Voice–Nasality Interaction and Headedness in Voiceless Nasals*

Florian Breit

Abstract

Most recent work in Element Theory assumes that nasality and true voicing are represented by the same element, where the headed element encodes voicing and the dependent element nasality (Backley, 2011; Nasukawa, 1999, 2000, 2005, et alii). This assumption is questioned here and it is proposed that the voicing–nasality contrast may be encoded the other way around. It is argued that this hypothesis is in better agreement with the means by which headedness may encode additional information at phonetic interpretation. Under the assumption of an L/H-Parameter, it is shown how, in line with Lombardi (1991) and Botma (2005), only H-systems can possibly encode voiceless (or more properly *aspirated*) nasals and how the hypothesis that headed $|\underline{L}|$ encodes nasality provides a better fit for these systems.

Keywords: Voicing, Nasality, Voiceless Nasals, Laryngeal Contrast, Element Theory

1 Introduction

A large proportion of current work on voicing contrast takes the view that voicing contrast is represented by a set of at least two privative primes rather than a single equipollent [±voice] prime (Halle and Stevens, 1971; Harris, 1994; Honeybone, 2005) and it is well known that there is systematic interaction between nasal segments and voice in many languages. This has led to a number of proposals which posit that voicing is an inherent property of nasality. In fact, proposals in Element Theory (ET) have gone so far as to unify true voicing and nasality in a single privative prime, where a contrast between voicing and nasality is encoded via headedness and dependency, i.e. the relationship the prime has to the rest of the segmental content. The common view following Nasukawa (1999, 2000, 2005) is that headedness represents voicedness, while dependency represents nasality. In this paper I will challenge this view both on purely theoretical and empirical considerations. For the latter, I will discuss the case of 'voiceless' nasals in Icelandic, Welsh and Iaai. While cross-linguistically relatively rare compared to voiced nasals, these segments provide good empirical grounds on which an assumption converse to that of Nasukawa (2005) is to be preferred.

2 The representation of voicing and nasality

2.1 Laryngeal Contrast

Most current phonological work on voicing contrast assumes what is often termed 'laryngeal realism': The assumption that laryngeal contrast for voicing is not encoded in an equipollent [±voice] prime, but that there are at least two underlying privative primes involved. In articulatory phonology these are mostly associated with control of vocal fold tension. Frequently

* For their encouragement and many helpful comments on earlier drafts of this paper I thank Andrew Nevins, John Harris, and Bert Botma. I thank Anne-Laure Dotte for helping me with questions about Iaai. I also gratefully acknowledge the support of an AHRC RPM Studentship.

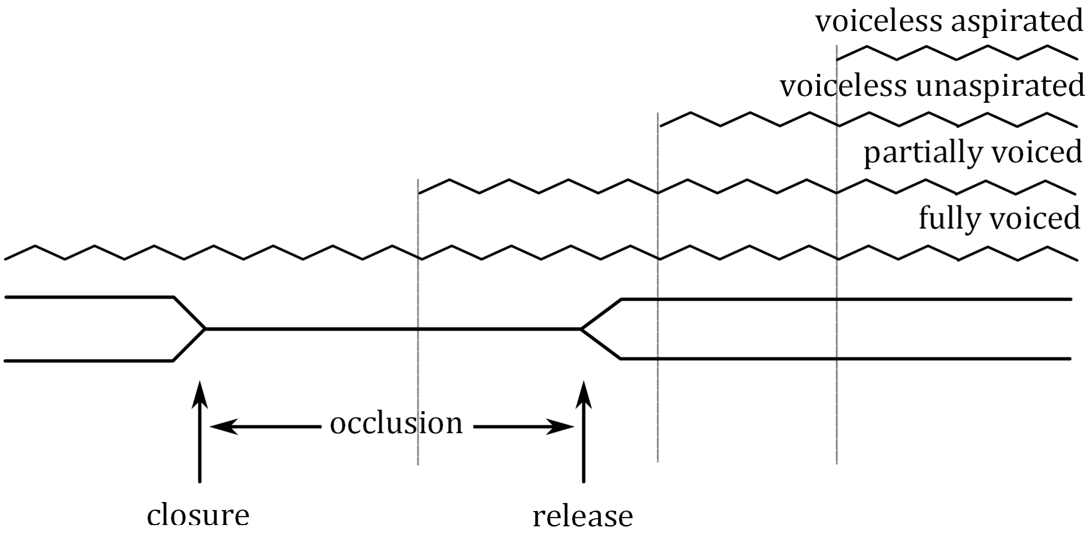


Figure 1: Different Brackets of VOT in Oral Stops.

[voice] is understood to specify active engagement of the vocal folds to produce vibration, while additional features such as [constricted glottis] and [spread glottis] control the spread of the arytenoid cartilage to induce tension or approximation of the vocal folds (Hall, 2007, p. 317). From this it can be construed that [voice] is responsible for true voicing and [spread glottis] for aspiration and breathy voice (Halle and Stevens, 1971; Itô and Mester, 1986; Iverson and Salmons, 1995). Theories such as Element Theory, which ground phonological representations in the acoustics of the speech signal rather than the articulatory mechanics of production, make a loosely analogous assumption involving a *low* and a *high* element, |L| and |H| respectively — two elements which are assumed to also encode tonality contrast as suprasegmental primes. In this view, |L| is understood to give rise to true voicing, reflected in low frequency acoustic energy and pulsing of the signal, and |H| is understood to give rise to aspiration, reflected in more high frequency spectral energy, while segments without either element default to voiceless unaspirated segments (cf. Backley, 2011; Harris, 1994).

Phonetically, these primes also align well with the measure of Voice Onset Time (VOT) in oral stops, this is the time delay between the release of oral occlusion and the onset of vocal fold vibration. Different brackets of VOT as illustrated in Figure 1 align with different phonological categories of voicing mode. True voicing is realised in some languages a continuous vocal fold vibration throughout the hold phase, while other languages realise this as partially voiced stop. Voiceless stops on the other hand can have a very small VOT, so that vocal fold vibration begins almost immediately after release of the occlusion, or there can be a delay between release and onset of vocal fold vibration as found in aspiration (Ashby and Maidment, 2005, pp. 92–95). Given three phonological representations such as |L|, | |, |H| or [voice], [ ], [spread glottis] to encode this phonetic contrast, we moreover see what may be termed a ‘left to right alignment’: |L| or [voice] is associated with negative VOT, |H| or [spread glottis] is associated with positive VOT and an empty representation is associated with (near) zero VOT.

One of the basic observations behind laryngeal realism is that systems with a two-way voicing contrast, such as German, Welsh, English and French are not simply lenis v. fortis, but that they can be divided into two groups of systems: those which contrast true voicing to voiceless unaspirated segments and those which contrast voiceless unaspirated to voiceless aspirated ones. Importantly, the phonologically active property in both cases appears to be either true voice or aspiration, but not the voiceless unaspirated mode. French is an example

Rep.	Mode	French	English	Thai	Gujarati
|L|	voiced	/bo/ 'beautiful'		/bàa/ 'shoulder'	/baɾ/ 'twelve'
| |	voiceless	/po/ 'skin'	/peɪ/ 'bay'	/pàa/ 'forest'	/pɔɾ/ 'last year'
|H|	aspirated		/pʰeɪ/ 'pay'	/pʰàa/ 'split'	/pʰɔdz/ 'army'
|L, H|	breathy				/b̤aɾ/ 'burden'

Table 1: Possible combinations of |L| and |H| and their use across different languages. Adapted from Harris (1994, p. 135). Rep. = Representation.

of the former category, while English falls into the latter (Harris, 1994, p. 135). Assuming representations with the two elements |L| and |H|, we can refer to this apparent typological split as the L/H–Parameter, i.e. whether a given language specifies voicing contrast via |L| (French-type systems) or via |H| (English-type systems; cf. also Backley, 2011; Cyran, 1997, 2010, 2013, p. 136)[1].

Beyond these two-way systems, there are of course also systems with more than two distinctions. For instance Korean makes a distinction between voiceless unaspirated, mild aspiration and strong aspiration (Ladefoged and Maddieson, 1996, p. 56). Thai and Armenian are two languages which distinguish between true voicing, voiceless unaspirated and voiceless aspirated stops (Adjarian, 1899; Hacopian, 2003; Ladefoged and Maddieson, 1996; Lisker and Abramson, 1964). Laryngeal realism presents an immediate advantage here, since its combinatoric possibilities enable us to represent up to four contrasts in phonation mode, with as many as three phonologically active properties[2]. This is illustrated for four systems covering these possibilities in Table 1.

