

# Why final obstruent devoicing is weakening

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## 1 Introduction

There is a long-standing tradition in phonology of regarding the widespread process of final obstruent devoicing as a form of fortition, hardening (*Verhärtung*) or strengthening.<sup>1</sup> The view has deep roots in the philological tradition and continues to be widely held right up to the present day (see for example Iverson & Salmons 2007).

There is a less well established view that the process is rather one of lenition or weakening. Although this view is not always explicitly presented as such, it is inherent in proposals to treat final devoicing in terms of feature reduction or deletion (see for example Mascaró 1987, Brockhaus 1995, Lombardi 1995, Jessen & Ringen 2002).

The present paper has two main goals. The first is to show that the available evidence clearly favours the weakening account of final devoicing. The second is to present a unified model of phonological strength that unequivocally classifies final devoicing as weakening.

Of course it all depends on what we mean by strengthening and weakening. Like most scientific generalisations, the notion of strength in phonology is a metaphor. Its initial value flows from the way it allows us to put a name to a set of generalisations that would otherwise go unexpressed. This brings us to the first of the three main reasons I will present for rejecting the strengthening account of devoicing: it subverts important generalisations we can otherwise make about processes that uncontroversially do count as weakening, such as debuccalisation and spirantisation. The generalisations concern (i) the phonetic impact of weakening, (ii) the otherwise general tendency for final position to promote weakening and (iii) the way in which final devoicing sometimes interacts directly with weakening processes in the same language.

The other two reasons for rejecting the strengthening account coincide with the two main arguments used to support it. One is based on the observation that obstruent voicing, such as commonly occurs intervocally, is clearly a weakening process. Since devoicing apparently has the opposite phonetic effect, so the argument goes, it should surely be viewed as strengthening. The other argument takes the form of a claim that devoicing strengthens final obstruents in order to demarcate the right edge of words (Iverson & Salmons 2007).

As I will try to show below, neither of these arguments is particularly convincing. The first is based on a faulty conception of voicing as an entity that remains uniform across different segment types and phonological contexts. The second is based on the questionable assumption that processes with a demarcative function are necessarily strengthening in nature.

If strength is to be more than pure metaphor, we need to establish whether it correlates with any known phonetic property and whether it has any unitary presence in phonological representation. It is widely supposed that strength has a basis in sonority or degree of articulatory aperture. Neither of these definitions provides us with a unified

model of strength, let alone with a yardstick for determining whether final devoicing counts as weakening or strengthening

This paper outlines an alternative definition of phonological strength that unambiguously unifies final devoicing with processes uncontroversially regarded as weakening. The definition is based on the characterisation of speech as a carrier signal modulated by linguistically significant acoustic events. The strength of a segment can be defined as the extent to which it modulates the carrier signal. Any process that reduces the extent of a modulation counts as a weakening. Not only does this approach clearly establish final devoicing as a weakening process but it also invites connections with certain word-final processes that are not usually considered to be related to strength.

The first part of the paper discusses evidence showing that final devoicing clearly patterns with well established weakening processes. I will present this evidence at the same time as critiquing two of the main claims for treating devoicing as strengthening: that it is the phonetic opposite of voicing (§3) and that it serves to mark word-final position as strong (§4). The second part of the paper addresses the issue of whether strength has any unitary phonetic basis, starting with reasons for rejecting definitions based on sonority or articulatory aperture (§5). In §6, I outline the unified account of phonological strength that is provided by the modulated-carrier model of speech and show how this unambiguously classifies final devoicing as weakening. I conclude in §7 by considering the broad implications of this account for how we evaluate alternative feature representations of final devoicing. First, however, we need to dispose of one criterion that might have been assumed to help us decide between the strengthening and weakening analyses of final devoicing: neutralisation.

## 2 Neutralisation

Final devoicing has long been held up as a paradigm example of neutralisation. As illustrated by the Dutch examples in (1), a stem-final lexical distinction between voiced and voiceless obstruents is maintained before a suffix vowel but suspended word-finally.

(1) Dutch

	Singular	Plural	
(a)	va[t]	va[t]en	‘barrel’
	aa[p]	a[p]en	‘ape’
	me[s]	me[s]en	‘knife’
(b)	ba[t]	ba[d]en	‘bath’
	dui[ʃ]	dui[v]en	‘dove’
	hui[s]	hui[z]en	‘house’

It might have been tempting to cite this neutralising effect as evidence in favour of a weakening analysis – at least if we follow a tendency in the recent literature to conflate neutralisation with weakening on the one hand and strengthening with contrast maintenance on the other. The tendency finds expression in the use of output constraints that promote fortition and the preservation of distinctions in strong positions (see for

example Kirchner 1998, Zoll 2004). However, there are at least two reasons for rejecting neutralisation as a criterion for choosing between strengthening and weakening.

The first reason is that strengthening and contrast preservation should not be conflated. (Nor is there a strong cross-linguistic correlation between weakening and neutralisation (Gurevich 2004).) It is certainly true that strong positions can often sustain contrasts that are neutralised elsewhere. It is also true that prominent positions can promote strengthening. But these two characteristics are not intrinsically connected. Strengthening is potentially no less neutralising than weakening, a fact that can be established independently of devoicing. For example, the strengthening process that hardens continuants to plosives after nasals in Sesotho neutralises the continuancy contrast we see when we compare (2)a with (2)b (Doke & Mofokeng 1974):

(2) Sesotho			
		‘vb. me’	
(a) <i>t<sup>h</sup>eta</i>	<i>n-t<sup>h</sup>eta</i>	‘roll’	
<i>p<sup>h</sup>ehela</i>	<i>m-p<sup>h</sup>ehela</i>	‘cook for’	
(b) <i>rata</i>	<i>n-t<sup>h</sup>ata</i>	‘love’	
<i>fa</i>	<i>m-p<sup>h</sup>a</i>	‘give’	

In any case, there is another reason for not using neutralisation to adjudicate between the strengthening and weakening analyses: an on-going controversy over whether final devoicing is genuinely neutralising in the first place. A series of studies of some of the best known languages with devoicing has discovered small but significant phonetic differences between pairs of consonants that are supposedly merged by the process (e.g. Port & O’Dell 1985, Slowiaczek & Dinnsen 1985, Charles-Luce & Dinnsen 1987, Piroth & Janker 2004, Ernestus & Baayen 2006). The controversy continues partly because listeners in these studies cannot always detect these differences reliably and partly because of methodological concerns that the studies do not always adequately control for potentially contaminating factors such as orthography and pragmatic context. These findings do not call into question the fact that devoicing describes a real process (or collection of processes) with identifiable phonetic effects. In examining these effects below, we can side-step the issue of whether they result in true merger or not.

### 3 The disunity of voice

#### 3.1 Final devoicing and intervocalic voicing

We can illustrate the notion that final devoicing and intervocalic voicing produce phonetically opposite outcomes by comparing the Dutch examples in (1) with the Kalenjin examples in (3) (data from Katamba 1989).

(3) Kalenjin

	Progressive	
<i>kep</i>	<i>kebe:t</i>	‘notch’
<i>nap</i>	<i>nabe:t</i>	‘sew’
<i>ku:t</i>	<i>ku:te:t</i>	‘blow’
<i>luk</i>	<i>luge:t</i>	‘fight’

The observation that the outcomes are apparently phonetic opposites lies behind the traditional assumption that the two processes pull in different strength directions: voicing weakens a consonant, so devoicing strengthens it.

