Debuccalization and supplementary gestures

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1 Introduction

Debuccalization is a weakening phenomenon whereby various consonants will reduce to laryngeals. Although there is an extensive literature on lenition in general (Lavoie 1996, Kirchner 2001, Gurevich 2004, Bauer 2008, Gess 2009, among others), there has been little research on the phonetics and phonology of debuccalization as a category of lenition processes. The goal of the present investigation is to fill this gap.

The first four sections of this paper make up the background investigation of lenition and debuccalization, as well as establish the typological evidence of debuccalization. Section 2 proposes a definition for what debuccalization is (along with what it is *not*). In Section 3, an extensive typology of debuccalization processes, both historical and synchronic, is provided. The next section, Section 4, provides further background on debuccalization and the issues that the typology raises. Here, we attempt to unify debuccalization processes (Subsection 4.1), we refer to a previous study on perception and debuccalization (Subsection 4.2), and we look at the difference between initial motivation and synchronic formalism of debuccalization (Subsection 4.3).

Section 5 contains the primary analytic contribution of this paper. While a lot can be gained by viewing debuccalization as the loss of oral gestures, not all cases of debuccalization are so simple. Sometimes we find supplementary gestures in debuccalization phenomena. Supplementary gestures are gestures that appear in the debuccalized segment, but are not part of the corresponding non-lenited form (e.g. the glottal closure gesture in Indonesian /k/ → [ʔ]). Following Kirchner 2001, we assume that articulatory effort is the primary motivation for debuccalization, but we deviate from Kirchner in the assumption that faithfulness to features is the motivation for supplementary gestures. Instead, Kirchner's account is compared to other possible analyses—one involving dissimilation as a motivation, the other involving neutralization avoidance (Subsections 5.3 – 5.5). This section also sets out the design for two experiments that can help decide between these competing analyses (Subsections 5.6 and 5.7). The line of research that we propose accounts for certain generalizations about debuccalization that are not captured by previous analyses.

The final two sections wrap up the investigation. Section 6 attempts to answer the question of why debuccalization happens at all (as opposed to simple deletion). Section 7 concludes.

2 What is debuccalization?

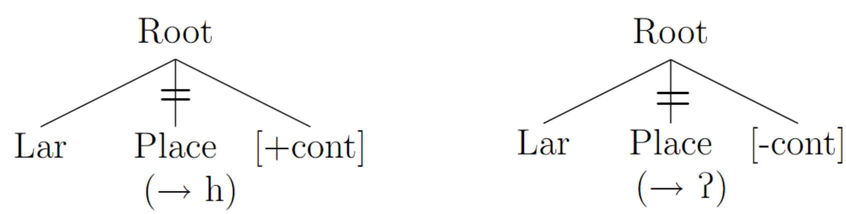
2.1 Defining aspects of debuccalization

Debuccalization is often defined as the loss of place of articulation. In other words, some consonant no longer has any obstruction or gesture in the oral tract, and the sound that results is a laryngeal consonant ([h], [ɦ], or [ʔ])[1]. The remaining sound could also be characterized as the addition of voicelessness, breathy voice, or creaky voice on an adjacent vowel, as opposed to a fully-fledged laryngeal consonant. Some authors (for instance, de Lacy 2002) discuss the debuccalization of nasal consonants to [N], the so-called phonologically placeless nasal, often realized phonetically as [ŋ], [ɴ], or a nasalized off-glide. Nasal absorption (VN → Ṽ) may also fall under the purview of debuccalization, if not in name than at least in spirit. For the present study, we will mostly assume the more restrictive definition of reduction to a laryngeal consonant. This is so we can narrow our investigation and be compatible with as many definitions as possible.

We will generally be discussing debuccalization in terms of gestural loss. Of course, the removal of oral gestures does not mean that the oral tract is doing nothing. For instance, when there is an intervocalic [h], the tongue is still performing the gestures of the previous and following vowels. From the point of view of Articulatory Phonology (Browman & Goldstein 1986), debuccalization is the loss of oral gestural *targets*, not the loss of all gestures. The consonant [h] does not provide an oral target, but there is still oral movement, which is the interpolation of oral targets for preceding and following sounds (c.f. Beckman & Pierrehumbert 1986 for tonal patterns in Japanese).

From a feature geometry perspective, debuccalization involves delinking some node (usually Place), while retaining the features associated with laryngeal specification (McCarthy 1988, who cites Goldsmith 1981 and Clements 1985). Iverson 1989 argues that fricatives debuccalize to [h], because what is left is the Laryngeal node and [+continuant]. The Lar node and [+cont] is sufficient to characterize [h], and so no further features need be added. Stops, on the other hand, debuccalize to [ʔ], because what remains is Lar and [-cont].

(1)



(figures adapted from Padgett 1995)

The strong version of this claim (that all fricatives only debuccalize to [h], and all stops only debuccalize to [ʔ]) is falsified by the typological survey in Section 3. However, in this paper we will agree with Iverson 1989 that the *default* debuccalization pattern[2] for most

[1] Gildea 1995 includes the velar fricative [x] as a possible outcome of debuccalization. This is generally not called debuccalization in the literature, so I assume this is done for ease of analysis of the Cariban data.

