Lenition[1]

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1. Introduction

This paper has two purposes. The first and principal purpose is to argue that lenition is not intended to reduce effort but instead to accomplish another goal, namely, to increase intensity and thereby reduce the extent to which the affected consonant interrupts the stream of speech. The second is to propose that phonetic constraints be separated from phonological constraints in an optimality theoretic grammar.

Lenition has long been thought to be effort reduction, and to reflect the speaker's preference to hypo-articulate whenever possible (Passy, 1891; Grammont, 1933; Lindblom, 1990; Kirchner, 1998; cf. Lavoie, 2001; and see also Gurevich, 2004 for a more detailed account of the cases compiled by Kirchner). This preference has been described as the realization in speech of Zipf's Principle of Least Effort (Zipf, 1949). On its face, this explanation of lenition is implausible, because the differences in effort between the lenited and unlenited pronunciations are so miniscule that they can hardly be what motivates a speaker to lenite. Both the differences in the distance the articulators travel (mere millimeters) and the time scales (at most tens of milliseconds) are much too small for effort to differ detectably between the two pronunciations. Indeed, differences in effort have only been documented for speech for very much larger and longer-lasting differences (Moon & Lindblom, 2003).

The paper's argument does not, however, rest on the implausibility of this explanation but instead on two empirical supports. The first support is a demonstration that consonantal lenition does not depend on the openness of flanking vowels, although it does depend on the openness of flanking consonants. This finding will support the contention that lenition is not governed by how far articulators have to travel but instead by the difference in intensity the speaker wishes to create between the affected segment and its neighbors. The second support is evidence that lenition is likewise governed by the position of the affected segment within a prosodic constituent. Consonants lenite inside prosodic constituents and not at their edges, and lenition therefore conveys to the listener that the current constituent is continuing rather than ending or a new one beginning. A lenited segment conveys the continuation of the current prosodic constituent better because it is more intense and interrupts the signal less. Lenition thus complements the fortition observed at phrase edges that reduces signal intensity and interrupts the signal more.

Both supports indicate that speakers lenite in order to influence the listener's percept of how separate a segment is from its neighbors. The lenited pronunciation is achieved when the articulators reach a specific, relatively open articulatory target, which produces the desired acoustic consequences – principally, greater intensity – and not because the articulators have undershot a closer articulatory

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target.[2] Once the target is chosen, articulators are expected to move to it along the shortest path, so articulation is efficient even if not minimally effortful. If this is the right perspective on how a lenited pronunciation is chosen, then the phonetic constraints that influence that choice should not be incorporated directly into the phonological grammar (cf. Kirchner, 1998, 2004) but instead indirectly (Smith, 2002, in press).

The rest of this paper consists of seven sections. In §2, I define lenition, and briefly discuss how it might be construed as effort reduction. In §3, I discuss the cases presented by Kirchner (1998, 2004) as evidence that lenition is more likely in the context of more open than closer vowels, in order to reduce the distance articulators must travel, and show that in none of these cases is lenition unequivocally more likely in the context of more open vowels than less open ones. Next, in §4, I turn to evidence that the openness of flanking consonants does influence whether lenition occurs. Lenition should depend on the openness of flanking consonants but not flanking vowels because consonants that differ in the openness of their articulations differ far more in intensity than do vowels differing in openness. In §5, I turn to evidence which shows that lenition is common within prosodic constituents, but often prohibited or at least constrained at their edges. §6 distinguishes articulatory undershoot from effort reduction. §7 presents the results of an acoustic analysis of word-initial stop pronunciations in Spanish across contexts which differ in the extent to which they encourage lenition. This section has two purposes: to test the hypotheses developed in the preceding sections and to introduce a novel, semi-automatic method of detecting lenition from the acoustic signal. Finally, §8 lays out the way in which this analysis might be incorporated into an optimality theoretic grammar where the phonetics influences the constraint set indirectly rather than being incorporated directly into the phonological grammar.

2. Defining lenition and its relation to effort reduction and speaking style

A number of changes in the pronunciation of consonants are widely accepted as instances of lenition: spirantization of stops, e.g. /b/>[β], opening of fricatives into approximants, e.g. /β/>[ʋ], debuccalization, e.g. /f/>/h/, and outright deletion, e.g. /h/>[0]. In the first three cases, a more open articulation replaces a closer one; this is of course true for deletion as well if the deleted segment has an oral articulation. The articulation may open more than a single step; for example, in Spanish, voiced stops lenite to frictionless approximants. I will argue later, in §4.4, that what is important about these changes is that the lenited pronunciation reduces the extent to which the consonant interrupts the stream of speech, but for the moment, it is enough to note that the resulting pronunciation is more open.

Because these changes are most often observed next to vowels and more open consonants, they can all also be described as undershooting the consonant's original closer articulatory target in the context of sounds with more open articulations. This articulatory target is undershot because the articulators simply do not move as far as they would otherwise. Because they move a shorter distance, it is been frequently argued that speakers are trying to expend less effort when they produce the lenited pronunciations. Because Kirchner (1998, 2004) presents the most recent and detailed case for this interpretation, I have focused on his arguments and evidence in this paper.

According to Kirchner, an articulation is more effortful if the articulators have to travel farther or faster.[3] Lenition would reduce effort by using shorter movements than those needed to get the

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[2] Lenition thus appears to be quite distinct from vowel reduction, where a vowel's target is undershot because there was not enough time to reach the unreduced target (Lindblom, 1963; Flemming, 2004; Barnes, 2006). Alternatively, the speaker may take less time in producing the vowel in a particular context, e.g., an unstressed syllable, in order to undershoot the target that would be reached in other more prominent contexts, precisely in order to convey that context's lack of prominence to the listener.

[3] Kirchner also suggests that it may take more effort to be precise in the movement or placement of articulators. As precision and the extra effort it may require are only relevant to explaining why speakers do not lenite stops to strident fricatives, it is tangential to the issues this paper is concerned with and will not be discussed further.

articulators all the way to the original target. A speaker may reduce effort by lenition when he has too little time to reach the consonant's target before having to move the articulators to the next target. Of course, if the speaker had moved faster, then there might have been enough time to reach the target, but a faster movement would also require more effort.

However, speakers generally move faster when they have to move farther (Kuehn & Moll, 1976; Ostry & Munhall, 1985; Munhall, Ostry, & Parush, 1985; Ostry, Cooke, & Munhall, 1987). The correlation of an articulatory movement's speed with its size indicates that speakers choose articulatory targets and then execute them with the speed necessary to reach them. An articulatory target is not undershot because the speaker did not speed up enough to reach the intended target, but instead because the speaker chose that smaller articulatory movement and moved the articulators only fast enough to reach that less distant target. A speaker may choose such an apparently undershot target when the appropriate style of speaking is hypo-articulation, as for example when speaking to an intimate in a quiet setting, or perhaps as a function of the sound's prosodic context (§5). Either way, the speaker's goal when speaking more languorously is not to reduce effort but instead to use the style of speaking appropriate to the circumstances.

3. Lenition and vowel openness
3.1. Phonetic reasons why vowel openness should influence lenition

Kirchner (1998) presents a number of cases that appear to indicate that consonants are more likely to lenite in the context of more open vowels. If lenition did depend on the openness of flanking vowels' articulations, that would be evidence that speakers do seek to move articulators shorter distances, perhaps for the purpose of expending less effort. Before getting into these cases, I briefly review the results of three studies that strongly suggest that consonants *should* be more likely to lenite next to more open vowels, because those vowels cause the consonant articulations to undershoot in one way or another. First, Farnetani (1991) presents electropalatographic evidence collected from speakers of Italian that shows the tongue contacts a substantially smaller area of the palate in [t,d,z], though not [ʃ], between open [a]s than between close [i]s. Second, Keating, Lindblom, Lubker & Kreiman (1994) show that the jaw is lower during the articulation of [b,l,k,h] by both English and Swedish speakers between more open [a]s and [e]s than close [i]s. They observe little difference in jaw height as a function of the flanking vowels for [s,t,d,f,r,n], presumably because their articulatory targets all require constrictions close enough that the jaw must be raised substantially. Finally, three of the four Spanish speakers studied by Romero (1996) produce more open consonantal constrictions with the tongue body next to [a] than [e], although all four make closer consonantal constrictions with the tongue tip next to [a] than [e], and the closeness of the consonantal constrictions made with the lips does not differ next to these vowels for three of the four speakers. The distances that articulators travel are consistently greater next to [a] than [e], except that the tongue body does not travel any farther in making the closure next to [a] than [e]. Although these data are disparate in nature and not all consonants behave alike, they nonetheless all indicate that consonantal articulations can be more open next to more open vowels, perhaps enough to critically undershoot their targets and lenite. Given these good phonetic reasons to expect lenition to be more likely or frequent next to more open vowels, it is actually surprising that none of the cases that Kirchner cites as evidence of the phonologization of these phonetic tendencies hold up. These cases are taken up in the next two sections.

3.2. Vowel closeness and spirantization in Bantu

Grammont (1933) describes how consonants are spirantized next to more open vowels in many Bantu languages:

Ainsi dans nombre de parlers bantous une occlusive devient mi-occlusive ou spirante quand elle se trouve placée par l'addition d'un préfixe ou d'un suffixe entre voyelles ouvertes; mais elle reste d'ordinaire intacte entre voyelles fermées... *C'est une assimilation partielle de la consonne aux voyelles relativement à l'ouverture...* Plus les voyelles sont ouvertes, plus la position qu'elles demandent aux organes est éloignée d'une occlusion et la rend difficile; au contraire, après les voyelles les plus fermées, i et u, une occlusion n'est pas malaisée. [163]

In a number of Bantu languages, a stop becomes a partial stop or spirant when it is placed between open vowels through the addition of a prefix or suffix, but it ordinarily remains intact between close vowels... *This is a partial assimilation of the consonant to the vowels' relative openness...* The more open the vowels, the farther is the position they demand of the organs of articulation from occlusion and [occlusion] is made difficult; on the contrary, after the closest vowels, i and u, occlusion is not impaired. [my translation and emphasis]

The examples in (1) from Southern Sotho illustrate this effect with alternations of root-initial consonants determined by the presence or absence of the reflexive prefix *i-* (Doke & Mofokeng, 1957):

(1)	Infinitive ɦʊ-	Infinitive-Reflexive ɦʊ-i-	Alternations	Glosses
a.	ɦʊbɔna	ɦʊip'ɔna	b ~ p'	"see"
b.	ɦʊlaɛla	ɦʊit'aɛla	l ~ t'	"command"
c.	ɦʊfɛp'a	ɦʊipʰɛp'a	f ~ pʰ	"feed"
d.	ɦʊrat'a	ɦʊitʰat'a	r ~ tʰ	"love"
e.	ɦʊsɛba	ɦʊitsʰɛba	s ~ tsʰ	"slander"
f.	ɦʊʃap'a	ɦʊitʃʰap'a	ʃ ~ tʃʰ	"beat"
g.	ɦʊɬaba	ɦʊitɬʰaba	ɬ ~ tɬʰ	"stab"
h.	ɦʊɦap'a	ɦʊikʰap'ɛla	ɦ ~ kʰ	"seize"

(1a,b) show that voiced stops in the infinitive alternate with ejectives in the reflexive infinitive ([l] is an alternant of /d/), and (1c-h) show that voiceless fricatives alternate with voiceless aspirated stops. The vowel [i] of the reflexive prefix is one of two "super-close" vowels in Southern Sotho. (1) shows that obstruents are pronounced with a narrower oral constriction (1c-h) and/or a tighter glottal constriction (1a,b) next to this vowel. Alternatively, narrow oral constrictions are replaced by more open ones and the tight glottal constriction is relaxed next to vowels that are not super-close. Either way, it appears that the closeness of the vowel determines the closeness of the oral constriction and the tightness of the glottal one.