The grounds for treating intervocalic obstruent voicing as weakening are pretty well established. In particular, it displays two characteristics that can reasonably be considered symptomatic of weakening. First, whenever it is sensitive to prosodic or morphological domain structure, it typically occurs in what are independently known to be weak or ‘non-prominent’ positions, such as non-initial in the foot or stem. Second, as illustrated by the Basaa examples in (4)a, it frequently co-occurs with spirantisation or vocalisation. And these processes can be identified as weakening quite independently of the voicing issue, as illustrated by Tuscan Italian spirantisation in (4)b (see Giannelli & Savoia 1980) and Central American Spanish vocalisation in (4)c (see James Harris 1983).

(4) (a) Basaa

	Reversive	Passive	
<i>kap</i>	<i>kewel</i>	<i>kewa</i>	‘to share’
<i>tet</i>	<i>tiril</i>	<i>tira</i>	‘to pound’
<i>lok</i>	<i>luyul</i>	<i>luya</i>	‘to lie’

(b) Italian

Standard	Gorgia Toscana	
<i>kapo</i>	<i>ka<math>\phi</math>o</i>	‘head’
<i>prato</i>	<i>pra<math>\theta</math>o</i>	‘meadow’
<i>amiko</i>	<i>ami<math>x</math>o</i>	‘friend’

(c) Spanish

Castilian	Cibaeño	
<b>pape</b> [l]	<b>pape</b> [y]	‘paper’
<b>a</b> [l]go	<b>a</b> [y]go	‘something’
<b>ma</b> [r]	<b>ma</b> [y]	‘sea’
<b>ca</b> [r]ta	<b>ca</b> [y]ta	‘letter’

Given the popularity of the strengthening take on devoicing, it is somewhat surprising to note – as Brockhaus does in her 1995 analysis of the process in German – that the process displays essentially the same two ‘weak’ symptoms as intervocalic voicing. First, at least for many purposes, word-final position undoubtedly counts as non-prominent, especially when compared with initial position within, for example, the word or foot. (We should of course not be too hasty in assuming that final position is always weak in this sense, especially in light of Iverson & Salmons’ (2007) claim that devoicing serves to signal word ends by marking them as strong.) Second, devoicing often co-occurs with processes with independently verifiable weakening effects. We

will examine evidence of these two characteristics in some detail below. But even a preliminary acknowledgement that intervocalic voicing and final devoicing are similar in these two respects suggests we should review the notion that the outcomes of the two processes are phonetic opposites of one another.

### **3.2 Active versus passive voicing**

The assumption that final devoicing produces the opposite outcome to intervocalic voicing is itself based on another, more general assumption: phonetic voicing is phonologically classifiable as [+voice] (or some equivalent category), irrespective of the type of segment or the phonological context it occurs in. Following Itô, Mester & Padgett (1995), let us call this the ‘unity of voice’ principle. Although the assumption may have a certain pedagogical usefulness in introductory phonetics and phonology courses, it is known to be incorrect in certain crucial details. The available evidence points unequivocally to a fundamental disunity of voice. The evidence is of three types, involving differences among (i) segment types, (ii) phonological contexts and (iii) languages. We can briefly review the first two of these right away, before moving on in the next section to a more detailed consideration of the third.

The main segment-type evidence involves the well established distinction between spontaneous and non-spontaneous voicing (cf. Halle & Stevens 1971). The absence of a build-up of intra-oral air pressure in sonorants allows for continuous airflow across the glottis, thereby facilitating spontaneous vocal-fold vibration. In contrast, voicing in obstruents is inhibited by a build-up of oral pressure and can in most circumstances only be maintained by the non-spontaneous activation of some compensatory gesture.

As to the phonological-context evidence, the status of voicing within the class of obstruents themselves varies according to phonological position. And it does so in a way that bears directly on the contextual difference between final devoicing and intervocalic voicing. The inhibitory effect of obstruent stricture on vocal-fold vibration makes itself felt most forcefully at the beginning and end of utterances and words. Intervocalically, however, there is the potential for the spontaneous voicing of the surrounding sonorants to be interpolated passively through the obstruent, especially if it is of reduced duration (Westbury & Keating 1986, Rice & Avery 1989, Kirchner 1998, Iverson & Samuels 2003, Avery & Itsardi 2001, Harris 2003, Jansen 2004).

On the basis of this contextual difference within the obstruent class, we are entitled to conclude that final devoicing and intervocalic voicing are not phonetic opposites at all. Rather they are two sides of the same coin: each moves an obstruent towards a phonetically inert or unmarked state. This suggests that whatever we conclude about the strengthening or weakening status of one of the processes necessarily also holds of the other. Since we have independent reasons to treat the voicing process as weakening, a natural conclusion would be that devoicing must be weakening as well.

### **3.3 Voicing versus aspiration languages**

The third reason for rejecting the unity-of-voice assumption concerns differences in the way voice contrasts manifest themselves in individual languages. Convenient as the traditional voiced-voiceless terminology may be for broadly describing languages with

a two-way laryngeal contrast, it is quite unhelpful for our present purposes. This is because it glosses over precisely the kind of phonetic detail we need to take account of in deciding whether obstruent devoicing counts as strengthening or weakening. In particular, it abstracts away from the different ways in which the timing of voicing activity can be used to signal laryngeal contrasts in plosives. In doing so, it ignores the major typological distinction between voicing languages and aspiration languages (cf. Jakobson 1949), based primarily on differences in voice onset time in word-initial plosives (as first systematically measured by Lisker & Abramson 1964). For our present purposes, we may class as voicing languages those where a two-way laryngeal contrast in initial plosives takes the form of a distinction between a plain series with zero or near-zero lag-time and a prevoiced series with long lead-time. The corresponding contrast in aspiration languages is realised as a VOT difference between zero lag-time (plain) and long lag-time (aspirated).

Final devoicing occurs both in voicing languages (such as Dutch) and in aspiration languages (such as German). The use of the single term DEVOICING might be taken to imply a process with the same phonetic effect in both types of language. Let us consider whether this implication is justified or not.

On the face of it, the situation in voicing languages seems pretty straightforward. In languages of this type that lack devoicing (such as French and Hungarian), final voiced plosives are ‘post-voiced’ in a way that roughly mirrors the prevoicing of initial plosives; that is, there is a significant time lag between the onset of post-vocalic stop closure and the offset of voicing (Flege & Hillenbrand 1987, Jansen 2004). DEVOICING in voicing languages (such as occurs in Dutch, Catalan and Russian, for example) can thus be considered an accurate term for the process that excludes post-voiced obstruents from final position. We can thus say that, in voicing languages, it is the plain series of obstruents that survives in final position: obstruents in this position lack the active laryngeal component that characterises the voiced series in initial position.

The corresponding situation in aspiration languages seems less straightforward. What does it mean to say that devoicing can occur in a language that lacks actively voiced obstruents? An often implicit way of justifying the use of the term DEVOICING to describe languages of this sort is to compare final obstruents with intervocalic counterparts. In standard German, for example, the intervocalic *d* of **Bade** is phonetically voiced, so it seems to make sense to describe the final *t* of **Bad** as devoiced. This is an invidious comparison, however, in light of the fact mentioned above that voicing in intervocalic stops can be spontaneous in nature. In the case of German, there is good reason to view intervocalic *b*, *d*, *g* as plain stops that are passively voiced as a result of vocal-fold vibration seeping through from the surrounding vowels (cf. Jessen & Ringen 2002). So the term DEVOICING is not a particularly felicitous way of describing what happens to obstruents in German-style languages, since there is nothing intrinsically voiced to devoice in the first place.