2.2 Nasality

The assumption that the feature [nasal] is a privative prime is quite widespread in articulation based theories, since no phenomena seem to have been recorded in which orality (i.e. [−nasal]) appears to be phonologically active, while phenomena such as nasal harmony are not uncommon (cf. e.g. Y. Kim, 2002). Since in an articulatory model nasality is dependent on velar position, the [nasal] feature is then responsible for active lowering of the velum, while in absence of the feature the velum defaults to adducted position. In this view, there is nothing obvious that [nasal] has in common with the laryngeal elements at interpretation.

While earlier proposals in Element Theory have assumed a largely analogous element |N| to represent nasality and the associated acoustic low-band murmur, it is now commonly assumed that both voicing and nasality are covered by the range of interpretation of the low element |L|. Botma (2004) principally associates |L| with sonorancy, which capitalises on the possibility of characterising nasals as what may be referred to as sonorant stops: stops which have an oral occlusion, yet allow relatively uninhibited airflow through opening of the velopharyngeal port. With this assumption, |L| provides a link between the sonorant properties of

[1] Though should this indeed be a binary parameter, one should wonder how system such as Thai and Gujarati are to be specified for this. A realistic typology along such a parameter thus likely needs to be more complex.

[2] That is, under negligence of other laryngeal primes such as [constricted glottis] and any segment-internal structure such as the head–dependent relationship in ET, which further increase the combinatoric possibilities.

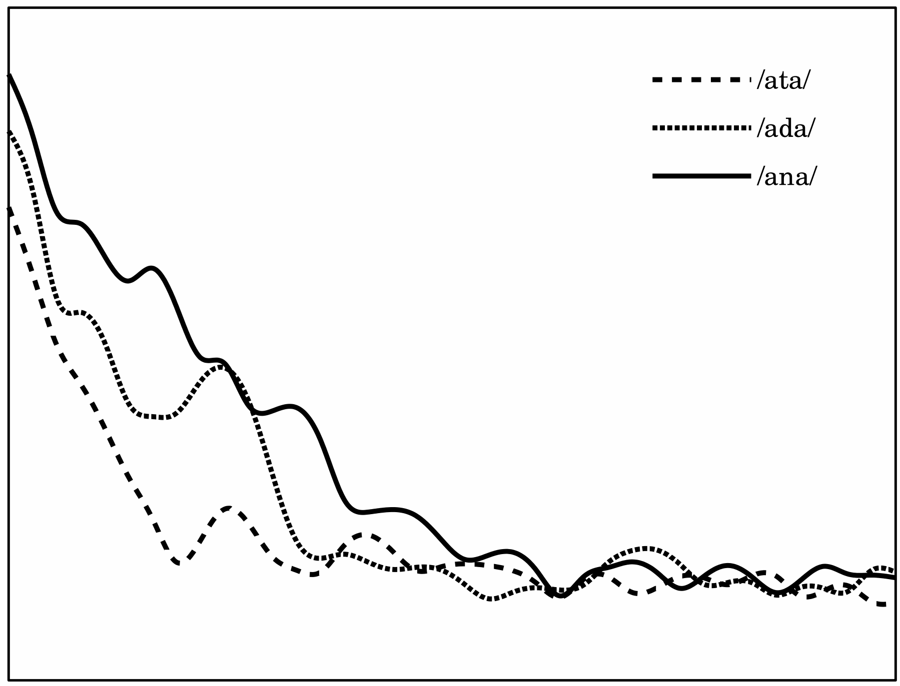


Figure 2: Spectral patterns for intervocalic hold phase of voiceless, voiced and nasal alveolar stops for a speaker of German.

approximants and nasals.

In terms of acoustics, passing the speech signal through the nasal cavity does two things. First, it functions as a filter and dampens the higher frequencies in the signal. Second, it functions as a resonator and introduces a number of new formant frequencies often known as nasal murmur. This nasal murmur is mostly composed of low energy and diminishes toward the higher frequencies in the spectrum. As such, the acoustic properties of both true voicing and nasality share a property: they are both characterised by low frequency energy. Somewhat simplistically, we can then assume that low tone, nasal murmur and slack vocal folds are all associated with a lowering of the mean energy concentration in the acoustic signal. Similarly to the observation made about |L|→| |→|H| being associated with length of VOT, | |→|L|→|N|[3] can be associated with higher density of low energy in the acoustic signal. To visualise this, compare the three spectra from the acoustic signal during the hold phase of oral occlusion of a voiceless unaspirated, voiced and nasal alveolar stop in Figure 2 [4].

Of course, if |L| is responsible for both nasality and voicing, it follows straightforwardly that most languages should have voiced nasals but that nasals with other modes of phonation should be relatively rare cross-linguistically — a prediction that appears to be borne out (cf. Ladefoged and Maddieson 1996; UPSID). Another line of argument which links voicing with nasality is provided by arguments that attribute prenasalisation in some languages to a phenomenon called ‘hypervoicing’. That is, prenasalisation is a means of further reinforcing the

[3] |N| being a placeholder for that version of |L| which is to be interpreted as nasality.

[4] N.B.: At present, only limited data is available on the comparative acoustic patterns of different stops’ hold phases in different phonetic and phonological environments and it is thus of some importance that further research be carried out to confirm and consolidate these findings.

characteristics of voicedness in an already voiced stop (see e.g. Iverson and Salmons, 1996). This hypothesis seems to be in good agreement both with Botma's (2004) sonorancy assumption and with the observation of nasality enhancing low energy concentration in the acoustic signal. Conversely, Korean has a phenomenon in which nasal stops appear to be denasalised in word-initial position. This can be seen as the opposite of hypervoicing: denasalisation presents a reduction in sonorancy and a shift toward less prominent low energy concentrations, in effect causing the nasal stop to be perceptually more similar to a plosive than a nasal stop (cf. Chen and Clumeck, 1975; Jones and Minn, 1924; Y. S. Kim, 2011).

The main arguments for the unity of the nasal and low elements were developed by Nasukawa (1999, 2000, 2005)[5]. Nasukawa (1999, 2000, 2005) also argues that the difference between voicing and nasality should principally be attributed to headedness, a notion I discuss further in section 2.3. He argues that headed $|\underline{L}|$ represents voicing, and unheaded $|L|$ is interpreted as nasality. Thus, Nasukawa (1999, p. 66) proposes the following analysis:

(1) INTERPRETATION OF THE ELEMENT L (NASUKAWA):

$\|L\|$	nasal
$\|\underline{L}\|$	voiced

While the proposal in (1) has been commonly adopted (cf. e.g. Backley, 2011), it stands in some contrast to the observation that nasality appears to be a more salient version of the acoustic and sonorant properties of voicing. It has been a long-standing assumption in Element Theory that headed elements are interpreted as the purest realisation of the prime's properties. As Backley (2011) notes discussing why vowels composed of only a single element should be headed:

> This makes sense, because if headedness gives an element acoustic prominence, then a single element should always be headed because its acoustic pattern entirely dominates the expression. (Backley, 2011, p. 42)

Then, if nasality is the most salient and prominent expression of $|L|$, it would make sense to assume that headed $|\underline{L}|$ is interpreted as nasality and unheaded $|L|$ as 'mere voicing'. We may thus formulate an alternative hypothesis to Nasukawa's proposal in (1), namely that headed $|\underline{L}|$ is interpreted as nasality:

(2) INTERPRETATION OF THE ELEMENT L (ALTERNATIVE):

$\|\underline{L}\|$	nasal
$\|L\|$	voiced

The proposal in (2) aligns well with the phonetic properties of nasality, voicing and aspiration discussed above. Both VOT and acoustic low v. high energy concentrations give us an alignment $|L| \leftarrow |\,| \rightarrow |H|$, headed $|\underline{L}|$ for nasality can then be seen as an extension of this alignment, as apparent from the acoustic patterns in Figure 2, $|\underline{L}| \leftarrow |L| \leftarrow |\,| \rightarrow |H|$. This is not possible under Nasukawa's proposal, which would predict that voicing is the most salient expression of the low element.

[5] Note that Nasukawa assigns the label $|N|$ to the unified element, whereas I have adopted the label $|L|$ in line with the vast majority of current literature.

2.3 Head, Dependent and Complement

In the previous section, headedness was introduced as a principal means to determine interpretation of the prime |L| as either voicing or nasality. As such it is of some importance to define more precisely what is meant by headedness.

Headedness in early versions of Government Phonology (e.g. Kaye, Lowenstamm, and Vergnaud, 1985) formed an essential notion of the compounding operation in what was called the element calculus. This was a process which translated elemental representations into SPE-style feature bundles which could then be phonetically interpreted. The compounding operation $\alpha \circ \beta$ combined one pair of elements at a time. Each element was assumed to consist of a set of features, a specific subset of which would propagate onto another element if compounded. Since this subset which propagates was specific to each individual element, the compounding operation had to be non-commutative, and the element which propagated its features over the other was called the *head*, while the one serving as the canvas for this was called the *operator*.