To understand what is actually going on here, it is necessary to consider the history of these Southern Sotho facts and to situate them in the larger history of sound changes involving stops and their interaction with the super-close vowels in the Bantu family. Proto-Bantu is reconstructed with voiced and voiceless series of stops, *b,*d,*g,*p,*t,*k (Guthrie, 1967-1970).[4] In many of the daughter languages, the voiceless stops remain unchanged, while the voiced stops alternate between stop pronunciations after nasals, [mb,nd,ŋg], and fricatives or approximants elsewhere, [β,ð/l,ɣ].[5] Different reflexes are observed, however, when the following vowel is super-close. Proto-Bantu is reconstructed with seven vowels: super-close *i̟, *u̟, and *i, *u, *e, *o, *a. The vowels represented by the unadorned symbols "i" and "u" are themselves produced with quite close constrictions, just not as close as those of their super-close counterparts. Many languages in the family have retained the original seven vowels along with the super-close pronunciations of the highest vowels, while in many

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[4] Guthrie also reconstructs palatal stops, *j and *c. As these reconstructions are controversial and their reflexes are far more idiosyncratic than those of the bilabial, alveolar, and velar stops, I will not discuss them here.

[5] Of course, many daughter languages have different reflexes than these, but this array is so widespread that it can be treated as a more or less typical development.

others the super-close vowels have merged with those just below them, and only five vowels now contrast. Regardless of whether a daughter still has seven vowels or only five, stops often have quite distinct reflexes before the super-close vowels than before the other vowels. Most often, these distinct reflexes are strident fricatives, whose place of articulation is jointly determined by the stop's original place and the backness of the super-close vowel.
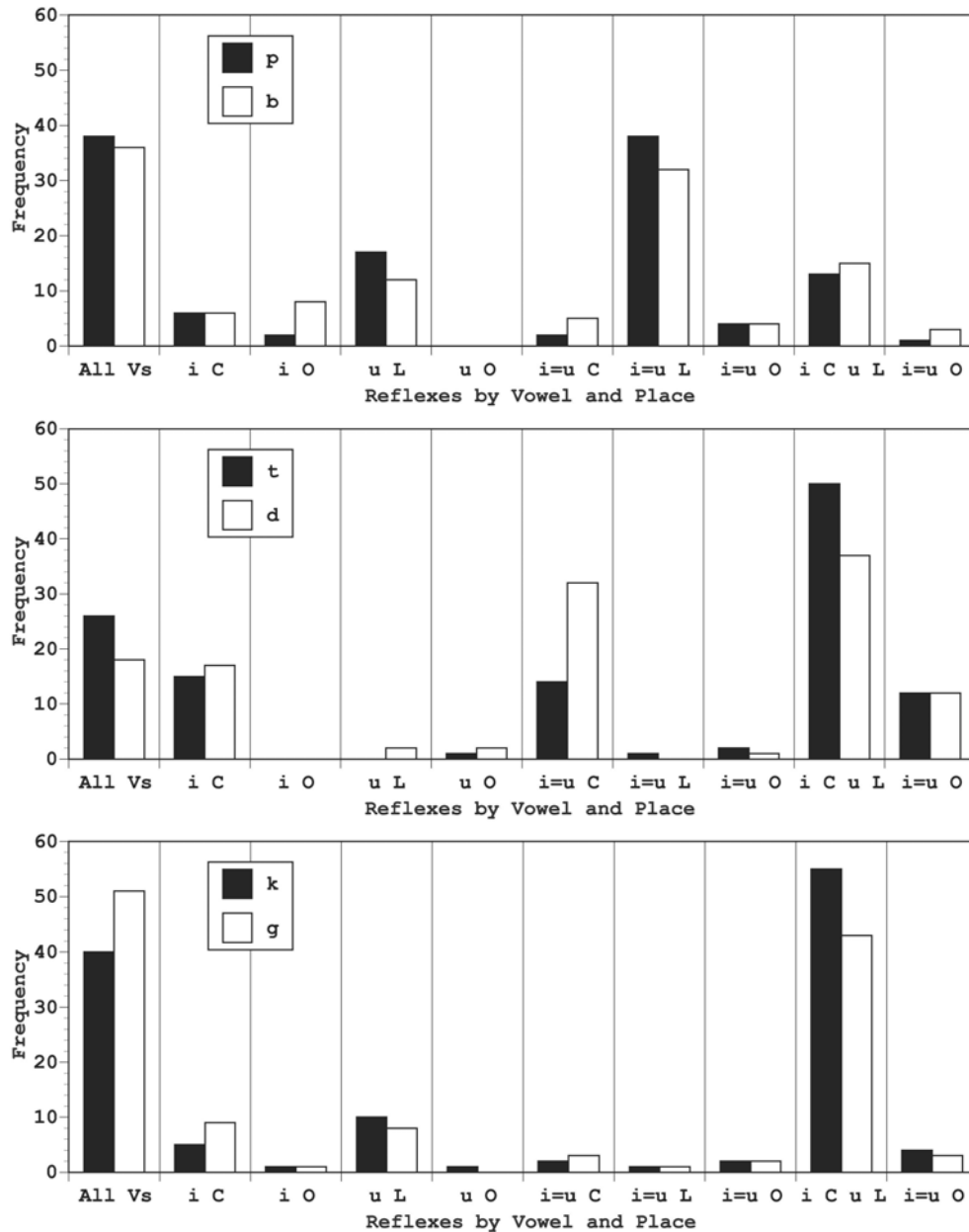

Figure 1. Frequency of particular reflexes of Proto-Bantu bilabial, alveolar, and velar stops in 121 representative daughter languages. "All Vs" = identical stop reflexes before all vowels, "i" = super-close *i̧, "u" = super-close *u̧, "C" = coronal fricative reflexes, "L" = labial fricative reflexes, "O" = other reflexes, "i=u" indicates reflexes are the same before both super-close vowels.

Figure 1 shows the frequency with which particular stop reflexes occur before the super-close vowels in the 121 representative languages for which Guthrie gives the present-day reflexes. The black bars in each panel of the figure represent the reflexes of original voiceless stops, the white bars reflexes of original voiced stops. The "all Vs" bars show how often the same stop reflexes occur before all vowels, the bars labelled "i" and "u" show how often distinct strident fricative reflexes developed before the super-close vowels *į and *ụ, respectively, and those labelled "i-u" show how often the same strident fricative reflexes developed before both super-close vowels. The strident fricative reflexes of an original stop before a super-close vowel are either labial, most often [f] and [v] (bars labelled "L"), or coronal, most often [s] and [z] (bars labelled "C"). The figure shows that the strident fricative reflexes of original bilabial stops, *p and *b, are most often labial [f] and [v] before both super-close vowels, while those of original alveolar stops, *t and *d, are most often coronal [s] and [z] before the front unrounded super-close vowel *į but labial [f] and [v] before the back rounded super-close vowel *ụ, although a substantial minority of languages have coronal reflexes for original *t and especially *d before both super-close vowels. Finally, original velar stops become coronal strident fricatives before the front unrounded super-close vowel but labial strident fricatives before the back rounded one. These patterns show that both the place of articulation of the original stop in the proto-language and the backness and rounding of the super-close vowel determine the fricative reflex's place of articulation. For my purposes, the most important feature of these developments is that the stops become fricatives before the super-close vowels in a large number of Bantu languages; that is, complete occlusion is given up precisely in the contexts where one would expect it to be easiest to maintain.[6] The development of strident fricatives before super-close vowels is most likely a by-product of their constrictions being so narrow that they impede air flow out of the mouth. The resulting build-up in intraoral air pressure behind the constriction would cause air flow through it to speed up enough to become turbulent and noisy (Ohala, 1983). The noise source is produced at the point of the vowel constriction, which accounts for the influences of the vowel's backness and rounding on the place of articulation of the resulting fricative. What the super-close vowels do is preserve the acoustic signature of an obstruent, a local noise source, but in many of the Bantu languages they do so at the expense of the stops' original constriction.

Let us now apply this perspective to the reflexes of Proto-Bantu stops in Southern Sotho, which are laid out in full in Table 1.

Contexts	*p	*b	*t	*d	*k	*g
_*a	ɸ	b	r	l	ɦ	0
*N_	pʰ	p'	tʰ	t'	kʰ	k'
_*į	ɸ	b	r	d	s	0
_*ụ	ɸ	b	r	d	f	0
_*įa	tsʷʰ	tsʷ'	r	ts'	s	0
_*ụa	tsʷʰ	tsʷ'	tsʷʰ	tsʷ'	f	0

Table 1. Reflexes of Proto-Bantu stops in Southern Sotho by context: *a stands for all vowels but super-close *į and *ụ, *N for a preceding nasal, and *įa and *ụa for diphthongs in which the super-close vowels are pronounced as the corresponding (on)glides [j] and [w]. "0" indicates that *g has been lost except after nasals.

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[6] Occasionally the reflex is an affricate rather than a fricative, but fricative reflexes are vastly more frequent than affricates. For the reflexes of voiced stops, this could reflect the very general tendency in present-day Bantu languages to have fricative or even approximant reflexes of stops that are not preceded by nasals, but there is no comparable tendency for the reflexes of voiceless stops to be fricatives, too.

The reflex of *d before all vowels but the super-close ones (context _*a) is [l], but it remains [d] before both super-close vowels (_*i̥ and _*u̥ contexts), and becomes voiceless and ejective before the even closer glide counterparts of these vowels (_*i̥a and _*u̥a contexts = [ja,wa]). In this language, the super-close vowels preserve and even augment the original obstruency of the stop because their constrictions are narrow enough to obstruct air flow, cause air pressure to rise behind the constriction, accelerate flow through the constriction enough to produce turbulence and a local noise source, while the constrictions of all other vowels are too wide to obstruct air flow enough to produce such a source and thus do not constrain the loss of obstruency. Contrary to Grammont's (1933) claims, the more open vowels do not cause the speaker to undershoot the stop articulation and produce a fricative or approximant; that is, they do not cause "une assimilation partielle de la consonne aux voyelles relativement à l'ouverture." Instead the more open articulation is adopted across the board unless its adoption is prevented by a following super-close vowel.[7] The stop's obstruency is not preserved directly by the close constriction of the super-close vowels, but instead indirectly by the aerodynamic and acoustic side effects of their articulation.[8] As documented above, many other Bantu languages have replaced stops with fricatives in these contexts. Whether they maintain and even augment the stops' original closure, as they have done in Southern Sotho, or transform stops into strident fricatives, as in these other, more innovative languages, the super-close vowels consistently produce noisier reflexes than are found in other contexts, and thus ensure that obstruency is preserved.

3.3. Other cases where lenition appears to depend on vowel openness

In this section, I turn more briefly to the other examples that Kirchner (1998) cites as evidence for his claim that lenition is more likely next to more open vowels.

The first language is Chitwan Tharu, an Indic language spoken in Nepal (Leal, 1972). In this language, the retroflex stop /ɖ/ is realized as a flap [ɽ] intervocalically and finally (both contexts are post-vocalic), and similarly breathy voiced /ɖʰ/ is realized as a breathy voiced flap [ɽʰ] intervocalically – the breathy voiced consonants do not occur finally. The voiced lamino-alveolar affricate /dʒ/ is pronounced as the corresponding fricative [ʒ] intervocalically. Finally, /b/ is sometimes realized as [β] intervocalically, but not finally, where it is pronounced [b]. Kirchner suggests that [β] occurs between non-high vowels, citing the examples [deβasu] 'I will give' and [kaβətur] 'pigeon' cf. [pabitrə] 'sacred' but these are the only examples in the source, and there is at least one exception [abe] 'if' with [b]. Chitwan Tharu is thus a weak case at best for lenition being more likely next to more open vowels.