What sort of obstruents survive in final position in aspiration languages with devoicing? According to the strengthening account of German, they come out as fortis – the term used to describe the aspirated plosives that occur word-initially. In fact, Iverson & Salmons (2006, 2007) explicitly classify the final voiceless plosives as aspirated too. (Brockhaus (1995) also employs this description but reserves it for lexically voiceless final stops; these for her remain phonetically distinct from the

devoiced series, which she identifies as plain. Her analysis thus takes on board the claim of Port & O'Dell (1985), Piroth & Janker (2004) and others that devoicing is not fully neutralising in German.) Iverson & Salmons' terminology is consistent with a tradition of using the term *ASPIRATED* (sometimes qualified by terms such as *PARTIALLY* or *LIGHTLY*) to describe final voiceless plosives, not just in German but in other languages as well, including Danish, Klamath, Kashmiri, Turkish (see Vaux & Samuels 2005 and the references there) and English (Gimson 1995). However, this description is problematic on at least two counts.

Firstly, the final voiceless obstruents in German are not reported to be significantly different phonetically from devoiced obstruents in voicing languages. If we specify the German series as aspirated, phonetic consistency would demand that we do the same for the corresponding series in voicing languages. In other words, we would have to recognise a type of language in which aspiration is licensed word-finally but not initially. Whether there is any typological precedent for this state of affairs is quite controversial. While most phonologists would deny any such precedent, Vaux & Samuels (2005) argue that aspiration is the unmarked state for final voiceless plosives, including in voicing languages. Of course even if we subscribe to the majority view on this, we could ignore considerations of phonetic consistency and just say that the phonological specification of final voiceless obstruents varies according to whether they occur in aspiration or voicing languages.

Secondly, there is the question of whether it is accurate to describe German final plosives as aspirated in the first place. Although VOT is only one of a wide range of potential cues to voice contrasts (cf. Kingston & Diehl 1994), its long-lag instantiation in initial pre-vocalic plosives is acknowledged to be one of the most robust measures of aspiration (as originally noted by Lisker & Abramson 1964). While VOT is measurably continuous in speech production and the acoustic signal, its behaviour in speech perception and phonological distinctiveness is very clearly categorical. Referring to degrees of aspiration may be a convenient way of describing timing differences in articulation or acoustics, but it is not a valid way of talking about perception or phonology. There is a well-established VOT point (around 35 ms) at which listeners' identification of initial plosives tips abruptly from plain to aspirated (see Keating 1984). If a final plosive is to be described as aspirated, it would be reasonable to expect it to display similarly categorical timing behaviour. This is indeed what we find with pre-aspiration (as in some North Germanic and Celtic), where there is a significant time lag between voicing offset and closure onset in final voiceless plosives (Ladefoged & Maddieson 1996). But it is not what we find in German, where Iverson & Salmons (2007) explicitly describe the corresponding series as postaspirated.

In any case, there are circumstances where post-aspiration simply cannot be phonetically expressed as long-lag VOT in final plosives, namely when there is no following vowel for VOT to onset onto. The conditions necessary for long-lag VOT in a word-final plosive are only met when a vowel follows. When that vowel is part of a suffix, it of course blocks devoicing; however, lexically voiceless stops in this context (e.g. the *t* of **Boot-e** 'boats') do not show long-lag VOT. When the vowel is part of a following word, the possibility of long-lag VOT on the final consonant is closed off in many northern varieties by *harter Einsatz* – the appearance of an intervening glottal onset. However, in those varieties of German where *harter Einsatz* is either variable or

not present at all, it is clear that final plosives are not aspirated in this environment (without *harter Einsatz*, the *t* in **schaut aus** ‘seems’, for example, lacks the long-lag VOT of the *t* in **tauchen** ‘dive’). The same is true of voiceless final plosives in English (one of the reasons **taupe oak** is distinct from **toe poke**, for example).

We have to conclude that, when Iverson & Salmons (2007) and Vaux & Samuels (2005) use the term *ASPIRATED* to describe final plosives in German and other languages, they are identifying some property other than VOT. That property, we may surmise, is the voiceless noise burst accompanying the release of the plosive. The burst consists of a transient followed by a brief interval of high-intensity aperiodic energy (cf. Stevens 2002) – but crucially not by a prolonged interval of lower-intensity aperiodicity of the type that characterises long-lag VOT in word-initial aspirates. The burst might appear particularly noteworthy in final plosives when compared to languages where final voiceless stops are unreleased, either variably (as in many dialects of English) or obligatorily (as in many southeast Asian languages). But all plosives – plain, aspirated or otherwise – are by definition characterised by a release burst. In short, there is no reason for us to describe final voiceless stops in German as anything other than plain and released.

One of the main contributions of the work of Iverson & Salmons (2007) and Vaux & Samuels (2005), it seems to me, is that it highlights the need to distinguish aspiration from plosive release when describing final oral stops (see Jansen 2004 for further discussion of this point). What is traditionally referred to as final devoicing can suppress aspiration in this position without necessarily also suppressing plosive release. The latter property can of course also be suppressed (as in Thai for example), as part of a set of processes that we might refer to more generally as ‘delaryngealisation’ (see Honeybone 2005 and the references there). We will return to this point below.

To sum up: the traditional term *DEVOICING* describes a situation in which the only type of obstruent permitted in final position is plain. This is true irrespective of the nature of whatever laryngeal contrast may hold in other positions – be it one based on active voicing or one based on aspiration.

It is generally agreed that aspiration, like non-spontaneous voicing, requires the active engagement of an articulatory component that is lacking in plain plosives. The notion that a plain stop is somehow a diminished version of its aspirated and voiced counterparts might be taken as support for the view that final devoicing is weakening. However, if this conclusion is to have more than intuitive appeal, it needs to follow from a theory that defines a necessary connection between weakening and the lack or loss of components. Before taking up this issue in §6 below, let us consider the other main justification for treating final devoicing as strengthening: the claim that it serves to demarcate the ends of words.

## **4 Positional strength**

### **4.1 Devoicing as demarcative strengthening**

In presenting their case for viewing final devoicing as strengthening, Iverson & Salmons (2007) subscribe to Blevins’ (2006) claim that the process has its origins in the

inhibition of vocal-fold vibration commonly observed at the end of utterances. The explanation runs as follows. The high incidence of devoiced obstruents that are both utterance- and word-final provides a basis for learners to overgeneralise the pattern to all word-final obstruents, including those that are utterance-internal. (It is not made clear why the devoicing effect fails to overgeneralise to all segments, including sonorants, which can also be subject to utterance-final voicing decay.) At this point, strengthening by devoicing takes on the function of marking word ends.

In order to be able to evaluate the claim that final devoicing is demarcative strengthening, we need to answer two questions. First, is there evidence, independent of devoicing, that final position promotes segmental strengthening? That is, do we find evidence of consonants' manner or place characteristics being strengthened in this context? Second, is there a necessary connection between demarcative function and strengthening?

## 4.2 Word-final weakness

On the first of these questions, it has to be said right away that the strength enhancing properties Iverson & Salmons (2007) attribute to final position in German cannot be considered a language universal. Word-final position is overwhelmingly acknowledged to be a weak or position in the sense that it favours or fails to resist segmental changes (see Beckman 1997 for discussion and references), including weakening and deletion (cf. Escure 1977, Lass & Anderson 1975, Harris 1997).