In later (and current) Element Theory, this notion of a separate (articulatory) level of phonetic representation has however been abandoned. Instead it is assumed that each element is itself an independently interpretable cognitive prime which modulates the speech signal (Harris and Urua, 2001). Without the necessity to translate elemental representations into features, element calculus is of course obsolete, and with it the notion that elements have to be ordered and grouped into pairs for compounding. In place of multiple head–operator relations within a representations, the notion of a single optional head for the entire representations was adopted from Dependency Phonology, with the remaining elements in a representations considered to be dependent on the head.

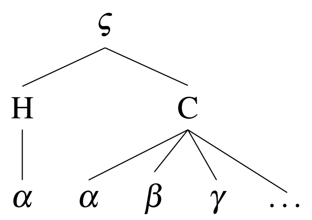
(3) SINGLE OPTIONAL HEADEDNESS CONDITION:
A segment may have exactly one head or no head at all.

Essentially this means that from within all the elements $\{\alpha_1, \ldots, \alpha_n\}$ in a segment, one element $x \in \{\alpha_1, \ldots, \alpha_n\}$ *may* be promoted to headhood. However, headedness in this sense is not to be understood exclusively in terms of a relation within the segmental representation, but can be considered to be reflected in the structure of the representation. As such, even though the set of all the elements in a segment might be identical, headedness alone is enough to distinguish two segmental representations phonologically: segmental representations are isomeric in nature.

(4) ISOMERICITY PRINCIPLE:
Two segments are phonologically distinct if and only if they are composed of different elements or have a different head.

Breit (2013, pp. 25–27) shows that with this in mind it is not sufficient to refer to only two disjoint sets (a head and the dependents), but that the basis on which these are to be defined is the overall content of the representation, i.e. the set $\{\alpha_1, \ldots, \alpha_2\}$ above, which is called the *complement*. Breit (2013) proposes that headedness can be understood as a partial order over that set, established by a single set in the complement. That is, a representation can be seen as a structure of the form $\{H, C\}$ where the complement C is a subset of the set of all the elements and the head H is a subset of C with a cardinality not greater than one. This is illustrated graphically in (5) below.

(5)



A *dependent* element under this proposal is any element in the set $C \setminus H$, i.e. any element that is in the complement but not also the head. In (5), α is the head, $\{\alpha, \beta, \gamma, \ldots\}$ is the complement and $\{\beta, \gamma, \ldots\}$ are all dependents.

A curious property of this proposal is that the head is represented twice within the segment, once in the head position and once in the complement position. This is however reflected directly in the interpretation of a representation and explains easily why a headed version of an element is more prominent in terms of its acoustic characteristics, and why the head distributes asymmetrically over the dependents at interpretation. This follows from the simple assumption that the complement is interpreted symmetrically (i.e. all the elements contribute in equal parts) and the head is interpreted in relation to their combination. Not only does this account for the higher saliency of the head due to it contributing twice to the segment, but since the head element necessarily is interpreted in the complement position, it follows that headedness can never remove any acoustic property introduced by the dependent version of the same element. Consequently, headhood can only enhance the properties of an element and perhaps add additional traits[6], but never remove any which are present in its dependent version.

Clearly, if this assumption is correct and nasality is a more salient version of the properties already present in voicing (with the possible addition of the characteristic murmur) as argued throughout this section, then Nasukawa's proposal in (1) is in conflict with the derived principle that headhood can only enhance but never decrease or remove traits from an element and the alternative proposal in (2) would be the one to be given preference on theory-internal grounds. In different words, only the proposal in (2) agrees with the notion that nasals are inherently voiced, and nasality adds additional characteristics to voicing.

3 Voiceless Nasals

3.1 Introduction

In the previous section it was discussed how both voicing and nasality can be represented by the same prime |L|, where nasality is a more enhanced interpretation of the same low-frequency energy characteristics already present in voicing. As such, both voicing and nasality stand in direct opposition to the aspirated segments represented by |H|, a prime associated with acoustic high-frequency energy. In this context, the hypothesis that both voicing and nasality are represented by |L| and headedness arbitrates between the two should clearly be reflected in phonological patterns which align with either the proposal in (1) or the proposal in (2). One case that may be especially insightful here because it necessarily involves arbitration between the phonological representation of phonation mode and nasality is laryngeal contrast in nasal stops. This section will present an analysis of nasal segments in three languages which

[6] Due to the head occupying a separate structural position, similarly to how the same representation may receive different interpretations in nuclei and onsets.

Segment	Nasukawa	Alternative
$\lvert\underline{H}, L\rvert$	nasal fricative	voiced fricative
$\lvert\underline{H}\rvert$	(voiceless) fricative	(voiceless) fricative
$\lvert H\rvert$	voiceless aspirated	voiceless aspirated
$\lvert\ \rvert$	voiceless unaspirated	voiceless unaspirated
$\lvert L\rvert$	nasal	voiced
$\lvert\underline{L}\rvert$	voiced	nasal
$\lvert L, H\rvert$	aspirated nasal	creaky
$\lvert\underline{L}, H\rvert$	undefined, perhaps creaky?	aspirated nasal

Table 2: Comparison of the combinatoric possibilities of $|L|$ and $|H|$ and their interpretation for Nasukawa's proposal in (1) and the alternative proposal in (2). It is assumed that $|H|$ represents aspiration and $|\underline{H}|$ frication.

employ a voicing contrast in nasals, highlighting how these segments can be analysed, how the representations of true voicing and aspiration interact and how they do or do not align with the proposed assignment of headedness in (1) and (2).

3.2 Laryngeal Contrast in Nasals

The presence of nasal segments is nearly universal across languages. Of all the languages recorded in the UPSID, 96.45% are classified as having at least one nasal segment in their phoneme inventories. In addition, for some of the languages there recorded as not possessing any nasal segments, such as Pirahã and Rotokas, it is known that nasals do at least occur as allophones (cf. Botma, 2004; Sandalo and Abaurre, 2010). Notably however, languages which contrast voicing in nasals are very rare: only 3.99% of the languages in UPSID contain nasal segments classified as voiceless.

Given the proposal that the same prime that is responsible for true voice is also responsible for nasality, this is perhaps not surprising. Under the proposal that headed $|\underline{L}|$ represents nasality and unheaded $|L|$ voicing in (2), together with the argument made in section 2.3 that a representation with a head X necessarily also contains the basic complemental version of X with all the properties it has as a dependent (i.e. $|\underline{X}|$ includes $|X|$), it is especially clear that the true voicing represented by $|L|$ will be present in any nasal by necessity. To counteract this and express laryngeal contrast, it is then necessary to employ the high element $|H|$. This immediately rules out the possibility of expressing laryngeal contrast in L-languages such as French, since the $|L|$–$|\ |$ contrast they rely on cannot be maintained if nasals necessarily contain $|L|$ by virtue of containing $|\underline{L}|$. This would limit laryngeal contrast in nasals to H-languages, in which $|H|$ can counteract the voicing introduced by $|L|$ and introduce high-frequency energy via aspiration, as has also been argued by Lombardi (1991) and Botma (2005) previously. It may be more proper then to call these segments *aspirated nasals* rather than voiceless. This is further supported by an air-flow experiment indicating that 'voiceless' nasals in Welsh are indeed both partially voiced and aspirated (cf. Ball and Williams, 2000; Scully, 1973) and by both acoustic and airflow studies of Burmese which also conclude that these nasals are partially aspirated and partially voiced (Bhaskararao and Ladefoged, 1991; Dantsuji, 1984).

While Nasukawa's proposal in (1) still necessitates an analogous typology where only H-languages can represent laryngeal contrast in nasals, this is merely due to the fact that the same

	Bilabial	Dental	Palatal	Velar
Lenis	m	n	ɲ	ŋ
Fortis	m̥	n̥	ɲ̊	ŋ̊

Table 3: The nasal consonants of Icelandic, based on Jessen and Pétursson (1998).

representation cannot include both the headed and the dependent version of the same prime (i.e. *|L̲, L|). The prediction that nasals are voiced by default and that fortis nasal segments must be aspirated does not directly follow — a representation with |L| in an L-system could well be a fortis segment if only headed |L̲| marks out the lenis forms. It has been argued that the antagonism in the properties represented by the elements |L| and |H| in itself makes representations containing both these elements somewhat marked (e.g. Backley, 2011) and this may sufficiently explain why aspirated nasals are typologically marked. However, it does not explain why nasals should default to being voiced, lenis segments cross-linguistically and why fortis nasals in general seem to be marked, as is predicted by the proposal in (2). Table 2 gives an overview of the combinatoric possibilities at hand and their predicted interpretations for the two proposals.