The second case is the Northern Turkic language Yakut (Krueger, 1962), where sounds represented by the symbols "k" and "X" are in complementary distribution, "/k/ is used after /ı i u ü/ [= /ɯ i u y/ JK] and before /e ö I ı u ü ıa ie uo üö/ [= /e ø i ɯ u y ɯa ie uo yø/ JK]; the back *stop* [my

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[7] Or after a preceding nasal. We will see repeatedly below that lenition is inhibited after nasals; see §4.6 for discussion.
[8] Adam Albright has brought to my attention a very different pattern in Lakhota, where aspiration is replaced by what he describes as velar frication consistently before /a,ã,o,ũ/, variably before /e,u/, and not at all before /i/, unless that vowel is an alternant of /a/. This frication also consistently replaces aspiration before /e/ when this vowel is an alternant of /a/, but some speakers apparently do so even before other /e/s. Frication is optional when the next syllable begins with a velar fricative /x/, e.g., *pʰa.xte ~ pxa.xte* 'forehead' and *tʰa.xcha ~ txaxcha* 'deer'. For audio files, go to http://www.inext.cz/siouan/DRILLS/stops.htm. Listening to these examples gives me the impression that the frication is more uvular than velar, i.e., it is farther back. This impression derives primarily from brief but audible trilling during the noise in many examples.

This pattern is opposite that observed in the Bantu languages in that a strong local noise source is produced before more open vowels. Perhaps, the more open vowels are produced with enough of a pharyngeal or uvular constriction to produce a local noise source there. Aspiration itself is already quite intense in this language even when the noise source is not audibly local. Its considerable intensity could be produced by a very high volume of air flow through an exceptionally wide open glottis and/or by a constriction deep in the pharynx. Either way, even a relatively modest pharyngeal constriction might therefore be narrow enough to impede air flow through it, raise oral air pressure behind it, and create a local noise source in the middle or upper pharynx.

emphasis] /χ/ is used before /a o/ and after /a e o ö ıa ie uo üö/ [= /a e o ø ɯa ie uo yø/ JK].” [60] The sound represented by “k” occurs after high vowels and that represented by “χ” after non-high ones. In citing Yakut as an example of lenition conditioned by vowel openness, Kirchner apparently misinterpreted Krueger’s use of “χ” as indicating a fricative, when this symbol actually stands for a voiceless aspirated uvular affricate [qχʰ], “In spite of the symbol /χ/ denoting a fricative, the articulatory nature of this sound is that of an affricate, a strongly aspirated stop [q] followed by the corresponding continuant [χ], thus, [qχˑ].” [62] This is simply not lenition, but instead assimilation in place to the pharyngeal constriction of [a,o]; a very similar pattern of complementary distribution is observed between [g] and [ʁ].

The third case is Mbabaram, a Pama-Nyungan language of Australia (Dixon, 1991), where, according to Kirchner, stops are more likely to voice after the low vowel /a/ than the high vowel /i/ and in turn more likely to voice after /i/ than the liquids /l,ɾ/. However, stops only voice after word-initial vowels and the only word-initial vowel in the language is /a/, so it is impossible to tell whether voicing is more likely next to a more open vowel in this language.

In Latin American Spanish (Resnick, 1975), [ð] is not pronounced more often in the first conjugation participial suffix -a(d)o [a(ð)o] than in the second and third conjugation participial suffix -i(d)o [i(ð)o]. However, this difference is just as likely to be a product of -ado’s greater frequency as its more open vowel: -ado occurs 1.75 times as often as -ido in the LexEsp corpus (Sebastián, Cuetos, Martí & Carreiras, 2000).

Finally, Kirchner notes that /w/ is often not pronounced in Korean before non-high vowels (Martin, 1992). It is far from clear, however, that the openness of the following vowel matters. According to Martin, “Before a mid or low vowel, the phoneme w freely drops after p, ph [a p.h cluster, not the aspirated pʰ: JK], ps, m, wu, o... In sloppy speech (and widely in Seoul) w often disappears after nonlabial sounds, too, when a mid or low vowel follows.” [36] Except when speech is sloppy, it appears that /w/ is not so much deleted as absorbed by a preceding labial articulation. This interpretation is reinforced by Martin’s description of /w/ as no more than a non-syllabic labial articulation of the following vowel, “For most speakers, the phoneme /w/ is represented by simple lip rounding, with the tongue position largely determined by the following vowel: wi [ẅi], wey [ö̤e], way [ɔ̈ɛ], wa [ɔa].” [24] A labial constriction would readily be absorbed by a preceding sound which is itself pronounced with a labial constriction, or perhaps would simply become perceptually inseparable from that sound’s labial constriction and thus not be transcribed. Finally, the only high vowel that can be preceded by /w/ is /i/ – neither /wu/ nor /wɯ/ occur in Korean – and the sequence /wi/ arises as the result of the recent breaking of the earlier front rounded vowel /y/ – /we/ arises similarly from the breaking of earlier front rounded /ø/. Thus, it is not at all clear that a segment /w/ actually occurs before high vowels in this language.

This review has either eliminated some cases altogether (Yakut, Mbabaram, and probably Chitwan Tharu) and shown that others may not indicate any influence of vowel openness after all (Argentinian Spanish and Korean). There is thus little or no evidence to support Kirchner’s claim that lenition is more likely next to more open vowels. In the next section, I review descriptions of a number of languages which show that the openness of neighboring consonants *does* influence lenition.

4. Lenition and consonant openness
4.1. Introduction

In this section, I will first describe a number of examples which indicate that lenition does depend on the openness of adjacent consonants’ articulations, even if not that of adjacent vowels’. I will then discuss the apparently problematic case of Nivkh, and show that it is not a problem after all because the changes in its consonants’ articulations are not instances of lenition. Then, I will take up the task of explaining why lenition should depend on consonant openness but not vowel openness. To anticipate that argument, closer consonants are much less intense during their constrictions than more open ones, whose intensity approaches that of vowels, but closer vowels are only slightly less intense than more open ones. Lenition opens a consonant’s constriction, increases intensity during that constriction, and make the affected consonant’s intensity more like that of a neighboring vowel or more open consonant

and less like that of a closer consonant. By reducing the drop in intensity during the affected consonant, lenition reduces how much that consonant interrupts the stream of high-intensity sounds, the vowels. That reduction is more effective if any flanking consonant is itself open enough not to interrupt the stream of vowels much than if that consonant is closer. Because vowels differing in openness differ far less in intensity than consonants differing in openness do, the intensity increase brought about by lenition reduces the extent to which the affected consonant interrupts the stream of vowels just as about as much when it occurs next to close vowels as when it occurs between more open ones.

4.2. Examples

In this section, I will briefly describe consonant lenition and the environments in which consonants lenite in Tümpisa Shoshone, Lowland Murut, Florentine Italian, and Koromfe. Although lenition differs in all sorts of ways in these languages, they jointly show that lenition is more likely next to more open consonants. They also show that the one consonantal context that typically does not permit lenition is following a nasal.

4.2.1. Tümpisa Shoshone

In Tümpisa Shoshone, a Numic (Uto-Aztecan) language spoken in Nevada (Dayley, 1989), oral stops are pronounced as the corresponding fricatives, and nasals are pronounced as nasalized glides between vowels; an /h/ may intervene between the preceding vowel and the affected consonant. In this language, geminate oral and nasal stops contrast with singletons. The only other clusters consist of a nasal followed by an oral stop and /h/ followed by an oral or nasal stop. Table 2 shows the different realizations of the single stops and the contexts in which they occur.

Contexts	p	t	ts	k	kʷ	m	n
#_V	p	t	ts	k	kʷ	m	n
#_V̥	p	t	ts	k	kʷ	absent	
N_V	b	d	z ~ dʒ	g	gʷ	m	n
N_V̥	P	t	ts	k	kʷ	m̥	n̥
V_V	β	ɾ,ð	z,ʒ	ɣ	ɣʷ	w̃	n ~ j̃
Vh_V	ɸ	ɾ̥	z̥	h ~ 0	hʷ ~ 0	hw̃	hn
V_V̥	ɸ ~ p	ɾ̥,θ	z ~ ts / ʒ ~ tʃ	x ~ k	xʷ ~ k ~ w	w̥̃	n̥ ~ j̃

Table 2. Pronunciations of Tümpisa Shoshone oral and nasal stops in different contexts.

At the beginnings of words and after nasals (above the dashed line), both oral stops and nasals remain stops, but after vowels or /h/ (below the dashed line), the oral stops are pronounced as fricatives and the nasals as nasalized glides – stop pronunciations remain possible when the following vowel is voiceless (the last row). Voicing is entirely independent of lenition: both oral and nasal stops are voiced between voiced segments, and they are both voiceless when a voiceless sound precedes or follows. In this language, lenition only occurs when the oral articulation on both sides of the affected segment is as open as a vowel – /h/ has no oral articulation of its own.

4.2.2. Lowland Murut

In Lowland Murut (A.K.A. Timugon Murut), an Austronesian language spoken in Malaysia (Prentice, 1971), the voiced stops /b,d,g/ are pronounced as the corresponding fricatives [β,ð,ɣ] after vowels, glides, and glottal stop – these segments only follow glides and glottal stop across a word

boundary.[9] The voiced stops also lenite to fricatives following other voiced stops, when they have themselves lenited because they follow vowels – these sequences, too, only arise across word boundaries. When the stops lenite, the following segment is always a vowel. The voiced stops are pronounced as stops after voiceless stops /p,t,k/, the voiced palato-alveolar affricate /dʒ/, the alveolar fricative /s/, the nasals /m,n,ŋ/, and the lateral /l/. Any consonant with a constriction narrower than that of a glide thus prevents lenition of a following voiced stop.

4.2.3. Florentine Italian

Speakers of Florentine Italian lenite the voiceless stops /p,t,k/ to a sound with a more open articulation between vowels; the glides /w,j/ and liquids /l,r/ may intervene between the affected consonant and the following vowel (Gianelli & Savoia, 1979, 1980; see also Marotta, 2001; Sorianello, 2001, 2003; Dalcher, 2006 for instrumental studies). /p,t,k/ are pronounced as stops [p,t,k] only after a consonant, phrase-initially, or when geminate; they may also be pronounced as true fricatives [ɸ,θ,x] in these contexts. Elsewhere, they are pronounced as frictionless approximants [ɸ,θ,x], [h], or 0. These lenited pronunciations are obligatory within words, as well as at the beginnings of words, so long as the preceding word ends in a vowel and no phrase boundary intervenes (these conditions will be assumed for lenited pronunciations at the beginnings of words in the rest of this discussion). The [h] and 0 pronunciations are common for /p,t/ *in corpo di frase*, i.e., before the last foot of a phrase, and *in stile trascurato*, i.e., "neglectful" style. 0 is more common than [h] for /p/, but /h/ is more common than 0 for /t/. /k/ is pronounced as 0 when it occurs between identical vowels, before back vowels, *in corpo di frase*, and *in stile trascurato*.

The other consonants also lenite to one degree or another, but the available descriptions of their behavior are much less systematic (with the exception of Dalcher, 2006). The voiced stops /b,d,g/ are pronounced as stops or as true fricatives [β,ð,ɣ] after consonants and at the beginnings of phrases, but otherwise as frictionless approximants [β,ð,ɣ ~ ɦ] inside and at the beginnings of words. The affricates /tʃ,dʒ/ are pronounced [ʃ,ʒ] obligatorily within words and usually at the beginnings of words, too. Finally, liquids and nasals are also pronounced with more open articulations [l̥,r̥,ṽ,r̃] in these contexts.

In this language, a following glide or liquid permits a stop to lenite, but no consonant with a closer constriction.[10]

4.2.4. Koromfe

The voiced alveolar and velar stops /d/ and /g/ in Koromfe, a Gur language of Burkina Faso (Rennison, 1997), lenite to [ɾ] (2b,c) and [ɣ] (3b,c), respectively, except at the beginnings of words and after nasals (2,3a). Notice that lenition is blocked after nasals regardless of whether they have the same place of articulation as the following stop. The examples in (2,3b) show lenition of these stops after vowels, while those in (2,3c) show it after consonants other than nasals. The last example in (2c) *wẽnnɾaa* "plug" is exceptional in that the flap pronunciation appears after a nasal.[11]

(2) Alveolar   [d]   [ɾ]

    a. "chest"   [d]atɛ   b. ba[ɾ]a   "husband"
             "heart"   bɪn[d]ɛ   dɛ[ɾ]ɣa   "hill"
             "small bit" gʊm[d]ɛ   ba[ɾ]ka   "thanks"
             "noon"   baŋ[d]ɛ   wʊ[ɾ]fɪɪ   "smallness"

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[9] The only word or morpheme-internal clusters consist of a nasal followed by a stop.