It is certainly possible to find sporadic examples of individual languages where final position appears to act as a strengthening environment for manner, but even here the evidence is somewhat equivocal. For example, Korean fricatives are hardened to stops word-finally (as described in Kim 1979 for example). However, this has to be offset against the fact that this is just one consequence of a more general word-final effect that neutralises the Korean three-way laryngeal contrast in plosives, affricates and fricatives under a single lax stop series. And there is good reason to treat this laxing as a simplification or weakening process (as argued by Ahn & Iverson 2003).

By far the more general pattern is for word-final processes that target manner or place to have weakening effects. This point is underlined by the fact that final position often lines up with other positions that are independently acknowledged as weak, in particular internal codas. In the case of manner, this combined environment is the one favoured by some of the weakening processes mentioned above, including liquid vocalisation of the type illustrated by the Cibaño Spanish examples in (4).

The evidence is even more clear-cut in the case of place. It is difficult to imagine what a place-strengthening process would look like: the spontaneous emergence of place categories not historically attested in other, supposedly weaker positions perhaps? In contrast, it is very clear what place-weakening looks like: debuccalisation. And word-final position is precisely one of the positions that favours debuccalisation of stops and fricatives, as the northern Malay data in (5) illustrate (data from Onn 1980).

(5)	Northern Malay		
	STEM	NOMINALISED	
(a)	<i>ʔasaʔ</i>	<i>ʔasapan</i>	‘smoke’
	<i>kilaʔ</i>	<i>kilatan</i>	‘lightning’
	<i>sepaʔ</i>	<i>sepakan</i>	‘kick’
(b)	<i>balah</i>	<i>balasan</i>	‘finish’
	<i>habeh</i>	<i>habisan</i>	‘end’
	<i>negateh</i>	<i>negatefan</i>	‘negative’

The evidence from processes that target manner or place helps establish final position as a typically weak environment. If we tried to maintain that final devoicing simply bucks this trend by acting as demarcative strengthening, we would at the very least expect it not to co-occur with final weakening processes in the same language. However, this expectation is simply not borne out.

Consider the example of southern Catalan, where, as in other dialects of the language, final obstruent devoicing is traditionally described as neutralising; compare (6)a.i with (6)a.ii (see Lloret & Jiménez 2008 for data and discussion). As shown in (6)a.ii, voiced stops are subject to intervocalic spirantisation.

(6)	Southern Catalan				
(a)	(i)	<i>peti[t]</i>	‘small (m.)’	<i>peti[t̥]a</i>	‘small (f.)’
		<i>se[k]</i>	‘dry (m.)’	<i>se[k̥]a</i>	‘dry (f.)’
	(ii)	<i>fre[t]</i>	‘cold (m.)’	<i>fre[ð]a</i>	‘cold (f.)’
		<i>ce[k]</i>	‘blind (m.)’	<i>ce[ɣ]a</i>	‘blind (f.)’
(b)	(i)	<i>peti[ð] i dolç</i>	‘small and sweet’		
		<i>se[ɣ] i prim</i>	‘dry and thin’		
	(ii)	<i>fre[ð] i fosc</i>	‘cold and dark’		
		<i>ce[ɣ] i sord</i>	‘blind and deaf’		
(c)	(i)	<i>va[k]a</i>	‘cow’		
		<i>ca[s]a</i>	‘game’		
	(ii)	<i>va[ɣ]a</i>	‘strike’		
		<i>ca[z]a</i>	‘house’		

When intervocalic, word-final obstruents in southern Catalan are also subject to voicing and, in the case of stops, spirantisation. When we compare (6)b.i with (6)b.ii, we can see that this voicing shows up on both lexically voiceless and lexically voiced obstruents. The neutralisation here is directly due to final devoicing rather than to voicing itself. This can be established by noting that lexically voiceless obstruents are immune to voicing in word-internal position, where they maintain a contrast with lexically voiced counterparts (compare (6)c.i and (6)c.ii). To put it in derivational terms: word-finally, the neutralised output of devoicing is the input to intervocalic voicing. Final devoicing in southern Catalan thus occupies a place on a trajectory that includes two weakening processes, intervocalic voicing and spirantisation (e.g.  $b/p > p > \beta$ ). If devoicing really were demarcative strengthening, then we would have to conclude that the phonology of southern Catalan sends out contradictory signals: word ends are marked as strong by some processes but as weak by others.

We might have retreated to a position where Iverson & Salmons’ (2007) account of devoicing as demarcative strengthening applies only to German – or maybe only to

aspiration languages (and thus not to Catalan, a voicing language). However, in German too we find clear evidence that word-final position acts as weak for certain processes, including some that are entwined with devoicing (see Brockhaus 1995). Let us briefly consider a number of examples where final position lines up with one or other of two well-established weak environments – internal codas and unstressed syllables.

The combined environment of word-final position and word-internal coda hosts a range of weakening processes in various dialects of German. For example, it is the site of non-rhoticity (see (7)a) and, in some regional dialects, *l*-vocalisation (see the Austrian German examples in (7)b). In northern German, it is part of the environment where historical *g* is spirantised (see (7)c).

(7)	(a)	Pfi $\chi$ sich		‘peach’			
		Pfe $\chi$ d		‘horse’			
		seh $\chi$		‘very’			
	(b)	Schulter	Schu[y]ter	‘shoulder’			
		Gold	Go[y]d	‘gold’			
		Stuhl	Stu[y]	‘chair’			
	(c)	sagen	sa[y]en	‘say’	sagte	sa[x]te	‘said’
		Tag	Ta[y]e	‘days’	Tag	Ta[x]	‘day’

Note in (7)c how *g*-spirantisation intersects with devoicing in word-final position, yielding *x* in **Tag**. Let us now examine a more extensive illustration of how devoicing can interact directly with weakening processes in German.

In some varieties of northern German, historically fortis stops undergo voicing and, in the case of coronals, tapping when intervocalic within a foot (see (8)a).<sup>2</sup> The examples in (8)b confirm the contribution of the metrical condition: intervocalic fortis stops resist voicing/tapping when foot-initial. The voiced/tapped stops merge with their historically lenis counterparts (see (8)c), reinforcing the conclusion that the process is one of weakening.

(8)	(a)	Suppe	Sú[b]e	‘soup’
		bitte	bí[r]e	‘please’
		Zucker	Zú[g]er	‘sugar’
	(b)	Papier	Pa[pʰ]ier	‘paper’
		getaucht	ge[tʰ]áucht	‘dived’
		Paket	Pa[kʰ]ét	‘parcel’
	(c)	Grube	Grú[b]e	‘mine’
		Seide	Séi[r]e	‘silk’
		Fuge	Fú[g]e	‘seam’

In those northern varieties where *harter Einsatz* is only variably present, the other context where stops occur intervocalically is word-final before a vowel-initial word. As noted above, the absence of long-lag VOT from this otherwise favourable environment is one indication that these stops should not be classified as aspirated. This conclusion is bolstered by the fact that dialects with voicing/tapping show it here too, as illustrated in (9).

(9)	(a)	(i)	klipp und klar	kli[b] und klar	‘clearly’
			hat er	ha[r] er	‘he has’
		(ii)	hat Ernst	ha[r] Érnst	‘Ernst has’
			ein Schluck auf	ein Schlu[g] áuf	‘a toast to’
	(b)		gab ihm	ga[b] ihm	‘gave him’
			fand er	fan[d] er	‘he found’

Unlike the word-internal context, the word-final manifestation of voicing/tapping occurs regardless of whether the following vowel is unstressed (as in (9)a.i) or stressed (as in (9)a.ii). This is further confirmation that the process is sensitive to foot structure, a point we’ll return to immediately below. As with southern Catalan voicing/spirantisation, word-final voicing/tapping in the relevant German dialects applies to the merged output of devoicing. In the case of final stops, this means that the process affects not only historical *p/t/k* (as in (9)a) but also, as illustrated in (9)b, *b/d* (historical *g* is subject to the spirantisation illustrated in (7)c).