3.3 Icelandic

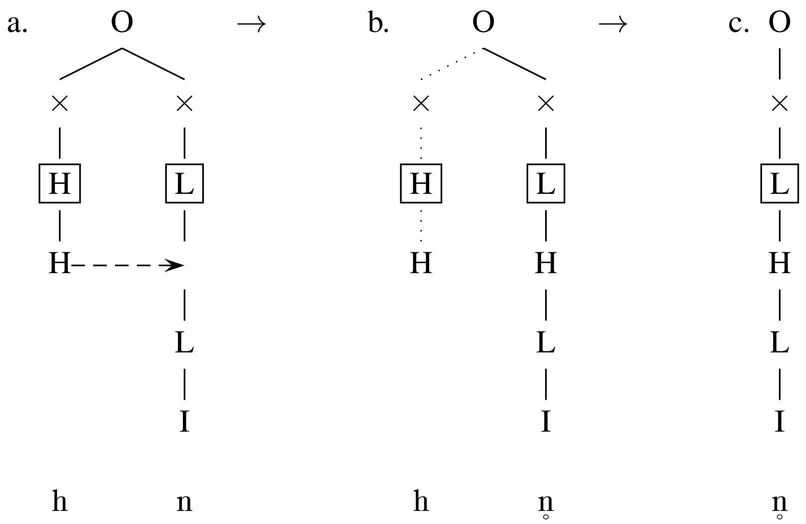
Icelandic features nasals with the four places of articulation bilabial, dental, palatal and velar, each of which has a lenis and a fortis variant, as illustrated in Table 3 (cf. Jessen and Pétursson, 1998). The palatal and velar nasals only occur immediately preceding palatal and velar stops respectively, with the dental nasal appearing elsewhere, so that [n, ɲ, ŋ] can all be classified as allophones of a phoneme /n/ which contrasts with the bilabial nasal /m/ (Pétursson, 1973).

A number of minimal pairs which illustrate the distribution of lenis and fortis nasals in Icelandic, taken from Jessen and Pétursson (1998) and Bombien (2006), are given in (6).

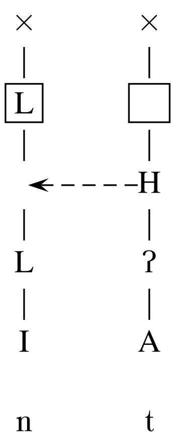
(6)		*Lenis*		*Fortis*		(Icelandic)
	a.	[niːta]	to use	[n̥iːta]	to knot	
	b.	[c^{h}ɛmpa]	to comb	[c^{h}hɛm̥pa]	hero	
	c.	[lampa]	lamb	[lam̥pɪ]	lamp	
	d.	[hɛnta]	to throw	[hɛn̥ta]	to be appropriate	
	e.	[hɛntɪ]	hand	[hɛn̥tɪ]	to dispose of	
	f.	[paʊɲcɪn]	afraid	[paʊɲ̊cɪn]	bank	
	g.	[laʊŋka]	to long for	[laʊŋ̊ka]	to knock	

It has been argued that the fortis series of nasals (and fortis sonorants more generally) are not truly phonemic in Icelandic, since their environment appears to be restricted to a post-vocalic environment in which plosive stops are realised with preaspiration (Árnason, 1986; Haugen, 1958). Under this view, the fortis nasals are analysed as devoiced segments where the preaspiration from a following plosive has spread leftward into the nasal. In Element Theory this can be analysed as leftward spreading of |H| from an adjacent plosive into a nasal (cf. Botma, 2004, p. 230). For word-initial fortis nasals, which are the only ones not to be followed by a plosive, it has been proposed that these are phonemically represented as a sequence /hN/, where the aspiration from /h/ spreads rightward into the nasal and the glottal fricative is subsequently deleted.

The derivation of a surface form such as [n̥iːta] from underlying /hniːta/ can be analysed as per the example in (7). Note that due to the importance attached to headedness in this paper, I added a box at the top of the melodic representations which represents the head position, while the primes attached below that tier represent the complement position. The derivation of [n̥iːta] involves two steps. First, |H| spreads rightward from the complement of /h/ into the complement of /n/ (a). Second, the entire timing slot for /h/ is delinked (b), resulting in the fortis nasal in (c).

(7)


A definitive analysis of the preaspiration spreading in post-vocalic position is slightly more complicated. Consider the word [hɛn̥tɪ] 'to dispose of'. Here, the fortis alveolar stop is in an environment where it would be realised with preaspiration (i.e. $^{?}$[hɛ^{h}tɪ]). In northern dialects of Icelandic however, which do not show preaspiration on post-vocalic plosives, the surface form of this word is [hɛnt^{h}ɪ], with a normally aspirated alveolar stop and a lenis nasal (Bombien, 2006, p. 65). If preaspiration can spread leftward into the nasal, but postaspiration in the same environment cannot, this poses the important question of if and how the two are different in their underlying representations. One possible answer to this question is that the representation in both cases is identical and feature dependent |H| (i.e. they are aspirated) and the two dialects differ only in how |H| is interpreted: either as pre- or postaspiration. As illustrated in (8), since the plosive has dependent |H|, it would be possible to posit that |H| spreads leftward into the representation of the nasal, analogous to the rightward spreading of dependent |H| in (7).

(8)


However, if |H| spreads leftward here, the question as to why in one dialect we find a fortis

	Bilabial	Alveolar	Velar
Lenis	m	n	ŋ
Fortis	m̥	n̥	ŋ̊

Table 4: The nasal consonants of Welsh.

nasal and in the other we do not remains unanswered and an additional assumption that northern Icelandic does not have this kind of spreading would have to be made. An alternative which does not pose this question would be to posit that neither dialect of Icelandic does in fact have a spreading process as in (8) and that in both cases the nasal is lenis. Instead, the preaspiration from the following stop may overlap partially with the hold phase of the preceding nasal stop. This would result in a nasal which is partially voiced and aspirated, just as Scully (1973) describes the realisation of fortis nasals in Welsh. As such these would be lenis, but on the surface virtually indistinguishable from truly aspirated nasals. This analysis is further supported by Bombien's (2006) finding that fortis sonorants in Icelandic vary in length compared to their lenis counterparts, something that can be explained by the still existent preaspiration of the following plosive which appears to temporally elongate the sonorant's own release.

While Icelandic does not immediately help us to arbitrate between the two proposals concerning the headedness of |L| then (this analysis works just as well under Nasukawa's proposal), it does provide a good illustration of the interplay between the two primes responsible for laryngeal contrast, |H| and |L| in these nasals. It also shows how difficult this can make it to even discern whether a nasal may indeed be aspirated due to its representation or whether this results from an environment such as preaspiration on a following stop — note especially that none of the possible proposals would concede that these nasals are fortis in the underlying representation, but if at all then only through the application of a phonological process.

3.4 Welsh

Welsh has nasals with three places of articulation: bilabial, alveolar and velar. As in Icelandic, all three nasals occur both in a lenis and a fortis variant, resulting in the full set of nasal stops in Table 4.

What is special about the set of fortis nasals in Welsh is that they occur solely as the result of initial consonant mutation (ICM; see e.g. Ball and Müller, 1992; Buczek, 1995; Cyran, 2010; Kibre, 1997). ICM is a phenomenon in which certain morphosyntactic environments trigger one of three classes of phonological change on the left edge of a targeted word. This can be either due to the syntactic configuration or due to an immediately preceding lexical item triggering the change (for more detail see e.g. Borsley, Tallerman, and Willis, 2012). For instance, the first person possessive /və/ 'my' triggers nasal mutation on the following item, causing the word /tad/ 'father' to be realised as [n̥ad] in the phrase [və n̥ad] 'my father'. There are three classes of this change, referred to as soft mutation, aspirate mutation and nasal mutation, which all target different sets of underlying 'radical' sounds. The patterns for these are listed in Table 5.

Of particular interest at this point is of course the pattern of nasal mutation (NM), which changes plosive stops into nasals but preserves their voicing association. This results in lenis plosives changing to lenis nasal stops and fortis plosives changing into fortis nasal stops, as is apparent from the last line in Table 5. Examples for all segments affected by NM are given

Radical	p	b	t	d	k	g	tʃ	m	n	ɬ	r̥
Soft Mutation	b	v	d	ð	g	∅[1]	dʒ[2]	v		l	r
Aspirate Mutation	f		θ		x			m̥[2]	n̥[2]		
Nasal Mutation	m̥	m	n̥	n	ŋ̊	ŋ					

[1]Consonant is deleted. [2]Reported in spoken language, but not currently accepted as standard (cf. Kibre, 1997, p. 11 for /dʒ/; King, 2003, p. 14 for /m̥, n̥/).