[10] Sound changes which have turned many clusters of heterorganic stops into geminates have eliminated cases in which we could test the effect of a following stop on lenition; however, there are words where nasals or fricatives follow, for example, *atmosfera, aritmetica, ipnosi, tecnica*; *capsula, opzionale*, so it is necessary to specify that a following consonant can only be a liquid or glide.

[11] In both (2) and (3), only the affected consonants at the indicated places of articulation are bracketed.

c.	gab[ɾ]ɛ	"knife"
	dɔf[ɾ]ɛ	"God"
	dɛɣ[ɾ]ɛ	"accusation"
	kut[ɾ]e	"root"
	hɔnd[ɾ]ɛ	"hoe"
	temb[ɾ]e	"brick"
	kʊ[ɾ]ɣ[ɾ]aa	"dry (progressive)"
	boŋs[ɾ]ʌʌ	"love (progressive)"
	boll[ɾ]e	"window"
	w̃ɛnn[ɾ]aa	"plug"

(3) Velar   [g]   [ɣ]

a.	"inner yard"	[g]atɛ			
	"sp. tree"	kom[g]u			
	"shadow"	leŋ[g]em			

b.	po[ɣ]u	"claw"
	j̃ɔ[ɣ]faa	"milk (progressive)"
	kɔ[ɣ]sɔŋ	"lighter"
	ze[ɣ]ni	"lice"
	zo[ɣ]to	"scoop"
	ze[ɣ]ɾe	"rag"
	bu[ɣ]life	"bell"

c.	dɛɾ[ɣ]a	"hill"
	pas[ɣ]am	"split (gerund)"
	pas[ɣ]ɾaa	"split (progressive)"
	kut[ɣ]ʌ	"stump"
	kɛl[ɣ]am	"roast"

4.2.5. Summary

The segmental contexts in which stops do and do not lenite in the four languages discussed in this section are given in (4) (the prosodic limitations on lenition are discussed later in §5). The first three languages, Tümpisa Shoshone, Lowland Murut, and Florentine Italian, illustrate a common pattern, stops lenite next to vowels as well as next to consonants with more open articulations. Koromfe is far more liberal in the contexts in which it permits lenition: stops fail to lenite only after a nasal.

			Lenite	Do not Lenite
(4)	a.	Tümpisa Shoshone	V(h) _V	C_, N_ (C = oral stop)
	b.	Lowland Murut	V ({w̪,j,ʔ,LC*}) _ V	After any other C
			* "LC" = a lenited C	
	c.	Florentine Italian	V_ ({l,r,w̪,j}) V	C _
	d.	Koromfe	{V, Oral C} _ {V, C}	N _

These examples clearly show that the openness of a flanking consonant can determine whether a stop can lenite. We could even infer from these contexts a scale of consonant openness, with [h,ʔ] being the most open (Tümpisa Shoshone), followed in order by [w̪,j] (Lowland Murut, Florentine Italian) and [l,r] (Florentine Italian), and then fricatives and stops (Koromfe). Somewhat surprisingly, the nasal stops are more extreme along this scale that oral stops, as they block lenition even in the most liberal language, Koromfe.

4.3. The problem presented by Nivkh (Gilyak)

Before trying to explain why consonant openness should matter, while vowel openness does not, we must consider the apparently troubling case of Nivkh (A.K.A. Gilyak), a Paleo-Siberian isolate spoken on Sakhalin Island. This language is troubling because it appears that oral stops lenite to fricatives after sounds with open articulations, vowels and glides, and also after sounds with the closest articulations, oral stops, but not after sounds with intermediate constrictions, fricatives. Stops also do not lenite to fricatives after nasals, but this failure is now familiar even if still mysterious. However, spirantization in Nivkh may not be a case of lenition after all, but instead dissimilation of continuancy. In order to show this, I will have to describe the distribution of stops and continuants in Nivkh in some detail.

The data on which this case is made come from Shiraishi (2006), who describes the West Sakhalin dialect (cf. Blevins, 1993). Nivkh has the consonants in (5).

	Bilabial	Dental	Palatal	Velar	Uvular
(5) Voiceless unaspirated stop	p	t	c	k	q
Voiceless aspirated stops	pʰ	tʰ	cʰ	kʰ	qʰ
Voiced fricatives	v	r	z	ɣ	ʁ
Voiceless fricatives	f	r̥	s	x	χ
Nasals	m	n	ɲ	ŋ	
Glides	w		j		
Lateral		l			

The examples in (6) illustrate the contrasts between aspirated and unaspirated stops (6a) and between voiceless and voiced fricatives (6b) at the beginnings of words:

(6) a. "window"   pʰaχ   paχ   "stone"
       "sledge"   tʰu   tu   "lake"
       "sun"   kʰeŋ   keŋ   "whale"

    b. "dwell"   fi-   vi-   "go"
       "bake"   r̥a-   ra-   "drink"
       "put on clothes" xe-   ɣe-   "get, buy"

In all other positions, both contrasts are neutralized. Medially, stops are voiceless unaspirated after vowels (7a) and voiced after sonorant consonants (7b):

(7) a. "grandfather"   atak   b.   "woman"   umgu
       "brother"   ikɨn   "tell a story"   tɨlgu
       "knife"   caqo   "baby"   ojdom

Medially, fricatives are voiced next to any segment other than a stop (8a), where they are voiceless (8b):

(8) a. "folktale"   ŋɨzɨt   b. "horn"   muṛki
         "Ainu"   kuɣi   "corridor"   uski
         "open the mouth" hava-   "hand"   oχcol
         "bog bilberry"   cʰari   "place name"   noqsi
         "pig"   olɣoŋ
         "flower"   eŋvak
         "juniper"   ojra
         "to like"   e-zmu-
         "good"   urla
         "red"   paʁla
         "touch"   e-rʁap-

Finally, stops are voiceless unaspirated (9a), while fricatives are voiceless in absolute final position (9b) and next to stops (9c), but voiced before sonorants or fricatives (9d):

(9) a. "father"   itɨk   b. "bear"   cʰxɨf
         "arm"   tot   "sky, weather" lɨx
         "puppy, cub"   nonoq   "berry"   als
                                            "devil"   kins
                                            "summer"   tols
                                            "female bear"   aɲx

    c. "nettle"   hisk   d. "ice"   kʰarŋ
         "dressing gown" huxt   "oar"   ivɲ
         "net"   cʰesq   "Japanese"   sizm
         "excrement"   otx   "mat"   lavs
         "swamp"   cʰacf   "clothes"   haɣs
                                            "bowel"   ŋazf

These examples show that the laryngeal contrasts in stops and fricatives neutralize everywhere except at the beginnings of words. We turn next to the alternations between stops and fricatives that appear to be evidence of lenition.

The initial consonants of certain suffixes (10a), of the second elements of compounds (10b-d), and of the head in complement-head sequences (10e,f) alternate between stops and fricatives: voiceless aspirated stops alternate with voiceless fricatives (10c,f) and voiceless unaspirated stops alternate with voiced fricatives (10a,b,d,e):[12]

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[12] These links between alternants led Shiraishi (2006) to propose that voiceless aspirated stops and voiceless fricatives are both specified [spread glottis], while voiceless unaspirated stops and voiced fricatives are unspecified for laryngeal articulations. These specifications remain unchanged by the alternations in continuancy.

(10) a. "to the lake"   tu-roχ   b.   cʰo vɨɲx   "fish soup"
       "to the tundra"   tij-roχ   pʰeq vɨɲx   "chicken soup"
       "to the puppies" ŋajq-roχ   cʰxɨf pɨɲx   "bear soup"
       "to the water"   cʰaχ-toχ   eɣaᴺ bɨɲx   "beef soup"[13]
       "to the dog"   qan-doχ

                                         c.   cʰo r̥om   "fish fat"
                                              hɨjk r̥om   "fat of a hare"
                                              cʰxɨf tʰom   "bear fat"

     d. "trace"   cif   pʰ-ɨtɨk zif   "father's trace"
         "house"   tɨf   ɢalik rɨf   "Galik's house"
         "ring"   kujva   toto ɣujva   "silver ring"

     e. "drink"   ra-   cʰaχ ta   "drink water"
         "beat"   za-   qan dʒa-   "beat a dog"

     f. "kill"   xu-   cʰxɨf kʰu-   "kill a bear"
                                               aŋ kʰu-   "kill whom?"
         "shoot"   χa-   cʰxɨf qʰa-   "shoot a bear"
         "dwell"   fi-   vo ɲaqr̥pʰi-   "dwell in a village"
         "forget"   r̥xɨrp-   ɲiŋ tʰxɨrp   "forget us"

If the stop is taken as the original pronunciation in (10a-d), then the generalization is that a stop is spirantized after a vowel, glide, and oral stop, but remains unchanged after a fricative or nasal. And if the fricative is taken as the original pronunciation in (10e-f), then the generalization is that a fricative is hardened to a stop after a fricative or nasal, but otherwise remains unchanged. However, a more perspicuous analysis would note that stops become fricatives after other stops, while fricatives become stops after other fricatives, and that otherwise, fricatives are found after vowels and glides and stops after nasals. That is, precisely when neighboring obstruents would have the same value for continuancy in these constructions, the second dissimilates from the first. The other two environments, following a vowel or a glide versus a nasal, are where we expect fricative and stop pronunciations, respectively, from the patterns seen in the languages reviewed in §4.2. If this is the correct analysis, then Nivkh is not the problem that it first appeared to be for the hypothesis that consonants are more likely to lenite next to other consonants with more open pronunciations. Instead of stops leniting after other stops but not after the more open fricatives, stops and fricatives acquire the opposite value for continuancy after a stop and a fricative, respectively.

4.4. The consequences for lenition of intensity differences between consonants and vowels

The introduction to this section briefly explained why consonant but not vowel openness should influence the likelihood of lenition: opening a consonantal articulation increases intensity much more than opening a vocalic one does, and this difference in the size of the intensity increase makes lenition, itself an increase in consonantal openness and intensity, much more likely to be sensitive to the openness of a flanking consonant than that of a vowel. In this section, I present the evidence that differences in consonantal openness affect intensity much more than those in vowel openness do. This evidence comes from Parker (2002), a study of the phonetic correlates of sonority differences between the various consonants and vowels in English and Spanish. As a more sonorous articulation is likely to

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[13] The superscript "ᴺ" represents an abstract nasal specification which is not actually pronounced overtly in the Amur dialect of Nivkh from which these data are taken. It is actually pronounced in Sakhalin dialect, which has [eɣaŋ] for "cow" where the Amur dialect has [eɣa], and its presence can be inferred in the Amur dialect from the stop beginning the following word.

be more open, too, I will treat Parker's intensity values as a measure of openness.[14] Parker's data, collected from 20 English and 20 Colombian Spanish speakers (10 males and 10 females in each group), show that the intensity differences between the closest and most open consonants are quite large (18-24dB), while those between the closest and most open vowels are quite small (0-2dB).[15] The large range of consonant intensities shows that increasing a consonant's openness by leniting it can therefore increase its intensity dramatically. On the one hand, leniting a consonant next to one whose constriction is itself relatively open would dramatically reduce the drop in intensity, while failing to lenite a consonant next to one whose constriction is instead relatively close would sustain the large drop in intensity. On the other hand, leniting a consonant next to a more open vowel would reduce the intensity drop little more than next to a closer vowel. Thus, if lenition's purpose is to reduce the extent to which a consonant interrupts the stream of high intensity sounds, the vowels, then the openness of a flanking consonant should influence lenition but the openness of a flanking vowel should not because only consonants differ much in intensity as a function of their openness.[16] The probable communicative purpose served by reducing the interruption of the stream of vowels is discussed in §5.