For this example to count against the strengthening analysis of final devoicing, it is important to establish that intervocalic position in German only acts as weak under certain prosodic conditions. This is highlighted in (10), which spells out the different foot and word conditions under which an intervocalic stop can occur (in the absence of *harter Einsatz*). (In (10), word boundaries are marked by square brackets and foot boundaries by parentheses; the illustrative stops, here represented by *p*, are underlined.)

(10)

	WORD	FOOT		
(a)	Initial	Initial	V[(CV	zwei <u>P</u> ulte ‘two desks’
	Internal	Initial	V(CV	Pap <u>i</u> er ‘paper’
(b)	Internal	Internal	(VCV)	Sup <u>p</u> e ‘soup’
	Final	Internal	VC]V)	kl <u>i</u> pp und klar ‘clearly’
	Final	Final	VC)]V	schle <u>p</u> p áuf ‘draw up’

The foot- and/or word-initial contexts in ((10)a) resist voicing/tapping and thus count as strong. The contexts where voicing/tapping does apply, those in ((10)b), are all non-foot-initial; and it is this property that marks them out as weak. Since word-final position belongs to this non-foot-initial set, we can conclude that it counts as weak for the purposes of both tapping and voicing.

In those northern German dialects that have it, intervocalic voicing/tapping masks the effects of devoicing in one context. But what of the context where devoicing shows up as in other dialects, namely before a consonant or at the end of an utterance? If we were to maintain that devoicing acts as demarcative strengthening in only these last two contexts, we would be faced with the same paradox as we did with southern Catalan: word-final position is weak when a vowel follows but strong when a consonant or pause follows. The phonological delimitation of word ends would have to be assumed to switch on or off according to what follows – not a particularly advantageous property for a demarcative function to have.

### 4.3 Devoicing as demarcative weakening

This last point brings us back to the second of the questions posed at the start of this section: even when we can show that a segmental process has a demarcative function, does that necessarily mean it must be strengthening? Are strong consonants intrinsically better at demarcating domain edges than weak ones?

In the case of domain-initial position, the answer seems to be yes. The phonological evidence is pretty clear: positions that are initial in domains such as the stem, word and foot are frequently observed to promote strengthening processes and to resist weakening processes that target non-initial positions (again see Escure 1977, Lass & Anderson 1975, Harris 1997). This asymmetry chimes with phonetic evidence that talkers typically produce tighter and longer articulatory gestures in initial compared to non-initial positions (cf. Fougeron & Keating 1996, Keating *et al.* 2004). This presumably enhances the perceptual salience of initial positions (cf. Beckman 1997), which from the listener's standpoint is a beneficial result, given the privileged part played by initial segments in word recognition (cf. Nootboom 1981, Hawkins & Cutler 1988).

However, establishing that strengthening enhances the perceptibility of domain starts does not mean that it is necessarily a good way of demarcating domain ends. If anything, domain-final strengthening would dilute the value of domain-initial strengthening. Moreover, given the prevalence of weakening in domain-final position, we should at least consider the possibility that weakening itself might have a demarcative function. Whatever the basis of this function might be, it cannot be perceptual salience, at least at the position where the weakening occurs. In the case of weakening processes targeting manner or place, there's a clear sense in which weakening processes reduce the perceptual salience of a consonant. In the next section, I will try to make this notion explicit and show how it extends naturally to final devoicing. If weakening is to be viewed as having any kind of demarcative value, it surely lies in how it serves to accentuate the syntagmatic differences between segments in different positions (cf. Harris 2004, Shiraishi 2006, this volume). In excluding strong segments from non-initial positions, weakening increases the extent to which strong segments can be relied on to demarcate initial positions. And the more non-initial positions a given weakening process targets, the greater the reliability of this demarcative function is likely to be.

These remarks on the domain-delimiting potential of weakening are admittedly somewhat speculative. But it seems to me they depict a communicative scenario that is at the very least no less plausible than the one presented by the notion that final devoicing demarcates by strengthening. Moreover, they help clarify the point that there is no intrinsic connection between domain-final segments and increased strength.

With these remarks in mind, let us return to the specifics of final devoicing and consider the demarcative value of aspiration in German. I argued above that it is incorrect to describe final voiceless plosives in German as aspirated. However, suppose for a moment that this description were correct. The distribution of aspiration in German would then have to be stated like this: it occurs at the beginning of a word, or in the onset of a stressed syllable (that is, at the beginning of a foot), or at the end of a word. It should be clear that, with this distribution, aspiration is not going to help the listener tell the beginnings of words from the ends of words.

Once we acknowledge that German final plosives are plain, we are left with a much simpler distribution of aspiration in the language: it occurs only in salient positions that are initial in the word or foot. The demarcative potential of this distribution is clear, its usefulness enhanced by the high frequency with which the left edges of words and feet coincide in German. (The same point can be made about certain other Germanic languages, including Danish and English; see Harris 2004.)

## **5 Modelling strength**

### **5.1 In search of a unitary basis for strength**

The evidence reviewed in the first part of the paper helps establish phonological strength as a unitary phenomenon. The evidence shows that what might otherwise seem like a collection of diverse processes acts in a unified manner when it comes to the environments they occur in, the way they interact with one another and the directionality inherent in their outputs. If strength is to be more than just a label we give to this unitary behaviour, we need to discover whether it correlates with some independently established phonological and/or phonetic unity. For example, does it have a unitary feature representation? Is there some unitary phonetic parameter along which strengthening and weakening processes occur?

Note that asking these questions is not the same as asking what causes weakening and strengthening. It is widely taken for granted that weakening is caused by speaker laziness: that is, speakers undershoot production targets out of a need to minimise the expenditure of articulatory effort. Weakening then becomes phonologised when the results of undershoot become reinterpreted by listeners as targets in their own right. This account may or may not be right, but it has nothing directly to say about the impact weakening has on the segments it targets and whether this impact can be captured in any kind of unitary fashion.

This point is evident in the work of Kirchner, who attributes weakening to the activity of grammar-internal constraints that penalise the expenditure of articulatory effort (1998, 2001). Weakened consonants surface when these laziness constraints outrank competing faithfulness constraints that call for the consonants' segmental integrity to be respected. When Kirchner makes the claim that this provides a unitary model of weakening, it is important to understand that he is referring primarily to the causes of weakening. He is not overtly concerned with the question of whether weakening has a unitary impact on phonological forms. Implicitly, he seems to assume that it does not. This is clear from the fact that the representations he uses to illustrate how the various constraints interact contain collections of features and continuous phonetic parameters that are not related to one another in any particular way.

In this section, we will briefly consider two familiar models of phonological strength, one based on sonority, the other on articulatory aperture. Neither succeeds in providing a unified analysis of strengthening and weakening, and neither offers much insight into the question of whether devoicing counts as one or the other. This is in marked contrast to the rather less familiar model of strength I will present in §6.

## 5.2 Strength as articulatory aperture

The first attempt at a unitary phonetic definition of strength we will consider is one that relates it to degree of articulatory stricture and the extent to which this impedes airflow through the vocal tract. The basic idea is that stronger segments have tighter strictures and thus offer greater resistance to airflow. Weakening can then be thought of as articulatory ‘opening’ (Lass & Anderson 1975): it loosens stricture and thus reduces resistance to airflow.

