with base joint flexion: aperture and relative orientation.

Signs with an aperture relation between the thumb and the fingers are impossible to articulate without base joint flexion; furthermore, we do not find contrasts in base joint flexion in combination with the aperture feature [open]. We have proposed that relative orientation features apply only to the finger part of the articulator, and not to the whole hand. The base joints, just like the wrist and other joints of the arm, adapt to realize the combination of orientation and location features. For some signs this leads to base joint flexion in the citation form, but not for others. Variation in base joint position is predicted to occur: the signer may choose to let more of the "work" be done by the wrist joint instead of the base joints. Although we have little data on this variation so far, the underlying phonetic explanation that we proposed, namely that distalization limits articulatory effort, makes specific predictions about this variation that can be (experimentally) tested in the future. Specifically, the interaction between perceptual and articulatory needs could benefit from more perceptually oriented underlying specifications (cf. Boersma 1998). The same kind of work on the phonetic implementation of the state of the base joint should in principle also be done for the rest of the articulator.

For a set of exceptions that could not be explained by the phonetic implementation of either aperture or orientation, we suggested that their base joint flexion in citation forms is semantically motivated, and has to be dealt with in similar ways as other semantically motivated exceptions to phonological generalizations. Here, too, future investigations are necessary.

Although the data that we used and the proposals that we have made concerned only NGT, the phonetic and semantic nature of the phenomena involved suggest that it can be fruitful to look at other sign languages in the same way. A first impression of data from DGS, Thai SL and NZSL did not contradict our findings for NGT.

Since the base joint is the most proximal joint in the hand that is phonologically specified, the term "handshape" is a misnomer. We suggest the more neutral term "articulator", also capturing cases in which the articulator is either smaller (as discussed in this paper) or larger than the hand. Examples of signs where the articulator is bigger than the hand include NGT BOOM 'tree', BABY 'baby' (the same signs exist in ASL), and ASL DAY. Possibly there are many more cases than we had hitherto thought, having been misled by the prominence of handshape in all descriptions.

Finally, we would like to remark that the present findings also have some implications for other research fields and for practical applications. Psycholinguistic studies on "handshape" and orientation recognition could be hampered by the fact that users are not focusing on the hand as a whole but rather on the selected fingers, or whatever other part of the articulator is relevant. The same, of course, goes for studies on machine recognition of sign language, a rapidly growing field (see for example Harling & Edwards 1997). More and more (multimedia) dictionaries of sign languages are ordered by handshape or allow searching by handshape. If it is the case that handshape is a slightly misleading concept, it is important to warn the user about possible variations between handshapes that they see in real life, and ones that they (try to) find in the dictionary. Alternatively, one might design fuzzy search capacities, to account for differences in finger flexion, or order signs by sub-categories of the articulator representation such as finger selection and finger configuration.

Notes

* We would like to thank Alinda Höfer for helping us as an informant and for being the model for all the illustrations.

1. If one or two fingers are selected, this may refer to more than one handshape. For example, in a handshape with one selected finger, either the index finger or the little finger is selected (cf. Brentari et al. 1996). In the rest of this paper, as in the illustrations in (2), one-handshapes always concern the index finger, and two-handshapes always concern index and middle finger. The distinction in finger flexion that we discuss has never been proposed for other sets of selected fingers.

2. Opposed refers to the thumb being both abducted and hyperflexed at its carpometacarpal joints.

3. Different names have been used in the literature for handshapes with 90 degrees base joint flexion, such as "angled", "flat bent" and "bent". We will use the term "bent" in this paper.

4. One might argue that the proposal in Brentari et al. (1996) predicts that any feature occurs at least in the least marked set of selected fingers, which is in their model is indeed all four fingers selected.

5. The other traditional argument for the existence of a phonological feature is that the feature is needed to describe a phonological process. In studies of sign languages to date only very few processes have been described, and none of them involves finger configuration.

6. The arrows in all the illustrations we provide indicate only the direction of movement. Repetition of the movement, for example, is not indicated in these pictures. Some signs are illustrated with two pictures, for the beginning and end position of the articulators; in these cases we have not added arrows.

7. There is another lexical item that is more commonly used as the noun 'car'. The sign we refer to here is actually a classifier predicate with the meaning "a car moves forward". For sake of ease we gloss it as AUTO.

8. For the purposes of the SignPhon database, a citation form is the answer to the question: "what is the sign for xx?", where "xx" is a written Dutch word.

9. A similar proposal is made in Brentari (1998) to cover free variation of sign movements in general. However, Brentari does not specifically propose that *all* base joint movements should be considered as reduced path movements, as van der Hulst (1995) does. Brentari seems to imply that all handshape changes can be "phonetically enhanced" by articulating them with joints proximal to the MCP joints, but in general she is not very explicit about what the different (reduced and enhanced) forms of a given phonological parameter look like.

10. Actually, in the SignPhon corpus we used, which contains 2522 signs, only one sign with an aperture occurred that had two selected fingers, compared to 130 signs with one selected finger and 172 with all fingers selected.

11. In the same corpus of 2522 signs, 'flat' handshapes were 1.5 times as frequent as 'round' handshapes for signs with one selected finger, and 1.2 times as frequent for signs with four selected fingers.

12. In our earlier work we did not make explicit what part of the location specification the orientation feature refers to. In our model the main location (which typically does not change during a sign) is distinguished from setting values (which typically do change). Whether a side of the hand points in the direction of the final setting (and thus, towards the end of the movement) or in the direction of the location makes an important difference for body locations. We propose that it is the location value that a side of the articulator refers to, and not the end point of the movement. For signs in neutral space, it makes a difference whether or not a virtual object is present or not. If there is, the situation is analogous to the body location signs. If there is no imaginary object, the specified side of the articulator points in the direction of the end point of the movement.

13. The terms "proximal" and "distal" come from the anatomical literature (e.g. Luttgens et al. 1992), and refer to how far along the upper extremity (arm and hand) a joint is from its connection to the trunk. Thus, of the arm, the shoulder joint is the most proximal, and the joint between the last two segments of each finger is most distal. They are often used in a relative sense, for example in saying "the wrist is distal to the elbow".

14. Actually, denying a phonological role for the base joint implies the flat part of the hand in these signs *is not* part of the articulator. For that reason, it no longer makes much sense to talk about "handshape". We propose the term "articulator" to be more appropriate. The same argument also holds for articulator configurations in which there is an aperture relation specified. The phonologically relevant parts of the articulator are the thumb tip (or pad) and the fingers, but not the flat part of the hand. As in these cases there is little variation

in base joint position, the difference between "handshape" and "articulator shape" is less obvious, but we hypothesize that handshape is a misnomer for all articulator configurations.

15. However, see Sandler (1995) for proposals for perceptual specifications of handshape, such as [broad] and [compact].

16. See also the Thai Sign Language Dictionary (Suwanarat et al. 1990) where it is stated that all signs with a "bent-B refer to a measurable quantity" (p.258). Examples include money, time delimiters, and equality (fingertip orientation).

17. Possibly there is also influence of restrainedness, tenseness or the shape of the movement. We need to look into this further.

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