4.5. An alternative reason why vowel openness should not influence lenition

In §3.2-3, I showed that none of the cases that Kirchner cites as evidence that lenition is more likely next to more open vowels hold up, and in §4.4, I have just shown that lenition probably does not depend on the openness of flanking vowels because vowels differing in openness differ relatively little in intensity from one another. Perhaps, all vowels' articulations, including even the closest ones', are sufficiently more open than any consonant that they would all be likely to encourage a more open articulation of flanking consonants.[17] After all, consonants differ very little in the narrowness of their constrictions: the cross-sectional area at the point of constriction is of course 0 cm^2 for a stop, roughly 0.05-0.2 cm^2 for a fricative, and a minimum of 0.17 cm^2 for a glide (Stevens, 1998). A close vowel's cross-sectional area, 0.2-0.3 cm^2, is somewhat larger than even a glide's, (Stevens, 1998), and any more open vowel would of course have a larger cross-sectional area – the most open vowels have cross-sectional areas at their point of constriction of 2-3 cm^2. Given the small range of cross-sectional areas in consonants' constrictions, 0-0.2 cm^2 and close vowels' larger cross-sectional areas compared to glides', it would be supererogatory for differences in vowel openness to influence the likelihood of lenition. This explanation differs from the one developed in §4.4 in that it does not reflect any functional or communicative purpose which lenition might have. Instead, consonants are equally likely to lenite next to all vowels because even the closest vowels have articulations that are sufficiently more open than any consonant that speakers are as likely to undershoot the target degree of constriction in the consonant next to a close vowel as they are next to more open vowels.

Even so, the very small size of the differences in constriction degree between consonants indicates that very little if any effort is saved by undershooting the consonant's articulation, whether a stop lenites to a fricative or fricative to an approximant. These small differences in constriction degree between consonants also mean that opening a consonant's articulation next to a more open consonant would save very little effort in terms of the distance articulators must travel. The alternative advanced in the preceding section, that lenition can substantially increase a consonant's intensity, and that lenition is sensitive to flanking consonants' openness but not that of flanking vowels because consonants differing in openness differ far more in intensity than vowels, avoids both difficulties, by

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[14] The only sounds for which this is a problem are the nasals, whose oral articulations are as close as those of oral stops, but whose intensity and sonority are considerably higher.

[15] The intensity differences between open and close vowels reported by Parker are smaller than those reported elsewhere (Lehiste & Peterson, 1959), which may be as much as 6-8 dB. Because he measured intensity in vowels in words spoken in frame sentences, I suspect they are a more realistic estimate of the differences that would be observed in nature than the larger differences reported by others.

[16] Kenneth Stevens (p.c.) suggests that the *loudness* of the consonants is probably more important than their intensity in determining how much they interrupt the stream of speech. I agree, but as there are no data on the loudness of consonants, I make due with its acoustic precursor, intensity, here.

[17] I am indebted to my colleague, Lisa Selkirk, for bringing this perspective to my attention.

relying on the large *acoustic* and potentially perceptual consequences of differences in openness between consonants versus the small acoustic consequences of differences in openness between vowels. In this perspective, lenition has no articulatory motivation at all, but is instead a means of regulating the extent to which a consonant differs in intensity from flanking segments.

4.6. Why do stops not spirantize after nasals?

Stops do not lenite to fricatives after nasals in any of the languages discussed above; indeed, in the most liberal language, Koromfe, this is the only context in which they do not do so. Moreover, in Nivkh, sounds which are fricatives elsewhere become stops after nasals, and in many other languages, fricatives harden to stops or affricates after nasals. Finally, stops frequently intrude between nasals and fricatives, as in the common pronunciations of the English words *warm[p]th*, *ten[t]th*, and *leng[k]th*. Why should this cluster of phenomena arise? Steriade (1993) offers a version of what is probably the most widely accepted articulatory explanation for post-nasal hardening and intrusive stops between nasals and fricatives: an inadvertent oral stop closure emerges between a nasal and fricative when the speaker raises the soft palate before opening the oral cavity (see also Ohala, 1981). Speakers would not spirantize a stop after a nasal because doing so would require them to execute these two articulations simultaneously and such precise coordination is too demanding.

Parker's (2002) data show that the failure to spirantize after a nasal cannot be attributed to nasals' acoustic intensity. Nasals are more intense than any obstruent (2-6 dB more intense than most intense obstruents, the voiced fricatives), though less intense than liquids or glides (4-12 dB less intense than liquids). If stops never spirantized next to any sound less intense than a liquid, then an explanation that refers to flanking sounds' intensity might remain tenable, but that explanation incorrectly predicts that lenition should happen more often next to nasals than the less intense oral obstruents.

These facts suggest the failure of stops to spirantize after nasals is the one case that can better be handled in articulatory than acoustic or perceptual terms.

5. Prosodic conditioning of lenition

The review in §4.2 of cases showing that lenition depends on the openness of flanking consonants also showed that lenition depends on the consonants' prosodic position. In Tümpisa Shoshone and Koromfe, consonants do not lenite at the beginnings of phonological words, and in Lowland Murut and Florentine Italian, they do not lenite at the beginnings of phonological phrases. Otherwise, lenition is quite general, indeed obligatory in some languages. Why would consonants lenite inside prosodic constituents but not at their edges? If lenition reduces the interruption of the stream of high intensity intervals caused by the affected consonant, then it may convey to the listener that the current prosodic constituent is continuing rather than a new one beginning. Lenition would thereby complement the strengthening of segments at the edges of prosodic constituents (Fougeron & Keating, 1997; Keating, Cho, Fougeron & Hsu, 2000; Cho & Keating, 2001), which interrupts that stream of high intensity events more and in doing so signals to the listener that a new prosodic constituent is beginning rather than the old one continuing. In this interpretation, lenition, like strengthening, has a communicative purpose, to convey information to the listener about the prosodic grouping of strings. This purpose can only be achieved when susceptible sounds occur at potential prosodic edges, but this opportunism in no way diminishes the communicative value of these changes in pronunciation, when they occur.

Harris (2003) advocates an essentially identical motivation for lenition, using strikingly similar arguments, although he treats the increase in similarity between the affected segment and its neighbors as a loss of information (see also Harris & Urua, 2001). Information is lost if the lenition neutralizes a contrast, but otherwise not. Indeed, information is gained if the lenited segment occurs only within prosodic constituents of a certain size. I did not see his papers until this one was nearly complete, so the proposal presented here was developed independently.

6. Undershoot

Even if lenition is not effort reduction, it may still in some instances be the result of systematic undershoot of articulatory targets. Vowels are reduced when speakers move on to the next consonant's target before completing movement to the vowel's target (Lindblom, 1963; Flemming, 2004; Barnes, 2006). Leniting a voiced stop to the corresponding non-strident fricative, e.g. /b/>[β], /d/>[ð], /g/>[ɣ] or yet further to an approximant, also appears to be the result of undershoot: the speaker shortened the already brief stop closure so much that the articulators never got close enough together to close the mouth completely. However, in this case, the closure was not shortened because the speaker had to move quickly on to the next vowel's target, but instead to ensure that vocal fold vibration continued through all or most of the consonantal constriction. Vibration is hard to maintain during a stop closure because the rise in oral air pressure behind the closure can reduce the pressure drop across the glottis to the point that air stops flowing up through it, and once that air flow stops, the vocal folds stop vibrating. For this reason, the closures of voiced stops are inherently shorter than those of voiceless stops. If a speaker shortened them even further, the articulators could never get close enough to one another to interrupt air flow out of the mouth completely, and the result would be a voiced fricative (or approximant) rather than stop.

This case of undershoot and the resulting lenition is clearly not motivated by the desire to expend as little effort as possible, but instead to ensure that one phonetic property of the consonant, voicing, is reliably produced, even at the expense of another, complete closure of the oral cavity. The latter can in many languages be sacrificed because they otherwise have no non-strident fricatives with which the lenited pronunciations of the voiced stops might be confused. Finally, undershoot for this purpose appears to be the cause of the majority of instances of stop lenition: in Kirchner's (1998) catalogue, just voiced stops lenite in 54 languages versus just voiceless stops in 45 languages[18] – both voiced and voiceless stops lenite in 17 languages.

7. Testing hypotheses
7.1. Introduction

Thus far, this paper has largely been a vehicle for laying out hypotheses about the nature of lenition. While some of these hypotheses have been tested directly, others remained largely untested. It is the purpose of this section to begin to test them. Four hypotheses are tested:

(11) a. Lenition is more likely inside prosodic constituents than at their edges, because its purpose is to convey that a word beginning with the affected sound is inside a prosodic constituent.

b. Lenition is more likely next to a more open sound, a vowel, than a less open one, a nasal, because it reduces the interruption of the stream of high intensity sounds more next to sounds that are themselves more intense because their articulation is more open.

c. Lenition is not more likely next to a more open vowel than a closer one, because vowels differing in openness do not differ noticeably in openness.

d. Lenition is more likely in more frequent words than less frequent ones, because the listener needs less information to recognize more frequent words

These tests serve a secondary purpose, too: trying out a semi-automatic means of detecting lenition in acoustic signals. Most prior work on lenition has relied on classifying consonantal allophones from acoustic properties that can be seen in waveforms or spectrograms or on hand measurements of acoustic properties from such records (e.g. Dalcher, 2006). Unfortunately, the visual

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[18] This difference is bigger than it looks because a number of languages in which just voiceless stops are affected have no voiced stops.

criteria used are often hard to apply consistently, and hand measurements are so laborious that relatively little material may be measured. The proposed method not only avoids these difficulties but also provides a quantitative means of deciding whether a consonant has become categorically different as a result of lenition.

7.2. Methods
7.2.1. Speakers

The data reported here were collected from two adult female speakers of Spanish, from Ecuador (E) and Peru (P). Both were living in the United States at the time the recordings were made, but they reported that they used Spanish everyday. Neither reported any hearing or speaking disorder. Both were paid for their time.

7.2.2. Materials

The materials were forms of the verbs listed in Table 3. These verbs begin with the voiced and voiceless stops of Spanish, /b,d,g,p,t,k/ (/d,t/ are dental). These stops are followed by high, mid, or low vowels. Two verbs represent each of the 18 combinations of initial stop and following vowel, one is relatively high in frequency, and the other relatively low; frequencies were taken from the LexEsp corpus (Sebastián, Cuetos, Martí & Carreiras, 2000).

		Voiced			Voiceless		
		Vowel			Vowel		
Place	Frequency	Close	Mid	Open	Close	Mid	Open
Bilabial	High	*vivir* 2505	*beber* 608	*bajar* 977	*pedir* 1695	*pesar* 420	*pasar* 5324
	Low	*vibrar* 49	*versar* 36	*vagar* 66	*pitar* 17	*penar* 56	*pastar* 8
Dental	High	*decir* 15174	*dejar* 4872	*dar* 9452	*tirar* 596	*tomar* 2525	*tardar* 572
	Low	*distar* 60	*dentar* 13	*datar* 59	*timar* 16	*tostar* 18	*tajar* 8
Velar	High	*gustar* 1675	*gozar* 285	*ganar* 1309	*quitar* 647	*quedar* 4287	*caer* 1753
	Low	*guisar* 21	*gotear* 14	*galopear* 26	*cursar* 25	*quebrar* 89	*calzar* 53

Table 3. Verbs and their frequencies (out of the roughly 5.6 million words in the LexExp corpus). The forms of *decir* and *pedir* used had the high vowel [i].

Each of the 36 verbs was produced in four different syntactic contexts, following a word ending in the vowel [a] or the nasal [n] (12). Each verb's context was syntactically and semantically appropriate.