This definition is best suited to characterising weakening processes that target manner. The progression plosive > fricative > approximant that figures in spirantisation and vocalisation certainly involves opening in this sense. The definition might be extended to weakening processes that target place, but only at a push. Debuccalisation replaces one obstacle to the free passage of air through the vocal tract (caused by a supralaryngeal stricture) by another (glottal stricture). To accommodate debuccalisation, an opening account of strength would thus need to show that a constriction in the oral cavity impedes airflow to a greater extent than one at the glottis. (It is perhaps easier to see how this attempt might succeed with spirant debuccalisation ( $s > f$ ) than with stop debuccalisation ( $t > \text{ʔ}$ ).)

The opening account of weakening cannot, however, be extended to voicing or devoicing processes. The open glottis setting required for voiceless sounds impedes airflow to a lesser extent than the adducted vocal-folds setting required for voiced sounds. This would imply correctly that devoicing weakens obstruents but incorrectly that voicing strengthens them. Lass & Anderson (1975) themselves acknowledge this point, by placing intervocalic voicing on a ‘sonorisation’ trajectory that is independent of opening.

## 5.3 Strength as sonority

Another approach to strength equates it with sonority: weakening is claimed to render a consonant more sonorous (see for example Lavoie 2001). As with the opening account, this correctly predicts the segment trajectory we find in spirantisation and vocalisation, i.e. plosives > fricatives > approximants.

Extending this account to debuccalisation raises the controversial issue of whether sonority has a unitary phonetic definition or not (for a summary of the relevant literature, see Harris 2006). In what way can an input plosive be said to be less sonorous than an output glottal stop? According to one claim, sonority correlates directly with overall output of acoustic energy: the more sonorous a sound, the greater its amplitude or intensity (see for example Parker 2002 and the references there). The presence of a release burst lends a plosive more intensity than a glottal stop. So under this definition debuccalisation leads to a decrease in sonority – the reverse of what happens in spirantisation and vocalisation. This contradiction remains even if we assume that stop debuccalisation always passes through a stage where the plosive first loses its release burst (cf. McCarthy 1988). The first stage (from plosive to unreleased oral stop) still involves a decrease in intensity/sonority, while the second (from unreleased oral to glottal stop) potentially involves no change in intensity at all.

Nor does the sonority account of weakening fare much better when we turn to

voicing and devoicing processes. The question of where voiced and voiceless obstruents belong on the sonority hierarchy has never really been settled. (Of course if we take the view, shared by many researchers, that voice is orthogonal to sonority, we immediately relinquish any notion that strength has a unitary basis in sonority.) The problem becomes clear when we try to apply the intensity definition of sonority to oral stops. Does the periodic energy that radiates through the talker's neck during the hold phase of a voiced stop make it more sonorous than a voiceless counterpart? Or does the higher intensity of the aperiodic energy associated with the voiceless stop's release burst make it the more sonorous of the pair? In the light of these indeterminacies, we have to conclude that a sonority-based account of strength-changing processes makes no testable predictions about the directionality of voicing and devoicing.

In any event, there is one glaring empirical flaw in any sonority approach to weakening. Nasals occupy a stage on the hierarchy that is intermediate between obstruents and resonants (liquids and glides). Yet spirantisation and vocalisation routinely bypass a nasal stage when they weaken oral stops to resonants (see Harris 1994).

Neither the aperture-based nor sonority-based accounts allow us to identify a single phonetic dimension that correlates with phonological strength. Before we conclude that we are simply wrong to suppose there is such a single dimension in the first place, let us consider an alternative approach, one based on the carrier-modulation model of speech.

## **6 A modulated-carrier model of strength**

### **6.1 Speech as a modulated carrier signal**

Speech can be thought of as a carrier signal modulated by acoustic events. The carrier is linguistically void: it allows linguistic messages to be heard. The modulations are linguistically significant: they contain the information that enables messages to be understood. Although this way of conceptualising speech has been around for many years, my own exposure to it comes primarily from the more recent work of Ohala (see especially 1992) Traunmüller (1994, 2005).

An unmodulated carrier can be characterised as the schwa-like sound that is produced by a neutrally open vocal tract. The carrier thus lacks spectral prominences, reflecting the evenly spaced formant structure of schwa. The carrier is typically (though not necessarily) periodic. Although it contains no linguistic information, it divulges information about the talker's organism, emotional state and location.

The carrier provides a neutral baseline for the modulations, which contain the linguistic content of an utterance. The baseline can be modulated along various acoustic parameters, in particular amplitude, spectral shape, periodicity, duration/timing and fundamental frequency.

Carrier energy and modulation energy are of course not physically separate (for example, they are not separately displayed on spectrograms). Nevertheless, it is clear that listeners are able to tease them apart. That is, listeners winnow linguistic information from speech signals through a process of 'demodulation' (Traunmüller 1994).

The magnitude of a modulation can be measured in terms of the extent to which it deviates from the baseline set by the carrier. This can be expressed as the distance a modulation travels through an acoustic space defined by the parameters mentioned above (Ohala 1992). For example, the  $p$  in  $\partial p \partial$  modulates the carrier to a significantly greater extent than the  $w$  in  $\partial w \partial$ . The modulation produced by the plosive follows a relatively long acoustic trajectory that takes in a combination of changes in overall amplitude, spectral shape and periodicity. The modulation produced by the approximant follows a much shorter trajectory that involves little more than a change in spectral shape.

## 6.2 Strength as modulation size

The modulated-carrier model of speech provides us with a straightforwardly unified definition of phonological strength. Strength correlates directly with the magnitude of a modulation: the stronger the consonant, the greater the extent to which it perturbs the carrier signal.

Weakening processes diminish modulations, shortening the acoustic distance a targeted consonant travels from the carrier. We can characterise this overall effect as the loss or suppression of some aspect of the modulation associated with the unweakened consonant. In the case of weakening processes targeting manner or place, the suppressed aspect mainly involves one or more of the parameters of amplitude, spectral shape and periodicity. This idea has been presented in detail elsewhere (Harris & Urua 2001, Harris 2003, Harris 2004), so it will be enough to summarise it briefly here before proceeding to the question most relevant to this paper: what does this account have to say about final devoicing?

As to individual weakening processes that target place or manner, each can be seen to reduce the extent to which a consonant perturbs the carrier. Debuccalisation does this by suppressing the spectral properties that signal place. In the case of spirant debuccalisation (e.g.  $s > h$ ), this removes the frequency characteristics of the aperiodic energy associated with the consonant's continuous frication. In the case of stop debuccalisation (e.g.  $t > \text{ʔ}$ ), the equivalent characteristics of the plosive burst are removed along with formant transitions. Spirantisation (e.g.  $b > \beta$ ) and vocalisation (e.g.  $t > r$ ) both suppress the abrupt and sustained drop in amplitude associated with non-continuant consonants.

Each of these processes leaves some aspect of the modulation associated with the affected consonant more or less intact. A debuccalised stop retains its radical amplitude drop. A debuccalised fricative retains its aperiodic energy, albeit with reduced intensity. A spirantised plosive retains the spectral characteristics of the original consonant's release burst. A vocalised non-continuant retains its formant transitions.

The outcome of weakening being allowed to advance as far as deletion is the total suppression of any modulation associated with the original consonant: the consonant has been pushed to the point of total merger with the carrier signal.

### 6.3 Final devoicing and intervocalic voicing as modulation reduction

Now let us consider how processes affecting the voice value of consonants fit into the modulated-carrier picture. In the case of intervocalic voicing, let us start with the simplifying assumption that the main acoustic parameter involved here is periodicity. Later we will need to take into account cues to voice that are based on other parameters, especially duration/timing.