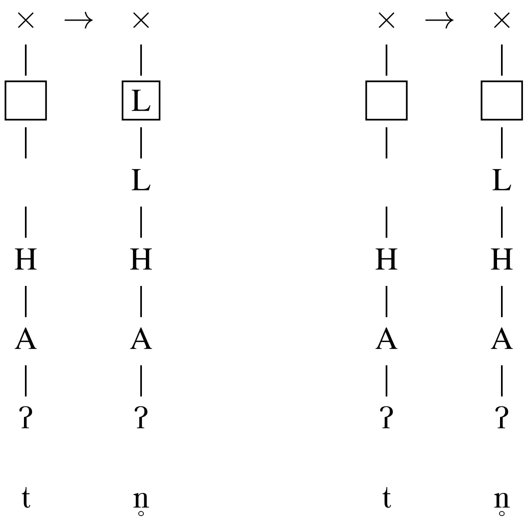
Table 5: The patterns of initial consonant mutation in Welsh.

in (9). Words beginning with any other segment are not affected by this change and simply remain unaltered (e.g. underlying /və ɬəvr/ 'my book' is also realised as [və ɬəvr]). Note example (9c) where [teːg] 'fair' is combined with the prefix [an] 'un-' to form [an̥eːg] 'unfair', which illustrates that affixes can also cause mutation on roots they attach to.

(9)	*Radical*		*Nasal Mutation*		(Welsh)
a.	[pabeɬ]	tent	[və m̥abeɬ]	my tent	
b.	[baŋor]	Bangor	[əm maŋor]	in Bangor	
c.	[teːg]	fair	[an̥eːg]	unfair	
d.	[diod]	drink	[və niod]	my drink	
e.	[kaɨrdɨð]	Cardiff	[əŋ ŋ̊aɨrdɨð]	in Cardiff	
f.	[goroɨʃad]	survival	[və ŋoroɨʃad]	my survival	

Since the trigger for ICM is the morphosyntactic rather than the phonological environment, this process does of course not involve phonological spreading as was hypothesised to be responsible for forming voiceless nasals through coalescence in Icelandic. Nonetheless, it is the phonological component of the grammar which has to realise the changes marked out in this way. While classical feature approaches such as Ball and Müller (1992) and Kibre (1997) analyse this as a simple switch from [−nasal] to [+nasal], a privative theory like Element Theory has to compose (i.e. add) or decompose (i.e. remove) further elements into/from the segment's representation. As such, the two proposals for the representation of nasality in (1) and (2) require different analyses of NM. Under the proposal in (2) where headed $|\underline{\mathrm{L}}|$ represents nasality and dependent |L| true voicing, |L| has to be composed into the head position, which by definition also includes composition into the complement (see Breit, 2013, pp. 28–31). Under Nasukawa's proposal in (1), where headed $|\underline{\mathrm{L}}|$ represents true voicing and dependent |L| nasality, composition of |L| into the complement is sufficient. Both possibilities are illustrated for the change [t]→[n̥] in (10a) and (10b) respectively.

(10) a. NM under (2) b. NM under (1)



Formally, the head and complement composition functions can be defined via the two mappings

$$\mathrm{comp}(\varsigma,\bar{v}) = \{\mathrm{H}(\varsigma),\mathrm{C}(\varsigma)\cup\bar{v}\},$$

and

$$\mathrm{hcomp}(\varsigma,\bar{v}) = \{\mathrm{H}(\varsigma)\cup\bar{v},\mathrm{C}(\varsigma)\},$$

where ς is the underlying segment, $\bar{v}$ is any set of elements, $\mathrm{H}(\varsigma)$ is the set containing the head and $\mathrm{C}(\varsigma)$ is the set containing the complement (Breit, 2013, p. 30). The proposed head composition in (10a) then must be given as a two-stage mapping $\mathrm{hcomp}(\mathrm{comp}(\varsigma,\{\mathrm{L}\}),\{\mathrm{L}\})$, where $\varsigma = \{\emptyset,\{\mathrm{H},\mathrm{A},\text{ʔ}\}\}$[7], while (10b) is covered by the direct mapping $\mathrm{comp}(\varsigma,\{\mathrm{L}\})$. Of course at this point the argument could be made that the simple complemental composition in (10b) is more economical and Nasukawa's proposal is to be preferred. To balance this, consider one of the other patterns of ICM illustrated in Table 5: soft mutation (SM). SM maps fortis segments to lenis ones and can be analysed as the complementary composition operation to what is proposed for NM: if NM composes |L| to both the head and the complement, then SM only has to composes |L| to the complement. Given that SM is much more frequent in the language and that current language change seems to point toward much of NM being replaced by SM, the analysis where headed |<u>L</u>| represents nasality is equally if not more economical.

Yet another clue as to the role of |L| and |H| in Welsh fortis nasals is provided by the pattern of aspirate mutation (AM), also given in Table 5. Traditionally, this involves a change from fortis stops to fortis fricatives with retention of place of articulation, though more recently this pattern appears to have been extended to cover the two lenis nasals[8] in colloquial speech for some speakers (King, 2003, p. 14). AM clearly involves compounding of |H| into the targeted segment to produce either a fortis fricative or a fortis nasal. Assuming a unified representation of aspiration and frication by |H| in analogy with |L|, this then involves either composition of headed |<u>H</u>| or dependent |H|, depending on which is assumed to result in frication.

The now common assumption is that analogous to Nasukawa's proposal |H| represents frication, while |<u>H</u>| represents aspiration (cf. Backley, 2011). Assuming Nasukawa's proposal

---

7 By comparison, simple $\mathrm{hcomp}(\varsigma,\{\mathrm{L}\})$ would yield the set $\{\{\mathrm{L}\},\{\mathrm{H},\mathrm{A},\text{ʔ}\}\}$ which is not well-formed since it violates the requirement that $\mathrm{H}(\varsigma)\subseteq\mathrm{C}(\varsigma)$.

8 N.B.: Since fortis nasals only occur as the result of ICM themselves, they can of course not be the target of ICM themselves.

	Bilabial	Labialised-Bilabial	Dental	Retroflex	Pre-Palatal	Velar
Lenis	m	mʷ	n̪	ɳ	ɲ	ŋ
Fortis	m̥	m̥ʷ	n̪̥	ɳ̊	ɲ̊	ŋ̊

Table 6: The nasal consonants of Iaai.

in (1), there are two problems with this. First, since the fortis stops already have headed $|\underline{\mathrm{H}}|$ in them they require decomposition of their head (essentially an instance of lenition), in order to result in a representation with only dependent |H|, while changing lenis nasals into fortis nasals requires introducing headed $|\underline{\mathrm{H}}|$ into the nasals — this makes the mappings opposite processes and thus does not really account for the expansion of the AM pattern to fortis nasals. Second, if the process were extended by means of a generalisation in the speakers mind, this should take the form of introducing complement |H| into the nasals and these segments should surface nasal fricatives *[m̃̃, m̃̃] or as creaky voiced nasals *[m̰, n̰], both of which are unattested in Welsh.

If together with the proposal in (2) where headed $|\underline{\mathrm{L}}|$ represents nasality it is assumed that headed $|\underline{\mathrm{H}}|$ represents frication and dependent |H| represents aspiration[9], then both the change from stop to fricative and from lenis to fortis nasal involve composition of |H|. However, since this requires head composition for the fricatives, this still poses the question why the nasals do not become fricatives. Since the single optional headedness condition from (3) forbids segments to be doubly headed, and $|\underline{\mathrm{L}}|$ is already the head of the nasals under the proposal in (2), |H| cannot compose into the head. However, since head composition also requires complemental composition as was seen from the illustration of the composition of headed $|\underline{\mathrm{L}}|$ in (9a), |H| still composes into the complement of the nasals, resulting in a fortis or aspirated nasal. For Nasukawa's proposal in (1), even if headed $|\underline{\mathrm{H}}|$ represents frication and the change of the nasals is not disjoint from the operation that applies to the fortis stops, since there is no head nothing would bar head composition and a nasal fricative would be expected.

Here the proposal that headed $|\underline{\mathrm{L}}|$ represents nasality provides a clear advantage in that it both allows for better generalisations and functions for an explanatory hypothesis able to account for the restrictions applicable to these phonological patterns in Welsh which rule out nasal fricatives. Further of course, as with Icelandic, Welsh provides much further evidence that composition of |H| is the underlying mechanism distinguishing fortis nasals from their lenis counterparts.