(12) a. Auxiliary, e.g. *ha* or *han* ___
           VP[Aux ___ ...
     b. Short Subject, e.g. *María* or *Juan* ___
           ...]NP VP[___ ...
     c. Long Subject, e.g. *La nueva méxicana de Santa Fé* ___ or
           La floridiana de Boca Raton ___
           ...]NP VP[___ ...
     d. Subordinate clause, e.g. *Después que María se casó,* ___ or
           Después que María y Juan casaron, ___
           ...]S S[___

The verb was never final in its clause. The syntactic distance between the verb and the preceding word increases from (12a) to (12b,c) and then once again to (12d) (the local syntactic structures are given below the examples), and it is expected that prosodic distance and the strength of any intervening prosodic boundary increase with syntactic distance (D'Imperio, Elordieta, Frota, Prieto & Vigario, 2005). The syntactic distance between the subject and the verb is the same in (12b,c), but the long subject is more likely to be in a separate prosodic constituent from the verb than the short one. In textbook descriptions, voiced stops become fricatives or approximants after vowels but not nasals, and voiceless stops remain stops in both contexts. However, Romero (1996) shows that voiceless stops may also be pronounced without complete closure (see also Lewis, 2000).

The sentences were separately pseudo-randomized for each speaker. The pseudo-randomization combined one randomly chosen form of each verb in a block of trials. The sentences in each block were printed on separate sheets of paper and were read one after another. After each block, the speakers chatted briefly with the experimenter before going on to the next. Each sentence was spoken once by each speaker. The speakers wore a head-mounted microphone that was not removed during the recording session. The fixed distance between the speaker's mouth of the microphone permits comparison of intensity values across tokens. The signal was amplified and then digitized directly at a sampling frequency of 44100 Hz with 16-bit resolution. The data were stored as .wav files, labelled, and then analyzed using a Praat script written for this purpose (Boersma & Weenink, 2006).

7.3. Results
7.3.1. Measurements

Simultaneous waveform and spectrogram displays were inspected and the beginning and end of the constriction corresponding to the initial consonant of the verb was marked. No attempt was made to be exceptionally precise in locating these events, but they were generally easy to detect. Figure 2 illustrates a typical case, of the pronunciation of the initial /b/ in *vibrado* as [β] following the auxiliary *ha*. When the preceding consonant was a nasal, only the oral portion of the constriction was marked. This approximate marking of the beginning and end of the constriction was the only hand work required, as all subsequent measurements were automatic.
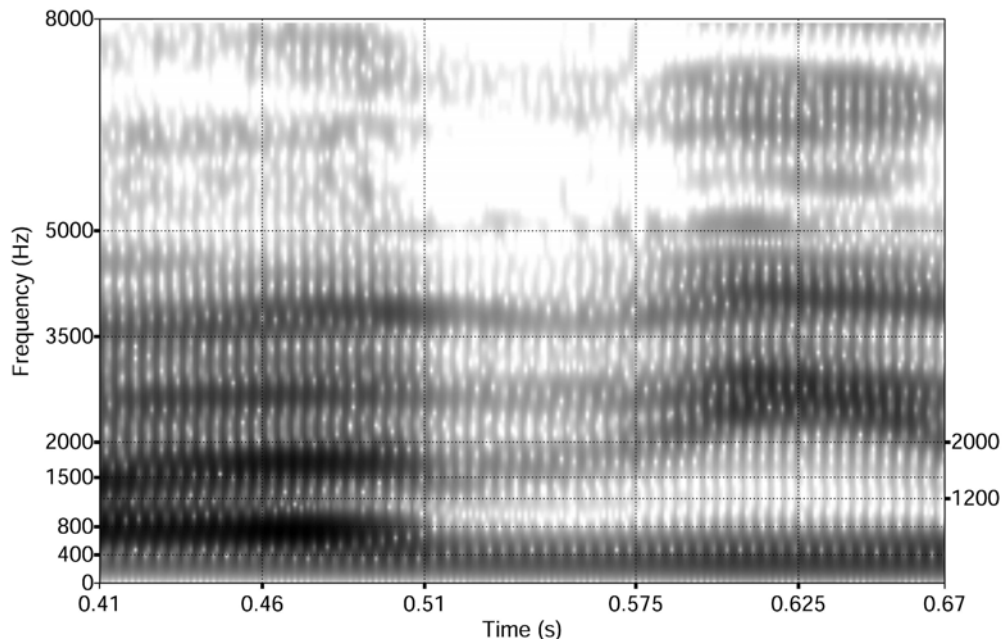

Figure 2. Spectrogram of [aβi] from *ha vibrado* with vertical lines designating the interval of the consonantal constriction, at 0.51 and 0.575s.

The next step was to bandpass filter the signal into six frequency bands: 0-400, 800-1500, 1200-2000, 2000-3500, 3500-5000, and 5000-8000 Hz (Figure 2);[19] these are the frequency bands used by Liu (1996) in her study of the acoustic landmarks for distinctive features of consonants. The intensity of the energy was extracted from each of the bands and first-differenced to exaggerate changes in its level (Figure 3).
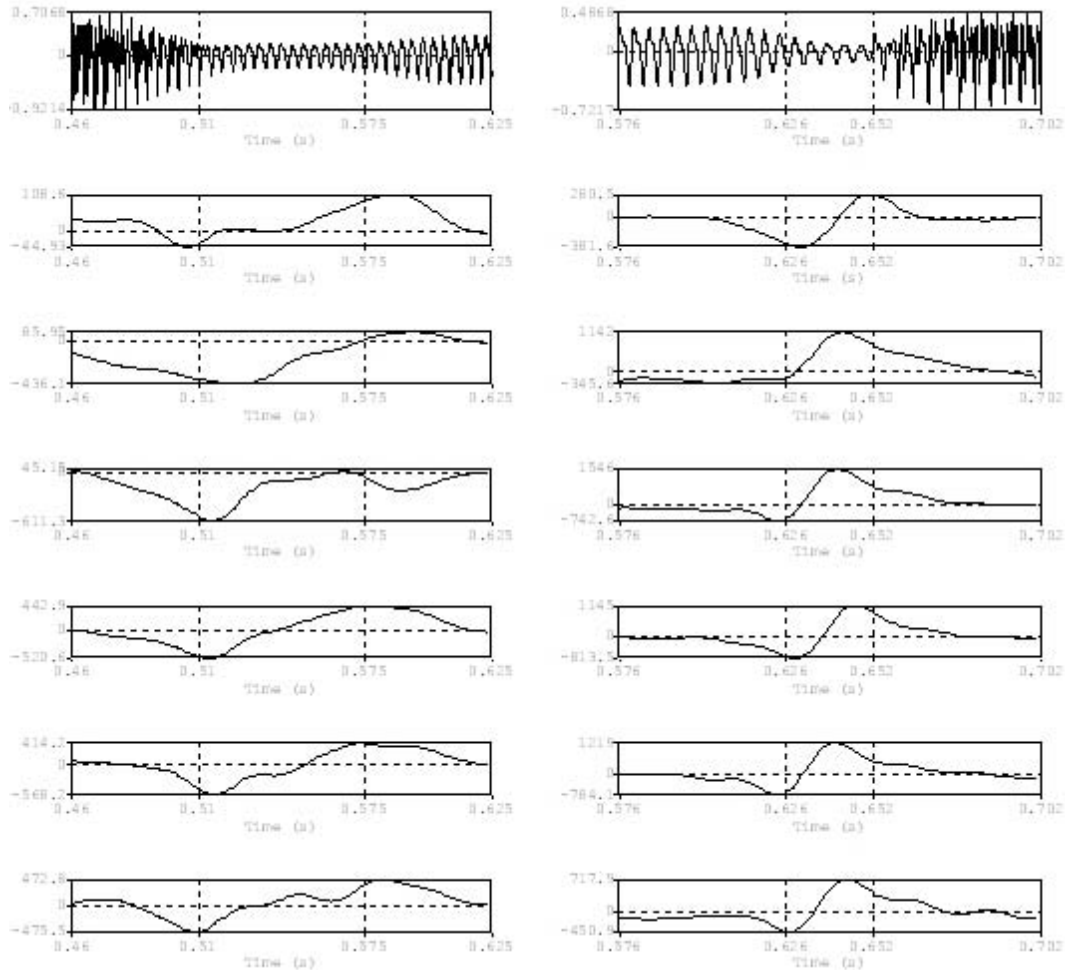

Figure 3. Top: waveforms of the constriction intervals for the initial consonants in *vibrado* (left) from *ha vibrado* and *datado* (right) from *han datado* ±50 ms on either side. The six panels below are the corresponding first-differenced intensity waveforms for each of the band-passed filtered intervals, from just below the top to the bottom: 0-400, 800-1500, 1200-2000, 2000-3500, 3500-5000, and 5000-8000 Hz. The vertical dashed lines are the approximate edges of the consonantal constriction as determined from the waveform and spectrogram (see Figure 2).

Finally, the value and time were extracted from the minimum closest to the marker placed at the beginning of the constriction and from the maximum closest to that placed at the end of the constriction. The minimum and maximum were sought within an interval extending 50ms on either side of their respective markers. Because these are the minimum and maximum of the first-differenced intensity trajectory, the minimum occurs at the moment when energy is falling fastest and the maximum at the moment when it is rising fastest, and not at the moments when intensity levels are minimal and maximal. More extreme minimum and maximum values and longer durations would

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[19] The skirts of the filters were 10% of the upper cutoff frequency.

correspond to less lenited pronunciations, because they would be produced by closer constrictions, held for longer periods of time. In 9.6% of cases for the Ecuadorian speaker and 9.1% of cases for the Peruvian, the maximum extracted from a particular band preceded the minimum. After these cases were discarded, roughly 250-300 measurements of the minimum, maximum, and the duration of the interval between them remained for each speaker in each frequency band.

Figure 3 displays the original waveforms as well as the first-differenced intensity waveforms for a spirantized token of the initial /b/ in *vibrado* spoken in the phrase *ha vibrado* (the same token as in Figure 2) and a more stop-like token of the initial /d/ in *datado* spoken in the phrase *han datado*. The Peruvian speaker produced both tokens. The vertical lines mark the approximate beginning and end of the oral consonantal constrictions, as determined from visual inspection of the waveform and spectrographic displays. Within each band, the minimum is the smallest value within an interval ±50ms from the first line, and the maximum is the largest value within ±50ms from the second.

These values were the dependent variables in multiple regression analyses carried out separately for each speaker's data in each frequency band. The independent variables in these analyses represent the linguistic characteristics of the stimuli described above. With one exception, these characteristics were encoded numerically such that higher values correspond to predictions of *less* lenition as their values increase (13). The exception was verb frequency, which was encoded unaltered. Because speakers are expected to be pronounce higher frequency words more casually (Bybee, 2001), this variable's encoding corresponds to a prediction of *more* lenition as frequency increases.

(13) a. Distance:

i.	Auxiliary	0	b.	Preceding segment:	
ii.	Short subject	1		i. Vowel	0
iii.	Long subject	2		ii. Nasal	1
iv.	Subordinate clause	3			

c. Voicing:

i.	Voiced	0	d.	Place:[20]	
ii.	Voiceless	1		i. Bilabial	0
				ii. Dental	1
				iii. Velar	2

e. Vowel height:

i.	Low	0
ii.	Mid	1
iii.	High	2

7.3.2. Regression equations

Only one regression model of each measure (minimum, maximum, duration) was considered for each speaker and frequency band, that in which all six independent variables were forced into the analysis. The general form of the regression equation is thus:

(14) $\{Min,Max,Dur\}_{\{E,P\}\{1..6\}} = \beta_0 + \beta_D*\{0,1,2,3\} + \beta_{PS}*\{0,1\} + \beta_V*\{0,1\} + \beta_P*\{0,1,2\} + \beta_{VH}*\{0,1,2\}$

where the bracketed values show the ranges for the dependent and independent variables (see (13); E, P indicate the Ecuadorian and Peruvian speakers, and 1..6 indicates the six frequency bands. β_0 is the constant term, and β_D-β_{VH} are coefficients representing the sizes of the effects of each of the independent variables).