In vowels, periodicity is a property of the carrier signal. It contributes to the audibility of linguistically significant acoustic events caused by modulations along the parameters of spectral shape (vowel quality) and fundamental frequency (tone). Once we acknowledge this separation between carrier and modulation properties in vowels, it is clear that intervocalic obstruent voicing counts as weakening in the sense just outlined (cf. Harris 2003). One way in which an intervocalic voiceless stop modulates the carrier is by introducing a discontinuity in periodicity. Voicing a stop in this position removes this discontinuity, allowing the periodicity of the carrier to seep through the consonant. The slope of the modulation produced by the stop as it interrupts the vowels is flattened still further when voicing co-occurs with spirantisation (as in  $p > \beta$ ). The tendency for the two processes to go hand in hand in this environment can be attributed to the fact that the opening of the consonantal stricture is accompanied by a decrease in duration; these combine to reduce the build-up of intra-oral air pressure, which in turn facilitates spontaneous voicing (see Ohala 1999).

Where does final obstruent devoicing fit into this picture? On the face of it, devoicing an obstruent at any point in the speech stream might seem to magnify the modulation produced by the consonant, since it switches off the periodicity associated with the carrier. However, to draw this conclusion would be to fall into the same trap as the unity-of-voice assumption discussed above.

The modulated-carrier model of speech invites us to think primarily about the listener's experience of the acoustic signal. But, we need also to take into consideration how the listener interprets the intentions of the talker (especially since listeners are of course also normally talkers themselves). The well-founded distinction between spontaneous and non-spontaneous voicing, which – as noted above – is fundamentally inimical to the unity-of-voice assumption, is drawn initially on the basis of how the talker's vocal folds behave under different aerodynamic conditions. We can plausibly assume that the listener implicitly takes this distinction into account when demodulating the speech signal (Ohala 1981). The listener needs to be able to distinguish between periodicity that is part of the carrier signal and periodicity that represents a linguistically significant modulation. In other words, the listener has to determine when periodicity is being used to deliver the linguistic message and when it forms part of the message itself.

To achieve non-spontaneous voicing, the talker makes an active articulatory gesture with the intention of signalling the voiced term of a contrasting voiced-voiceless pair of obstruents. To recognise this term, the listener must then interpret the resulting periodicity as part of a modulation that contains the talker's intended message. The fact of successful communication is enough to confirm that this is what listeners actually do. Exactly how they do it, though, remains an open question. Does the articulatory and aerodynamic distinction between spontaneous and non-spontaneous

voicing correlate with some verifiable acoustic distinction that listeners can directly rely on in speech recognition? Or, if the two types of voicing are not acoustically distinct, are listeners still able to infer the distinction indirectly on the basis of other information that is locally present in the speech signal (as suggested by Stevens 2002 and Kingston *et al.* 2008)? For example, do listeners assign differing significance to periodicity according to whether it co-occurs with other acoustic events that signal the contrast between obstruents and sonorants? This is an empirical issue that, to the best of my knowledge, has yet to be systematically investigated in the speech perception literature.

It is undoubtedly true that voicelessness contributes to the modulation produced by a post-vocalic word-final stop. But that does not alter the fact that voicelessness is the natural or unmarked state for stops in this context. That is, it is an aerodynamically favoured consequence of the oral stricture responsible for a major part of the stop's modulation, namely a radical drop in amplitude.

The high incidence of final devoicing in the world's languages can be taken as a reflection of the essential inertness of voicelessness in stops in this position (Westbury & Keating 1986). In comparison, the various properties that can be used to maintain final laryngeal contrasts can be viewed as being actively deployed by the talker. As is well known, the range of these properties is quite large, and certainly larger than can be comfortably accommodated by a literal reading of VOICE. A non-exhaustive selection of the properties that can be utilised to carry laryngeal distinctions in post-vocalic stops is presented in the form of contrasting pairs in (11) (see Denes 1955, Chen 1970, Raphael 1975, Javkin 1976, Mack 1982, Kohler 1984, Walsh & Parker 1984, Flege & Hillenbrand 1987, Kingston *et al.* 2008 and the references there). Some of the properties can co-occur within the same language, while some are clearly mutually exclusive.

(11) CONTRASTING 'LARYNGEAL' PROPERTIES IN WORD-FINAL STOPS

Pre-aspiration	No aspiration
Glottalisation	No glottalisation
Lack of release	Plosive release
More intense release burst	Less intense release burst
Longer stop closure	Shorter stop closure
Shorter preceding V	Longer preceding V
Faster V-to-C formant transitions	Slower V-to-C formant transitions
Rapid voice off-set	Delayed voice off-set
Absence of significant low-frequency energy at VC transition	Presence of significant low-frequency energy at VC transition

Each of these contrasting pairs involves some property that can be viewed as an addition to the basic structure of a plain stop. (It is not relevant to our immediate purposes whether the additional property attaches to the 'voiced' or 'voiceless' member of a two-way contrast or to some member of a more complex set of contrasts.) Put differently, each property magnifies the modulation produced by a stop relative to that

of a plain counterpart. The modulation's acoustic trajectory is extended by following a route through not just periodicity (as might be implied by a literal reading of VOICE) but also, depending on the particular property, duration/timing, spectral shape, amplitude and fundamental frequency.

In sum, the modulation produced by a voiceless plain stop in word-final position is smaller than those produced by stops featuring modifications of the type listed in (11). Phonological processes that neutralise laryngeal contrasts in final stops under a single plain series thus have the shared effect of diminishing modulations in that position. According to the definition of strength as modulation magnitude, these processes thus count unequivocally as weakening. This definition is not restricted to the classic type of devoicing that neutralises two-way contrasts in voicing languages and aspiration languages. It also covers the whole range of delaryngealisation processes, including those that neutralise three- or four-way contrasts involving more complex combinations of properties such as those in (11).

## **7 Conclusion: implications for feature theory**

It is not the purpose of this paper to propose or subscribe to a specific feature representation of final devoicing. Nevertheless, let us briefly consider where the modulated-carrier model of strength stands in relation to the broadly distinguishable approaches to the representation of devoicing that have been adopted in the recent literature.

If we are right in thinking that strength has a unitary phonetic basis, then it would be reasonable to expect it also to have some unitary basis in phonological feature representation. With standard feature models belonging to the SPE tradition, this is certainly not the case. That is hardly surprising, given historical disagreements about what the phonetic basis of strength might be and about which particular processes count as weakening or strengthening in the first place. The contrast with assimilation processes is striking. There is general agreement about what qualifies as assimilation, and since the 1970s there has been more or less general agreement that processes of this type are best captured in terms of feature spreading.

With standard features, there is no unified way of representing strength (which is why some phonologists advocated the introduction of independent 'strength scales' on the model of the sonority hierarchy, cf. Foley 1977). There are at least three alternative ways of representing weakening using standard features: deletion, spreading, or the replacement of one value by another. Debuccalisation, for example, can be represented as the deletion of a feature-geometric Place node (cf. McCarthy 1988). Intervocalic spirantisation can be represented as the assimilation of [continuant] from the flanking vowels (cf. James Harris 1969, Mascaró 1984). Vocalisation requires [+consonantal] to be relaxed by [-consonantal].