3.5 Iaai

Iaai, an Austronesian language spoken in New Caledonia, has an unusually large number of nasals at six places: bilabial, labialised-bilabial, dental, retroflex, pre-palatal and velar[10]. Again, the entire series of nasals occur both in a lenis and a fortis variant (Maddieson and Anderson, 1995; Ozanne-Rivierre, 1976; Tyron, 1968), as illustrated in Table 6. It is also notable that, not unlike Icelandic, Iaai also features the voiceless pairs of the approximants /ɥ, ɥ̊/, /w,

9 Earlier work such as Harris (1994) normally assumes dependent |H| to represent aspiration, while frication is attributed to an independent prime |h|.

10 But cf. Tyron (1968) who does not list retroflex nasals as part of the Iaai phoneme inventory.

w̥/, and /l, l̥/[11]. Minimal pairs for the six nasals, taken from Palmer (2008, p. 81), are given in (11) below.

(11)		*Lenis*		*Fortis*		(Iaai)
	a.	[omʷeeʈ]	fish sp.	[om̥ʷeeʈ]	crab sp.	
	b.	[mita]	soft	[m̥ita]	vomit	
	c.	[n̪e]	cuttlefish	[n̪̊e]	allow	
	d.	[ɳook]	solid	[ɳ̊ook]	hang	
	e.	[ɲi]	tomorrow	[ɲ̊i]	in	
	f.	[ŋe(ɳu)]	talk about	[ŋ̊e(le)]	regard	

As opposed to Icelandic and Welsh, where it has been questioned whether fortis nasal are actual phonemes since they appear to occur only as the result of phonological coalescence or ICM, the status of fortis nasals as phonemes in Iaai has not been questioned in the literature to-date. In fact, Palmer (2008) makes a convincing argument for the full phonemehood of fortis sonorants in Iaai. The analysis of fortis nasals as phonological coalescence of underlying sequences of /hN/, as has been advocated for these segments in Icelandic, can in principle be ruled out by two properties of Iaai's phonology. First, Iaai does not allow complex onsets, which would limit /hN/ to coda+onset environments. As is apparent from the word-initial appearance of these segments in citation forms (cf. ex. 11b–f), they are clearly not limited to such an environment. Second, as Palmer (2008, p. 81) points out, codas in Iaai are restricted to word-final position. This in effect limits any CC clusters to environments crossing word-boundaries, which again is clearly not the context in which these segments are found in Iaai. In order to defend a coalescence analysis, it would have to be posited that Iaai does in fact allow complex onsets, but that they are restricted to the form /hC/. This however poses the big question why no other onsets of the form /hC/, apart from those coalescing into fortis sonorants, are attested in Iaai, so that it needs to be assumed additionally that these clusters are limited to sonorants. Lastly, it would have to be assumed that Iaai has a restriction which only allows these onsets in underlying representations but not on the surface, motivating a process of merger which ignores the same sequences elsewhere (e.g. across syllable or morpheme boundaries). Clearly, upholding this view would seem to be so strongly limited in focus and introduce exceptions focused on such a narrow subset of Iaai phonology that it would be nothing other than a cumbersome and seemingly unnatural way of claiming that fortis sonorants in Iaai are essentially equivalent to singular units which function as full phonemes of the languages for all purposes but lexical storage (and even there, by virtue of being the only complex onsets are readily identifiable single units).

Despite this argument in favour of fortis nasals' status as true phonemes, with underlying representations featuring both |L| and |H| together, there are also contexts which provide evidence that Iaai has a process which changes lenis into fortis nasals by composing |H| into the segment. Consider the examples in (12), taken from Maddieson and Anderson (1995, p. 180), originally from Ozanne-Rivierre (1976).

[11] The interested reader may note that Welsh features both a lenis and fortis alveolar trill, /r, r̥/, which is however neither the result of ICM nor questioned in terms of its status as a phoneme in the literature.

(12)	*Lenis*		*Fortis*		(Iaai)
a.	[weɳe]	name, det.	[w̥eɳii]	name, indet.	
b.	[naŋ]	brandish	[n̥aŋ]	brandish, incorp. obj.	
c.	[yca]	choose	[hyca]	choose, incorp. obj.	
d.	[an]	eat	[han]	eat, incorp. obj.	

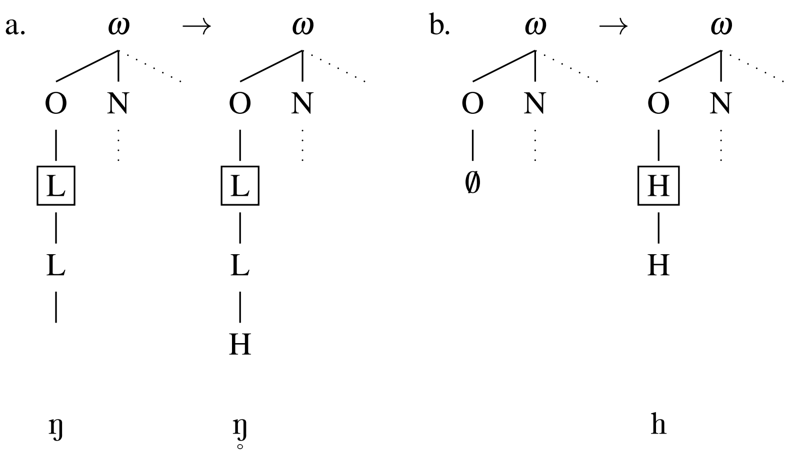
While the change from determinate to indeterminate verb in (12a) also involves a change at the end of the word, a general observation can be made that both the indeterminate and object incorporation forms of the verbs are associate with a change to the left edge of the word. This results in a lenis sonorant being changed into its fortis alternant or insertion of the fortis glottal fricative /h/. This process closely resembles the behaviour of AM in Welsh (cf. Table 5), which also turns lenis nasals into fortis nasals. Additionally, Welsh AM in some environments, such as after the third person feminine possessive /i/ 'her', also results in insertion of a fortis glottal fricative at the left edge of vowel-initial words. Compare the Iaai examples in (12) with the Welsh examples in (13).

(13)	*Lenis*		*Fortis*		(Welsh)
a.	[nain]	grandmother	[i n̥ain]	her grandmother	
b.	[maːb]	son	[i m̥aːb]	her son	
c.	[eirin]	plums	[i heirin]	her plums	
d.	[oren]	orange	[i horen]	her orange	

As illustrated in section 3.4, AM can be explained as composition of headed |$\underline{\text{H}}$| into the targeted segments. The appearance of /h/ before vowels can be further explained by the the generalisation that the process targets not simply the first consonant but the onset position. If the onset is empty, this results in a segment only consisting of |$\underline{\text{H}}$|, and thus word-initial /h/.

A similar analysis is possible for the case of Iaai indeterminates and object incorporation, which shows that this phenomenon is phonologically essentially the same as AM after /i/ 'her' in Welsh. Specifically, morphosyntactic environment triggers a process which composes headed |$\underline{\text{H}}$| into the onset. In cases where the onset is empty, this results in /h/ as an onset, as shown in (14b). Where the onset is a lenis nasal, this results in its fortis equivalent, as shown in (14a) — as was already the case with AM in Welsh, the single optional headedness condition in (3) prevents |H| from composing into the head position of the nasal. Again, if Nasukawa's proposal of dependent |L| for nasality were to be assumed, there would be nothing to prevent |$\underline{\text{H}}$| from compounding to the head position, and regardless which account is assumed for the analogous aspiration–frication question, since the appearance of /h/ shows clearly that what is composed is whatever represents frication, no generalisation can be made that would not lead to the prediction that the nasals should be fricatives or creaky voiced, rather than fortis/aspirated stops.

(14)



As a final indicator of voiceless nasals' status as true phonemes in Iaai may serve the fact that the majority of the French loanwords given in e.g. Dotte (2012) do not appear to contain any of these fortis sonorants; this is something that were to be expected if they are the result of a phonological process rather than underlying representation. A.-L. Dotte (personal communication, May 19, 2013) also confirms that she is not aware of any such loans, except the much older English loan ⟨hmudra⟩ (presumably /m̥ud̪a/) 'mud' (cf. Ozanne-Rivierre, 1984, p. 80).

3.6 Summary

This section began by discussing the overall distribution of so-called 'voiceless' nasals across languages. With information from the UPSID it was illustrated that, while nasals are extremely common, phoneme inventories with nasals classified as voiceless are extremely rare cross-linguistically. It was argued that this can be partially attributed to the assumption that, given the L/H–Parameter, only H-languages can form representations with fortis nasals, excluding these phonemes from all L-languages. It was further argued that a proposed element-antagonism between |L| and |H|, reflected in their opposing acoustic properties, makes representations containing both elements highly marked.