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[20] I predicted less lenition of more posterior stops, because intraoral air pressure typically rises more behind their constrictions than those of more anterior stops (Ohala, 1975; Javkin, 1977). The results hint instead that more posterior stops are more not less likely to lenite, apparently because velar closures are more often incomplete.

These models are characterized by two statistics, the proportion of variance accounted for by the independent variables (R^2) and the coefficients representing the direction and size of the effects of each of the independent variables (β values).

7.3.3. Proportion of variance accounted for

For the Ecuadoran speaker, the R^2 values ranged from 0.309-0.583 for the maximum, 0.218-0.469 for the minimum, and 0.253-0.312 for duration; for the Peruvian speaker, they ranged from 0.509-0.683 for the maximum, 0.118-0.509 for the minimum, and 0.282-0.404 for duration. Undoubtedly, better fits to the data could be obtained by including interactions among the independent variables as well as the main effects, but there is no principled basis for making predictions about how one variable's effect should depend on another's value. Accordingly, I will only consider these main effects models here.

7.3.4. Effect directions and sizes

The β values are of considerably more interest, as their size and significance tells us whether an independent variable had any effect on the measures of lenition, and their direction tells us what that effect is. The β values for word frequency show that this variable did not significantly affect either the minimum or the maximum for either speaker in any frequency band, and it only affected duration significantly for the Ecuadorian speaker in the fourth band (2000-3500 Hz) and for the Peruvian speaker in the fifth band (3500-5000 Hz). Both of these significant effects were positive (as were all the non-significant β values for word frequency for both speakers in the models of duration), which indicates that duration was longer when word frequency was higher. This outcome is contrary to the expectation that speakers are more likely to shorten and thus lenite in higher frequency words. One should not make too much of it, however, as word frequency was otherwise not significant. I suspect that frequency had little effect because all the verbs were used in syntactically and semantically appropriate contexts, which created expectations about the verb that would occur there that mitigated any effects of frequency. Moreover, each sentence was read silently before being pronounced, which would have familiarized the speaker with its contents.

Figures 4 and 5 display β values for the effects on the minima (Figure 4) and maxima (Figure 5) of the preceding segment (Figures 4,5a), the proximity to the preceding word (Figures 4,5b), and the voicing of the stop (Figures 4,5c). Each of these variables significantly affected these measures in a majority if not all of the frequency bands. The difference between a preceding vowel and nasal significantly affects the minima in all frequency bands for both speakers except for the Peruvian speaker in the sixth band (Figure 4a). In the first band, $β_{PS}$ values are significantly negative, which indicates that the effect of a preceding nasal is exaggerate how negative the minimum is in the 0-400Hz range compared to a preceding vowel. All the other significant $β_{PS}$ values are positive, which instead indicates that a preceding nasal makes the minima in these bands less negative than a preceding vowel does. This difference reflects the presence of greater energy in all frequency bands but the lowest following a nasal than a vowel. Finally, all the values are greater for the Ecuadorian than the Peruvian speaker, indicating that the preceding segment has a greater effect for her.

Distance from the preceding words had more modest effects on minima (Figure 4b), although the $β_D$ values are significantly negative for the lowest 0-400Hz band and significantly positive for the fourth and fifth bands (2000-3500 and 3500-5000Hz). Again, negative coefficients indicate more negative minima while positive ones indicate less negative ones.

Finally, the voicing of the consonant has a significant and uniform effect in all frequency bands for both speakers (Figure 4c): a voiceless stop makes the minima more negative than a voiced one, and more so in the lower than the higher frequency bands. The effect of voicing is larger for the Peruvian than the Ecuadorian speaker.

Minima are affected more by the stops' segmental context and one of their own properties than the syntactic or prosodic distance from the preceding word.
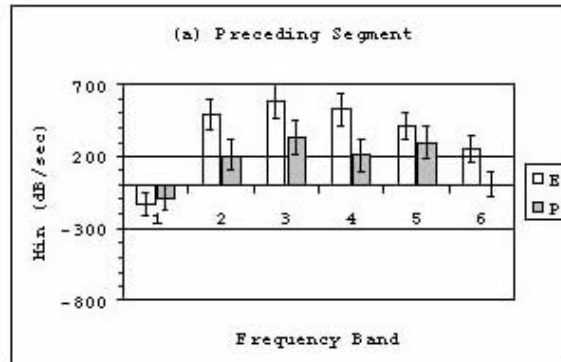
Figure 4a. β values (95% confidence intervals) for the effects of the preceding segment in models of the minima. 1-6 = the six frequency bands. White =Ecuadorian, Gray = Peruvian.
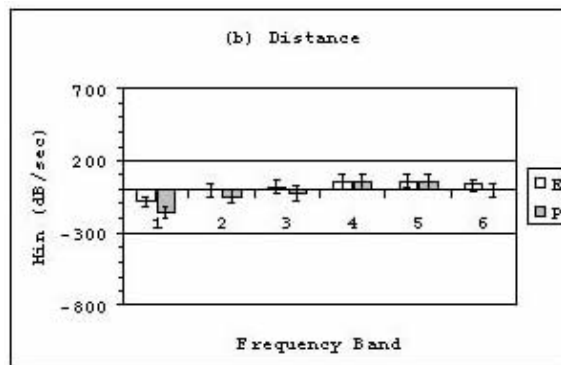

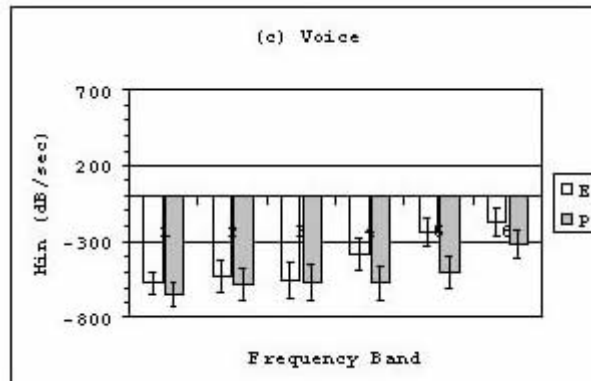Figure 4b. Syntactic/prosodic distance from the preceding word.

Figure 4c. Voicing of the affected stop.

Figure 5 shows a somewhat different pattern of results for the analyses of the maxima. Figure 5a shows that when the preceding segment is a nasal, the maxima are more positive in all frequency bands than when it is a vowel, although the effects of the preceding segment are only significant for the Peruvian speaker. The effects are also smaller for the lowest frequency band (0-400Hz) than the higher ones.

Syntactic or prosodic distance has much more consistently significant effects on the maxima than it did on the minima (Figure 5b): maxima are uniformly greater in all frequency bands for both speakers.

Voicing likewise has a consistently significant positive effect on maxima (Figure 5c), although that effect is greater for the second and third bands (800-1500Hz and 1200-2000Hz) than for lower or higher bands.
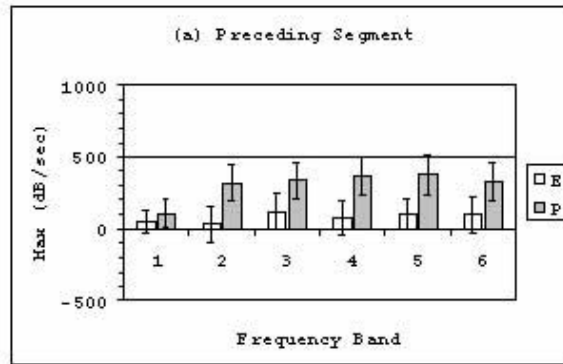
Figure 5a. β values for the preceding segment in model of the maxima.
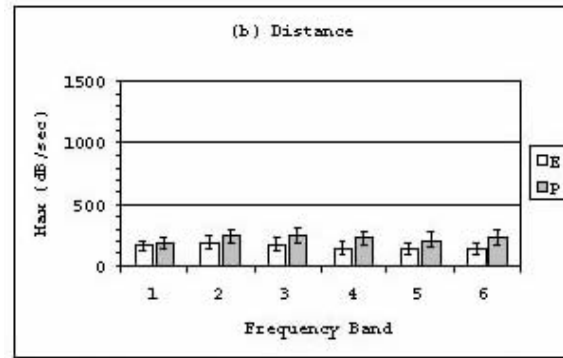

Figure 5b. Syntactic/prosodic distance from the preceding word.
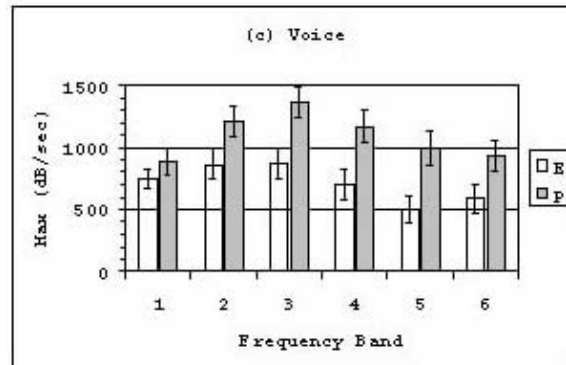

Figure 5c. Voicing of the affected stop.

Unlike minima, maxima are thus affected by the stops' syntactic or prosodic context as much as by their segmental context and intrinsic properties. This difference suggests that speakers mark the beginning of a more distant syntactic or prosodic constituent more robustly than the end.

More generally, if a more negative minimum and a more positive maximum indicate less lenition, then stops are less lenited after a nasal, after a more distant preceding word, and when voiceless.

Place of articulation has no consistent nor significant effect on either the minima or maxima. The height of the following vowel also has no significant effect on the minima, but it does significantly affect the maxima in the second and third bands. The β_{VH} values for both speakers are negative in these bands, which indicates that their maxima are smaller when the flanking vowels are higher. These values indicate that stops are more lenited next to higher than lower vowels.

Only one variable affected duration consistently in all bands for both speakers, syntactic or prosodic distance from the preceding word. Unsurprisingly, β_D values were also positive: the duration

of the interval between the minimum and maximum increased by roughly 50ms for each increment in syntactic/prosodic distance. Voicing also had a significantly positive effect on duration, but only for the Peruvian speaker, whose voiceless stops were 30-40ms longer in all frequency bands than her voiced ones.

Two of these results nearly follow textbook predictions: stops lenite less after nasals than vowels and when voiceless than voiced. They also lenite less when the preceding word is farther away syntactically and prosodically. The sizes of these effects, particularly that of voicing, suggest furthermore that the effects are categorical. Both the textbook and categorical character of these results probably reflect the fact that the speakers produced these utterances with some care and formality. The analytical technique can, however, be applied just as readily to less careful and formal speech. The results of doing so will be reported elsewhere.

8. Phonetic motivation of constraints[21]

Many constraints in optimality theoretic grammars are phonetically motivated, e.g., the constraints of syllable margins and peaks reflect sonority differences between classes of segments (Prince & Smolenksy, 1993). Although these sonority differences cannot be defined in terms of any single phonetic correlate, they can still be characterized phonetically, principally in terms of acoustic intensity but also other phonetic properties (Parker, 2002). The patent phonetic motivations of many constraints raise the question of how directly those constraints should refer to or even embody their motivations. The case of the syllable margin and peak constraints shows one way in which this question has been answered. These constraints take the form, *Margin/Low Vowel, ..., *Margin/Voiceless Stop and *Peak/Voiceless Stop, ..., *Peak/Low Vowel, where the ellipses stand for fixed hierarchies of constraints referring to segment classes of decreasing and increasing sonority, respectively, and phrases such as "low vowel" and "voiceless stop" refer to the bundles of features defining these natural classes. The ranks of the constraints in both hierarchies are determined, indeed fixed by the sonority scale, in which low vowels have the highest value and voiceless stops the lowest. *Margin/Low Vowel and *Margin/Voiceless Stop are top and bottom-ranked in the margin hierarchy because languages disfavor more sonorous syllable margins and favor less sonorous ones, while the rankings are reversed in the peak hierarchy because they disfavor less sonorous syllable peaks and favor more sonorous ones.