All three of these alternatives have been turned to in the representation of intervocalic voicing and final devoicing. Spreading is utilised in what can be considered the orthodox textbook analysis of intervocalic voicing as the assimilation of [voice] from the surrounding vowels (see for example Carr 1993). Replacement is employed in what is perhaps the most traditional analysis of devoicing: [+voice] → [-voice]. Deletion

figures in analyses that treat final devoicing as the suppression or absence of a privative laryngeal feature (although what the specific feature is varies from one account to another, cf. Mascaró 1987, Goldsmith 1989, Wiese 1990, Brockhaus 1995, Lombardi 1995a, 1995b, Jessen & Ringen 2002). Of these various mechanisms, it should be clear that feature deletion takes us closest to the notion that weakening diminishes the modulation produced by a consonant.

Privativeness is a basic requirement of any proposal that sets out to treat weakening as feature deletion. Bivalent features intrinsically imply the replacement rather than the deletion of values (for full discussion, see for example van der Hulst 1989 and Harris & Lindsey 1995). With bivalency, replacement can be implemented in one step, by directly rewriting one feature value with its complement. Or it can be implemented in two steps as *faux* deletion – by deleting one value and then having the complement value filled in by some independent ‘default’ mechanism (the method associated with underspecification theory (see for example Archangeli 1988) and adopted for vowel weakening by Crosswhite (2004) among others).

Implementing authentic deletion with privativity requires each feature to be defined in such a way that deleting it does not necessitate the introduction of some other feature to safeguard the phonetic interpretability of the affected segment. Privative feature models are not always constructed with this design property in mind (although for explicit proposals that it should be rolled out across the entire feature set, see for example Harris & Lindsey 1995, Backley & Takahashi 1998, Nasukawa 2005, Botma 2004, Backley & Nasukawa, this volume). The notion is more often invoked in proposals for specific features, particularly so for those that represent laryngeal contrasts.

Most proposals for privative laryngeal features assume that plain stops are laryngeally unspecified (see Mascaró 1987, Harris 1994, Lombardi 1995a, 1995b, Iverson & Salmons 1995, 2006, Jessen & Ringen 2002). That is, unlike with underspecification, plain stops are phonetically interpretable without the need for the filling-in of default laryngeal values. Other types of stop are then specified by the presence of additional features that we can think of as moving a stop away from a plain baseline. Deleting these additional features returns a stop to its basic plain state.

Treating weakening as feature deletion in a privative model leads naturally to treating strengthening as feature insertion. This is indeed how Iverson & Salmons (for example 2003) analyse final devoicing in German: final obstruents acquire or retain a [spread glottis] feature that is suppressed in certain other positions. However, the validity of this particular use of feature insertion is undermined by the evidence that final devoicing should not be treated as strengthening in the first place.

Taking plain stops as an unspecified baseline implies subscribing to ‘laryngeal realism’ (Honeybone 2005) – the assumption that laryngeally specified stops have different representations in voicing and aspiration languages (see for example Anderson & Ewen 1987, Harris 1994, Lombardi 1995a, 1995b, Iverson & Salmons 1995, 2003, Jessen 1998, Jessen & Ringen 2002, Avery & Itsardi 2001). Aspirates are represented in terms of a feature such as [spread glottis], [H] or some equivalent. Actively voiced stops are represented in terms such as [slack vocal folds], [voice] or [L]. Plain is thus contrasted with [spread] in aspiration languages, with [slack] in voicing languages and with both [spread] and [slack] in languages such as Thai with a three-way contrast.

The laryngeal-realist approach was initially tailored to the representation of contrasts in prevocalic stops. At least in the case of voicing languages, it extends relatively straightforwardly to word-final stops: in a language that maintains a contrast in this position, the [slack] series appears as post-voicing, in a language with final devoicing, [slack] is suppressed.

An equivalent extension cannot be made so straightforwardly with aspiration languages. In initial position, [spread] is uncontroversially realised as long-lag VOT. On one view, this is also the feature that is suppressed by final devoicing in these languages (Jessen 1998, Jessen & Ringen 2002). However, there is an alternative view that the feature targeted by devoicing is [slack], even though the relevant languages lack an initial prevoicing contrast (Brockhaus 1995, Lombardi 1995b). The disagreement, it seems to me, stems from the largely unresolved issue of whether [spread] is suited to the characterisation of word-final stops in languages that maintain a laryngeal contrast in this position.

In aspiration languages without devoicing, traditional phonemic reasoning would lead us to consider [spread] to be the contrastive feature in both word-initial and word-final position. But this immediately raises a question mark over how the feature should be phonetically defined. Adhering to a strict interpretation of laryngeal realism (and bearing in mind the conclusions reached in §3 above), we would probably want to reserve [spread] in final position for pre-aspirated plosives. We can only extend the feature to other contrastive phonetic properties in this position (such as some of those in (11)) by adopting a rather less literal interpretation of realism. That would allow us to redefine [spread] as a cover feature that encompasses an apparently diverse range of phonetic effects (in which case some more abstract feature label would be more appropriate).

There is of course a radical alternative: to abandon phonemic thinking and allow for laryngeal contrasts in initial and final stops to be specified in terms of different sets of features. According to this ‘hyper-real’ approach, each of the properties in (11) would in principle need to be considered for independent feature status. An untrammelled proliferation of features would be avoided by assuming that sets of acoustically similar properties should be grouped together on the grounds that they present integrated cues to a given laryngeal contrast, in the manner proposed by Stevens and Blumstein (Stevens & Blumstein 1978, Blumstein & Stevens 1980). (One such set might be the ‘low frequency energy’ property proposed for postvocalic ‘voiced’ stops by Kingston *et al.* (2008). This integrates at least three similar acoustic effects which combine to concentrate energy at low frequencies near the onset of stop closure: lowered first formant, lowered fundamental frequency and sustained low-frequency periodicity.)

Pursuing a non-phonemic approach allows us to grant feature status to the release burst property discussed in §3, thereby highlighting its independence from aspiration (see Harris 1990 and Steriade 1993 for rather different proposals along these lines). In this way, we can draw a clear distinction amongst languages with word-final delaryngealisation between those that suppress only aspiration (e.g. German) or voicing (e.g. Catalan) and those that also suppress plosive release (e.g. Thai).

Whichever version of laryngeal realism we choose to run with, it should be clear that this overall approach is in keeping with the notion that features map to modulations of the carrier signal. Each privative laryngeal feature adds some ingredient to an

obstruent that magnifies the modulation it produces.

To sum up: deletion analyses of final delaryngealisation in general and devoicing in particular are compatible with the notion that features code modulations of the carrier signal. Delaryngealisation decreases the modulation produced by a final obstruent, and the most direct way of representing this effect in the phonology is by feature deletion. The same goes for intervocalic voicing. Feature deletion transparently records the fact that this process removes a discontinuity in periodicity that the consonant would otherwise impose on the VCV sequence.

In short, feature suppression is the most direct way of capturing the fact that final devoicing, like intervocalic voicing, is a weakening process.

## Notes

- 1 This is a revised version of a chapter that appeared in Nasukawa, N. & P. Backley (eds.) (2009), *Strength relations in phonology*, Berlin: Mouton de Gruyter. The main change involves corrections to inaccuracies and lacunae in my reporting of the work of Wiebke Brockhaus (1995). I'm very grateful to Wiebke for pointing out the errors to me, and I wish to place on record my sincere apologies for having misrepresented her work in the earlier version. Part of the paper was presented at the workshop *Strength Relations in Phonology*, Tohoku Gakuin University Sendai, 5-6 September 2006. Many thanks to the workshop participants for their very helpful comments.
- 2 My thanks to Ulrike Pohlmann for providing the Schleswig-Holstein German examples given here and for discussing their analysis.

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