Following this, the three languages Icelandic, Welsh, and Iaai, were discussed. It was shown why the status of these fortis nasals as true phonemes is disputed for Icelandic and Welsh. In Welsh, these segments are the result of ICM, and in Icelandic there is some evidence that they are underlyingly represented as /hC/ sequences or simply the impressionistic result of phonetic overlap in speech production. However, both of these processes provided evidence that these representations feature |H| and are consequently best described along the lines of *aspirated* segments (what was mostly referred to as fortis) in phonological terms.

In contrast, it was shown that for Iaai, there is not only no evidence that these segments are not true phonemes, but that there are in fact strong reasons to believe these items are underlyingly represented as singular segments, due to a ban on complex onsets and the occurrence of these segments in environments without any possible consonant clusters which could lead to coalescence. However, there again appeared to be a process similar to Welsh AM which altered lenis nasals into fortis nasal in an environment where words without any overt onset appear to gain an initial /h/, again leading to the conclusion that |H| is responsible for marking these segments out as fortis in Iaai.

Both the processes in Welsh and Iaai also showed that an analysis where headed |L̲| represents nasality may be advantageous since it rules out the composition of |H| into the head of an existing representation, which in turn allows for a better generalisation that unifies the appearance of fricatives and fortis nasals in the same environment without predicting unattested nasal fricatives.

4 Discussion & Conclusion

At the outset of this paper was the proposal that both true voicing and nasality are represented by the same phonological prime, the low element |L|.

First, it was argued that laryngeal contrast is represented by two opposing (antagonistic) elements, |L| and |H|, where |L| represents true voicing and |H| represents aspiration. The combinatoric possibilities afforded by this, and how this can map onto the way languages implement voicing distinctions, were illustrated in correspondence to both VOT and acoustic characteristics. It was shown that |L| is associated with negative VOT and low-frequency energy and |H| with positive VOT and high-frequency energy, while representations without either default to near zero VOT or an uninfluenced acoustic signal. For languages that have a two-way voicing contrast, it was argued that a central parameter, the L/H-Parameter, reflects whether that language contrasts a neutral empty representation to either representations with |L| or to representations with |H|.

Second, the proposal that nasality is represented by the same prime as true voicing, |L|, was evaluated under consideration of how laryngeal contrast is effected by these two primes. The first proposal considered was that from Nasukawa (1999, 2000, 2005) in (1), who argued that headed $|\underline{\mathrm{L}}|$ represents true voicing and dependent |L| nasality. This was contrasted to the possibility of an alternative proposal in (2), where dependent |L| represents true voicing and headed $|\underline{\mathrm{L}}|$ represents nasality. It was shown how under the latter proposal, nasality can be seen as a more salient version, or extension of, true voicing as represented by |L|. This was reflected in independent proposals such as that by Iverson and Salmons (1996) who propose that prenasalisation in Mixtec is a case of hypervoicing, which aligns well with an analysis where prenasalisation from hypervoicing is essentially the result of fortition of the prime responsible for voicing in the first place, i.e. $|\mathrm{L}| \rightarrow |\underline{\mathrm{L}}|$.

Next, a formal definition of segmental structure and the notions of head, dependent and complement in Element Theory were adopted from Breit (2013). Based on this it was shown that while an element in head-position could be receive an interpretation that includes additional properties beyond its dependent version, including an element as a head always also includes all the properties it would have as a dependent element. Thus it was concluded that headedness can only ever make the properties of a prime more prominent or add additional traits, but never remove any traits or make its characteristics less prominent. This principle was shown to align well with the hypothesis that headed $|\underline{\mathrm{L}}|$ represents nasality and dependent |L| true voicing based on the acoustic evidence discussed prior, which showed that nasality introduces more low-frequency energy than true voicing and also adds characteristic nasal murmur. In addition, it was argued that this proposal accounts for the observation that nasals are by default voiced.

A further argument that was made was that, independent of which proposal for the headedness of |L| is assumed, fortis nasals must feature |H| as they are incapable of expressing the neutral phonation type by virtue of always containing a laryngeally relevant prime, and consequently only H-languages can have fortis nasals (cf. Botma, 2005; Lombardi, 1991). In the later discussion of fortis nasals in Icelandic, Welsh and Iaai, this was shown to be true for each of these languages. All three languages had a process such as ICM, preaspiration or /h/-coalescence which changed lenis nasals into fortis nasals, which it was argued could be best analysed as composition of |H| into the nasals. The fact that in two out of the three languages fortis nasals appear to not actually form part of the underlying lexical representations, but rather appear to be purely the result of these phonological processes, further served to highlight the markedness of segments with both of the laryngeally active primes. The cross-linguistic distribution of fortis nasals further showed that these segments are extremely limited cross-linguistically. This was argued to reflect both the divide along the L/H–Parameter and the markedness associated with the antagonism between the primes |L| and |H|.

On the issue of whether Nasukawa's proposal in (1) or the alternative proposal in (2) is preferable, both the analyses of Welsh and Iaai provided further insights, while the analysis of Icelandic was equally compatible with either proposal. A challenge for Nasukawa's proposal was principally provided by the phenomena of NM and AM in Welsh and the AM-like phenomenon associated with indeterminates and object incorporation in Iaai. The proposal that |L| represents true voicing and headed $|\underline{L}|$ nasality allowed for a better overall account and for better generalisations here. This is especially true of AM in Welsh and the analogous process in Iaai, where lenis nasals change into fortis nasals but other lenis stops change into fricatives. Common to both was also the introduction of a glottal fricative in vowel-initial items. Here Nasukawa's proposal did not allow for a straight forward generalisation of all three surface phenomena (lenis nasals to fortis nasals, lenis plosives to fricatives, /h/ before vowels) as a single underlying process. Moreover, Nasukawa's proposal struggled to explain why these languages do not realise these segments as either fricative or creaky nasals.

Conversely, in the alternative proposal it was shown how since headed $|\underline{L}|$ already occupies the head position, which by the single optional headedness condition is restricted to a single prime, allows for the proposition of a unified underlying mechanism. It also accounts for the fact that the affected nasals result in fortis and not fricative or creaky nasals by virtue of this very fact: |H| cannot compound into the head since this is already taken up by $|\underline{L}|$ and so results in a dependent |H| in nasals, but in the other places the head position is free and so headed $|\underline{H}|$ can be composed resulting in the correct prediction of a fricative.

To conclude, it can be noted that both analyses seem to provide very concise and natural overall solutions to the situation across all the languages and the discussed phenomena surrounding voicing and nasality. However, the assumption that headed $|\underline{L}|$ represents nasality, converse to the common assumption, was shown to be clearly advantageous in allowing broader generalisations in at least some cases, and is favourable in that it is able to rule out the occurrence of nasal fricatives[12]. There appears to be clear evidence for the role that |H| plays in fortis nasals and it seems clear that these segments, at least phonologically, belong to the group of aspirated stops, rather than plain voiceless stops. Consequently, the L/H-Parameter is an important typological predictor of the possibility that such aspirated nasals may occur. It was also shown that the antagonistic relationship of |L| and |H| serves well as an explanatory hypothesis to further underline the rarity of voiceless nasals, especially as true phonemes of a language.

To gain further insights and a better understanding of the observations made here, much further research is clearly needed. This should expand on the number of languages with voicing contrast in nasals and associated phenomena. Of interest here should also be especially languages that make more than a two-way distinction in laryngeal contrast and carry these distinctions in nasals, languages which generally do not make a voicing distinction in stops but make a nasal–oral distinction, as well as nasal–oral stop variation in apparently nasal-less

[12] Note that nasal fricatives are phonetically possible to produce, but it is generally believed that they are restricted to disordered speech, though cf. also Shosted (2006).

languages such as Pirahã and Rotokas (Botma, 2004; Sandalo and Abaurre, 2010) and nasal harmony, for instance in Applecross Gaelic (Ternes, 1973) and Kikongo (Ao, 1991; Nevins, 2010). While Nasukawa (1999, 2000, 2005), Botma (2004), and others have already accrued vast evidence on voicing and nasality in such phenomena, it would be helpful to look specifically at the issue of headedness and the consequences of competing analyses in these contexts. Additionally, since |L| is also associated with the representation of low tone as a suprasegmental and there is evidence linking this with voice, such as tonogenesis, an interesting direction of future research may investigate whether such a relationship can be upheld for nasality and tone. Moreover, if consonant–vowel unity is taken seriously, similar questions arise with regards to vowel conditioned nasality in adjacent consonants and the role of the voicing-related flavour of |L| in nuclei which are commonly assumed to be inherently voiced rather than feature |L| to make them voiced.