Even so, the constraints themselves neither embody nor refer directly to these sonority differences, which are instead realized separately, in the sonority scale. In other words, the margin and peak constraint hierarchies *use* the ordering of segment classes in the sonority scale but do not need to refer directly to the phonetic bases for ordering segment classes in that scale. Separating the phonological constraints from their phonetic bases like this may appear at first to be hair-splitting, but without doing so, one cannot capture the fact that languages differ, or more precisely their grammars differ in where they draw the line between possible and impossible margins or peaks. For example, Mandarin does not permit stops in syllable codas, while Cantonese does,[22] and English permits liquids and nasals to be syllable peaks, but Spanish does not. If phonological grammars and the constraints of which they are composed are distinct entities from their phonetic bases, then those phonetic bases – here the sonority scale – may be the same across languages, i.e., genuinely universal, even while the uses to which they are put in particular languages differ. This is not to say that all phonetics is universal: Keating (1984), Kingston & Diehl (1994), Cho & Ladefoged (1999), and others have argued that languages differ phonetically from one another, too. Those cases all involve language-specific uses of universal aspects

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[21] Because my space is limited, many debatable points will be glossed over in this section. I therefore ask the reader to take this as no more than a programmatic sketch of my position, rather than a comprehensive defense.

[22] As presented above, the Margin constraint hierarchy does not distinguish between onsets and codas. Considerable evidence has accumulated showing that the Margin constraint hierarchy may actually only account for onset preferences. In many languages, more, not less sonorous consonants are preferred in codas, as exemplified by Mandarin. Some languages, e.g., Hawaiian, permit no coda consonants of any kind, the result of pushing the preference for syllables ending in more sonorous segments to its limit (see Prince & Smolensky, 1993; Smith, 2002, in press and references cited therein).

of phonetic behavior, which are phonetic rather than phonological because they do not alter the system of contrasts in the language.

Phonetics is not separated in this way from phonology in some optimality theoretic grammars, notably those developed to account for the distribution of laryngeal contrasts in obstruents by Steriade (1999), Boersma's (1998) functional phonology, and likewise Kirchner's (1998, 2004) account of lenition. Kirchner proposes a constraint family that he calls LAZY, whose members prohibit speakers from exerting more than specified amounts of effort in pronouncing particular sounds, in particular contexts, at particular speaking rates. When ranked high enough relative to competing faithfulness constraints that would preserve a sound's originally narrower degree of constriction in the present speaking register, the LAZY constraints select a pronunciation with a more open constriction as optimal because it requires less effort to achieve. The result is lenition.

Although I have argued above that lenition is not effort reduction, let us accept for the moment that it is in order to examine the consequences of Kirchner's approach for the structure of phonological grammars and for the relationship of phonetics to those grammars. Let us also accept that the effort required to produce a particular degree of constriction or to move articulators a particular distance can be measured in some recognized physical unit such as ergs or calories.[23]

The problem that immediately arises is that lenition substitutes one category for another, e.g., a fricative for a stop, an approximant for a fricative, a sound without an oral constriction for one that has one, or in the limit nothing for something. Moreover, languages typically select a subset of their phonological categories to undergo these substitutions. Categorical changes and selection of affected segments by category are not expected if the dimension along which the sounds change is a continuous scale of effort. The first problem might perhaps be solved by quantizing the effort scale, but this is an ad hoc, technical fix that disguises the categorical nature of the changes in the pronunciation that lenited sounds undergo. Moreover, quantization cannot fix the second problem, because dividing the effort scale into quanta does not by itself pick out the particular quantum that undergoes effort reduction.

There are, I think, two deeper problems here with any attempt to build physical scales directly into systems that manipulate categories. The first is that because speakers differ in their anatomy and physiology from one another, the absolute effort required for one speaker to achieve a particular degree of constriction is undoubtedly different from that required for another to achieve the same degree, and more importantly the difference in absolute effort between a narrower and more open degree of constriction also undoubtedly differs between speakers. Even if the relevant differences in effort between degrees of constriction are *relative* rather than absolute, it is still difficult to see how the individual language learner can discover the degree of relative effort required to produce a lenited versus unlenited pronunciation. In the end, this problem, too, arises from trying to regulate pronunciations by adjusting continuous values rather than choosing categories.

An analogy might be useful here. To serve a tennis ball successfully, among other movements, you must snap the wrist downward when striking the ball, a movement that tennis players call "breaking the wrist". If you do not break your wrist, the chances of the ball going anywhere but the service court are high, no matter what else you get right in the toss, swing, or follow through. The successful serve made by breaking your wrist at the moment when you strike the ball differs

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[23] It will be extraordinarily difficult to quantify in physiologically relevant units the effort required to move an articulator from one position to another. The time scales are so brief, the movements are so small and rapid, and the complexity of the patterns of contracting muscles is so great that these quantities will be very hard to measure. These considerations also should raise doubts as to whether a speaker's articulatory behavior can be governed by any concern for conserving effort, as they imply that the speaker may have just as much difficulty estimating the effort a particular articulatory movement requires as the experimenter. I suggest that a speaker's articulatory behavior is instead governed by an apparently related but in fact entirely distinct principle, *efficiency*. In this alternative conception, an articulatory movement is efficient when it reaches its target by moving to it along the shortest possible path from its current position. A speaker selects an articulatory target which will produce the set of acoustic properties that will in turn convey whatever phonological information the speaker wishes to transmit at that moment in the utterance.

categorically from the fault made when you do not.[24] What the language learner has to discover is the vocal equivalent of such categorical differences, specifically, the articulatory means of achieving the categorical difference between a fricative and a stop, an approximant and a fricative, etc. – these are the articulatory "targets" referred to in note 23. The learner probably does so by first *hearing* the difference between the lenited pronunciation and the unlenited original and then experimenting with his own articulators until he can reproduce the different pronunciations in the appropriate contexts. If the model for learning is a percept of the desired pronunciation, reducing effort should play little if any role.

One might object that this argument does not address how lenition became a process in a language in the first place. Might not the language have first lenited its stops to fricatives to reduce the effort its speakers had to expend? That is, could not the phonetic motivation for the sound change that introduced spirantization into the language have been effort reduction, even if this is no longer the case in the synchronic grammar? Blevins (2004) argues that many synchronic patterns are divorced in this way from the phonetic motivations of the sound changes that introduced them into the language. However, Kirchner (1998, 2004) does not adopt this stance but instead builds the effort reduction constraints directly into the synchronic grammar, where they would be what is learned.

The second problem is that speakers must produce lenited pronunciations in a variety of contexts. A look back at the cases reviewed in §4.2 above shows that they do so next to vowels and consonants that differ in their openness, backness, and other articulatory properties. Despite this variability in where the articulators are before and after the affected segment, speakers apparently achieve those targets reliably. Because the articulators must move different distances and in different directions to reach the intended target in different contexts, it is impossible to specify in any context-free fashion how much effort, either absolute or relative, a speaker must exert to reach that target. And it is certainly irrelevant what the effort would be to move the articulators there from their rest position (see Kirchner, 2004:321). Like the first problem, this one, too, vanishes if the target is specified categorically in acoustic or perceptual terms.

It is reasonable to ask at this point whether the alternative to effort reduction that I have argued for in this paper would also be bedevilled by these same problems. After all, that alternative is just as functionally motivated as effort reduction. The alternative was that speakers lenite consonants to reduce the extent to which the affected consonant interrupts the stream of high-intensity segments, the vowels. Lenition achieves this happy outcome by increasing that consonant's acoustic intensity. In this alternative, articulations are manipulated to achieve an acoustic or perceptual rather than articulatory goal – recall that an articulatory target is defined as the position or setting that will produce a particular set of acoustic properties, which will in turn transmit the desired phonological information. Because the ultimate goal is transmission of phonological information, which is itself categorical, the goal is also categorical rather than quantitative, so this alternative escapes from both problems.

Effort reduction fails to capture what determines a speaker's behavior because it is an account of only an early step in the speech chain, and not the entire event. Reducing the interruption of the stream of high intensity sounds by increasing a consonant's intensity is instead an account of the entire event: a more open articulation is chosen to increase acoustic intensity, reduce interruption, and thereby convey that the current prosodic constituent is continuing rather than a new one beginning.

I must of course still answer the question posed at the beginning of this section: how direct is the relationship between the phonetic motivations for my account of lenition and its phonological implementation? My answer is the same as it was for the peak and margin hierarchies: the phonetic motivations are outside the grammar. The grammar's concern is to choose those categories that will convey desired information about prosodic constituency. To do so, it need not itself know which categories correspond to particular degrees of constriction that produce more or less intense consonants. That information can be encoded in the sonority scale, which the grammar can again use,

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[24] As the reader might suspect, this analogy comes from personal experience. My tennis game was successful in all respects but service, where I consistently faulted, until an opponent told me one day that I did not break my wrist when striking the ball. To that opponent's chagrin, I went from faults to aces between that serve and the next.

in formally the same way as it does in choosing optimal syllable margins or peaks. The prosodic conditioning of lenition suggests that an approach using the insights of Beckman's (1997) account of positional faithfulness would be plausible. Such an approach would consist of faithfulness constraints specific to particular prosodic positions ranked above general faithfulness constraints, e.g., IDENT[CONTINUANT]/PC[... >> IDENT[CONTINUANT], where PC[... is the initial boundary of some prosodic constituent, and a related markedness constraint prohibiting a [-continuant] consonant from occurring in a particular segmental context, *[-CONTINUANT]/X_Y. The markedness constraint is drawn from a hierarchy of markedness constraints, whose ranking reflects the sonority scale just like the peak and margin constraints, *VOICELESS STOP/X_Y >> *VOICED STOP/X_Y >> ... >> *GLIDE/X_Y. The specification of the flanking segments, X and Y, would also reflect the ranking of segments by the sonority scale, in that both X and Y would specify lower limits in sonority value for the preceding and following segments in the context defining the markedness constraint. For example, in Florentine Italian, X is any segment as sonorous as a vowel and Y is any segment as sonorous as a liquid – "V" and "L" are shorthand for these limits in (15) and (16) below. If the markedness constraint is ranked between the position-specific and general faithfulness constraints, then lenition is limited to occurring within the prosodic constituent M, whatever it is – compare the optimal outcomes in (15) and (16):

(15) apra	IDENT[CONTINUANT]/ɸ[	*[-CONTINUANT]/V_L	IDENT[CONTINUANT]
a. apra		*!	
☞b. aɸra			*

(16) a] ɸ[pra	IDENT[CONTINUANT]/ɸ[	*[-CONTINUANT]/V_L	IDENT[CONTINUANT]
☞ a. apra		*	
b. aɸra	*!		*

One final comment is worth making in closing. In this approach, lenition is a side effect of prohibiting a less sonorous segment in a particular prosodic and segmental context, and not spreading of some property of the segmental context to the affected consonant (cf. Mascaró, 1984).

9. Conclusion

In this paper, I have argued that lenition's purpose is to reduce the extent to which a consonant interrupts the stream of speech and not to minimize the articulatory effort the speaker must expend in pronouncing that consonant. Lenition achieves this purpose by increasing the affected consonant's intensity. By reducing the interruption of the stream of speech, lenition conveys that the affected consonant is inside a prosodic constituent. This argument rests on three empirical supports. First, lenition is shown not to be more likely next to more open vowels, as would be predicted if its purpose were to minimize articulatory effort. Second, lenition is shown, however, to be more likely next to more open consonants. Intensity differs much more between consonants than vowels that differ in openness, so it is not surprising that an articulatory change whose purpose is to alter the affected consonant's intensity would be sensitive to articulatory differences in adjacent consonants that have large effects on their relative intensities but not to articulatory differences in vowels that have very small effects on their intensities. Third, new data collected from two Andean Spanish speakers show that lenition is categorically more likely inside a prosodic constituent than at its edge. The paper concludes with an argument that the constraints and their rankings in phonological grammars do not wear their phonetic motivations on their sleeves, even if such processes as lenition are functionally motivated. This gist of this argument is that lenited and unlenited pronunciations differ categorically rather than continuously.

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