References

Adjarian, H. (1899). “Les explosives de l’ancien arménien: étudiées dans les dialectes modernes”. In: *La Parole: Revue internationale de rhinologie, otologie, laryngologie et phonétique expérimentale*, pp. 119–127.

Ao, B. (1991). “Kikongo nasal harmony and context-sensitive underspecification”. In: *Linguistic Inquiry* 22, pp. 193–196.

Árnason, K. (1986). “The segmental and suprasegmental status of preaspiration in Modern Icelandic”. In: *Nordic Journal of Linguistics* 9, pp. 1–23.

Ashby, M. and J. Maidment (2005). *Introducing Phonetic Science*. Cambridge: Cambridge University Press.

Backley, P. (2011). *An Introduction to Element Theory*. Edinburgh: Edinburg University Press.

Ball, M. and N. Müller (1992). *Mutation in Welsh*. London: Routledge.

Ball, M. and B. Williams (2000). *Welsh Phonetics*. Edwin Mellen Press.

Bhaskararao, P. and P. Ladefoged (1991). “Two types of voiceless nasals”. In: *Journal of the International Phon* 21, pp. 80–88.

Bombien, L. (2006). “Voicing alterations in Icelandic sonorants – a photoglottographic and acoustic analysis”. In: *Arbeitsberichte des Instituts für Phonetik und digitale Sprachverarbeitung der Universität Kiel* 37, pp. 63–82.

Borsley, R. D., M. Tallerman, and D. Willis (2012). *The Syntax of Welsh*. Cambridge: Cambridge University Press.

Botma, E. D. (2004). “Phonological aspects of nasality: An element-based dependency approach”. PhD thesis. University of Amsterdam.

— (2005). “On the phonological interpretation of aspirated nasals”. In: *The Internal Organization of Phonological Segments*. Ed. by M. van Oostendorp and J. van de Weijer. De Gruyter, pp. 255–286.

Breit, F. (2013). “Formal Aspects of Element Theory”. MRes dissertation. University College London.

Buczek, A. (1995). “Lenition and fortition: Consonant mutation in Welsh”. In: *Licensing in Syntax and Phonology*. Ed. by Edmund Gussmann. Vol. 1. PASE Studies and Monographs. Lublin, Folium, pp. 187–216.

Chen, M. and H. Clumeck (1975). “Denasalization in Korean: A search for universals”. In: *Nasalfest: Papers from a symposium on nasals and nasalization*. Ed. by C. A. Ferguson, L. M. Hyman, and J. J. Ohala. Stanford, CA: Stanford University Linguistics Department, pp. 125–131.

Cyran, E. (1997). *Resonance Elements in Phonology: A Study in Munster Irish*. Lublin: Folium.

— (2010). *Complexity Scales and Licensing in Phonology*. Berlin: De Gruyter Mouton.

— (2013). *Polish voicing: Between Phonology and Phonetics*. Lublin: Wydawnictwo KUL.

Dantsuji, M. (1984). “A Study on Voiceless Nasals in Burmese”. In: *Studia phonologica* 18, pp. 1–14.

Dotte, A.-L. (2012). *Integration of loan verbs in Iaai (Loyalty Islands, New Caledonia)*. Talk presented at the Fifth Austronesian and Papuan Languages and Linguistics Conference, 4–5 May 2012, SOAS.

Hacopian, N. (2003). “A threnasalsVOT contrast in final position: data from Armenian”. In: *Journal of the International Phonetic Association* 33.1, pp. 51–80.

Halle, M. and K. Stevens (1971). *A note on laryngeal features*. Quarterly Progress Report 101. Research Laboratory of Electronics, MIT.

Hall, T. A. (2007). “Segmental features”. In: *The Cambridge Handbook of Phonology*. Ed. by Paul de Lacy. Cambridge: Cambridge University Press, pp. 311–334.

Harris, J. (1994). *English Sound Structure*. Oxford: Blackwell.

Harris, J. and E.-A. Urua (2001). “Lenition degrades information: consonant allophony in Ibibio”. In: *Speech, Hearing and Language: Work in Progress* 13, pp. 73–105.

Haugen, E. (1958). “The phonemics of Modern Icelandic”. In: *Language* 34, pp. 55–88.

Honeybone, P. (2005). “Diachronic evidence in segmental phonology: the case of obstruent laryngeal specifications”. In: *The Internal Organization of Phonological Segments*. Ed. by M. van Oostendorp and J. van de Weijer. Berlin: Mouton de Gruyter, pp. 319–354.

Itô, J. and R. A. Mester (1986). “The Phonology of Voicing in Japanese: Theoretical Consequences of Morphological Accessibility”. In: *Linguistic Inquiry* 17, pp. 49–73.

Iverson, G. K. and J. C. Salmons (1995). “Aspiration and laryngeal representation in Germanic”. In: *Phonol* 12, pp. 369–396.

— (1996). “Mixtec Prenasalization as Hypervoicing”. In: *International Journal of American Linguistics* 62.2, pp. 165–175.

Jessen, M. and M. Pétursson (1998). “Voiceless Nasal Phonemes in Icelandic”. In: *Journal of the International Phonetic Association* 28.1-2, pp. 43–53.

Jones, D. and K. Minn (1924). “spesimɜn koriən”. In: *lə mɜːtrə fɔnetik: ɔrgan də l̥ asɔsjaːsjɔ̃ fɔnetik ɜ̃ːtɜrnasjonal*. Pp. 14–15.

Kaye, J., J. Lowenstamm, and J.-R. Vergnaud (1985). “The internal structure of phonological elements: a theory of charm and government”. In: *Phonology* 2, pp. 305–328.

Kibre, N. J. (1997). *A Model of Mutation in Welsh*. Bloomington, IN: Indiana University Linguistics Club Publications.

Kim, Y. (2002). “Phonological features: privative or equipollent?” A.B. thesis. Harvard University.

Kim, Y. S. (2011). “An acoustic, aerodynamic and perceptual investigation of word-initial denasalization in Korean”. PhD thesis. University College London.

King, G. (2003). *Modern Welsh: A Comprehensive Grammar*. 2nd ed. London: Routledge.

Ladefoged, P. and I. Maddieson (1996). *The Sounds of the World’s Languages*. Oxford: Blackwell.

Lisker, L. and A. Abramson (1964). “A Cross-Language Study of Voicing in Initial Stops: Acoustical Measurements”. In: *Word* 20.3, pp. 384–422.

Lombardi, L. (1991). “Laryngeal features and laryngeal neutralization”. PhD thesis. University of Massachusetts, Amherst.

Maddieson, I. and V. B. Anderson (1995). “Phonetic Structures of Iaai”. In: *Proceedings of the 13th International Congress of Phonetic Sciences*. Ed. by K. Elenius and P. Branderud. Vol. 163-182. KTH & Stockholm University.

Nasukawa, K. (1999). “Prenasalisation and melodic complexity”. In: *UCL Working Papers in Linguistics* 11, pp. 53–70.

— (2000). “Nasal harmony as prosody-driven agreement”. In: *UCL Working Papers in Linguistics* 12, pp. 257–285.

— (2005). *A Unified Approach to Nasality and Voicing*. Berlin: Mouton de Gruyter.

Nevins, A. (2010). *Locality in Vowel Harmony*. Cambridge, MA: MIT Press.

Ozanne-Rivierre, F. (1976). *Le Iaai: langue mélanésienne d’Ouvéa (Nouvelle-Calédonie). Phonologie, morphologie, esquisse syntaxique*. Paris: Société d’études linguistiques et anthropologiques de France.

— (1984). *Dictionnaire Iaai–Français*. Paris: SELAF.

Palmer, B. (2008). “Voiceless sonorants – phonemes or underlying clusters?” In: *Australian Journal of Linguistics* 19.1, pp. 77–88.

Pétursson, M. (1973). “Phonologie des consonnes nasales en Islandais moderne”. In: *La Linguistique* 9, pp. 115–138.

Sandalo, F. and M. B. Abaurre (2010). “Orality spreading in Pirahã”. In: *Liames: Línguas Indígenas Americanas* 10, pp. 7–19.

Scully, C. (1973). “An experimental study of Welsh nasal mutations”. In: *Phonetics Department Report, University of Leeds* 4, pp. 47–71.

Shosted, R. K. (2006). “The Aeroacoustics of Nasalized Fricatives”. PhD thesis. University of California, Berkeley.

Ternes, E. (1973). *The Phonemic Analysis of Scottish Gaelic: Based on the Dialect of Applecross, Ross-shire*. Hamburg: Buske.

Tyron, D. T. (1968). *Iai Grammar*. Pacific Linguistics Publishers.