[2] *Default* here means that there are no mitigating constraints that would change the debuccalized form. A primary focus of this paper is to investigate what happens when debuccalization results in a laryngeal sound that is unexpected if we simply deleted oral gestures (i.e. non-default debuccalization).

fricatives is to [h], as [h] is the result of removing oral gestures and leaving laryngeal ones alone. We will disagree with Iverson's claim that plain stops debuccalize in the default case to [ʔ]—instead we argue that the default is usually [h]. Our view makes similar predictions to Padgett 1995, another feature geometric analysis. This is because, in Padgett's system, debuccalization involves delinking of a Place node that also includes [cont] and [cons] features.

This brings up an important distinction between the deletion of oral gestures and the deletion of oral features. In the arguments that follow in this paper, we will be viewing default debuccalization as loss of oral gestures.[3] In deletion of oral features, however, there appears to be more disagreement over exactly what should be deleted in default debuccalization. It could be the Supralaryngeal node (Clements 1985), the traditional Place node (McCarthy 1988, Iverson 1989), or the Place node with stricture features (Padgett 1995). Debuccalization can even involve more complicated feature manipulation—for Lass 1976, debuccalization involves copying the [cont] feature from the oral submatrix of features onto the laryngeal submatrix of features, followed by the deletion of the oral submatrix. These different points of view mostly revolve around whether we want [cont] to have a say in the default rule of debuccalization. It is our hope that the gestural view of default debuccalization provides a principled way to decide this. That is, the preservation of continuancy from non-lenited form to lenited form is not the real issue. Rather, the question of whether or not default debuccalization should result in a continuant should only take into account the laryngeal gestural score of the non-lenited form.

2.2 Lenitions that look like debuccalization, but aren't

There is some literature (Browman & Goldstein 1995, Sproat & Fujimura 1993) on consonantal weakenings of nasals and liquids that resemble debuccalization rather closely, but these papers have not been incorporated into the general discussion of debuccalization and lenition in the literature. For these authors, working in the framework of Articulatory Phonology, the timing of various articulatory gestures depends on syllabic position. For all the segments under consideration, there is a consonantal gesture (the gesture which is associated with a closure in the oral cavity, like the tongue-tip gesture of /l/) and a vocalic gesture (tongue-body gesture or velum-lowering gesture). These gestures are closely aligned in onset position (in terms of simultaneity), but in coda position the vocalic gesture tends to occur first, and the consonantal gesture tends to weaken in addition to being timed later. This type of misalignment and weakening looks a lot like debuccalization, and it may be closely related. However, the explanation given in Sproat & Fujimura 1993 cannot account for all debuccalization processes, because, as we will see, many of those processes occur intervocalically. According to their analysis, intervocalic position should be an excellent place for the timing of multiple gestures.

[3]More precisely, the unfaithful mapping of oral gestures in the gestural score of the input, where the input oral gestures correspond to no gestures in the output form.

2.3 Just adding gestures is not debuccalization

Many varieties of English have a phenomenon called glottal reinforcement[4], where voiceless stops become reinforced by a glottal closure gesture. This is not a case of debuccalization, because it involves the *addition* of laryngeal gestures without the concomitant removal of oral ones. As such, a glottally reinforced stop consonant does not appear to be a case of debuccalization (nor a case of lenition in general, depending on your point of view). Note, however, that a glottally reinforced stop can serve as the input to debuccalization ([ˀt] → [ʔ]), although it doesn't have to. See Milroy et al. 1994 for evidence that glottal reinforcement and glottal replacement are distinct processes in some British varieties of English, both historically and sociolinguistically.

3 Typological survey of debuccalization processes

The following tables and related examples provide an overview of the typology of debuccalization processes. Most of the data is from Lavoie 1996 and de Lacy 2002, who both provide tables of debuccalization processes. For all tables, * indicates that source is via Lavoie 1996, ♯ indicates that source is via Gurevich 2004 (often correcting entries from Lavoie 1996), and †indicates source is via de Lacy 2002.

[4]This phenomenon has many other names, including the ambiguous name 'glottalization'. To maintain clarity of discussion, we will use the terms 'glottal replacement' ([t] → [ʔ]) and 'glottal reinforcement' ([t] → [ˀt]). The terminology is relatively inconsistent, but within the literature this is the most clear terminology that I have come across.

3.1 Examples of debuccalization processes to [h]

Language	Reference	Debuccalization pattern
Ainu	Poser 2001	p t k tʃ ɾ → h in coda position
Ainu	Vovin 1993*	*g > h
Awa	Loving & Loving 1966 via Smith 2007	obstruents → h in coda position (static generalization?)
Babine	Story 1984*	x > h stem-finally
Canela-Krahô	Popjes & Popjes 1986*	j x > h initially
English (Scots)	Lass 1976	θ → h intervocalically (optionally)
Florentine Italian	Giannelli & Savoia 1979 via Kirchner 2001	k → h (younger speakers, moderate speech rate, between vowel and liquid/vowel)
Gondi	Tyler 1975*	consonants > h intervocalically
Irish	Padgett 1995	s t → h (environment unclear)
Japanese	Shibatani 1990	s p → h initially and intervocalically
Kannada	Schiffman 1983*	p > h word-initially
Kashaya	Buckley 1997	q qw → h in coda position
Kirundi	Goldsmith 1990	voiceless stops → h after nasals
Liverpool English	Watson 2001	t → h after short, unstressed vowels (monosyllabic words must be function words)
Miami (Illinois)	Costa 1991*	s x θ ʃ tʃ ç > h before voiceless stops
Middle Chinese	Pulleyblank 1984*♯	χ > h (Southern dialects)
Navaho	Kari 1976*♯	x → h medially
Nepali	Bandhu & Dahal 1971♯	ts^h → h intervocalically
Oscan and Umbrian	Buck 1904*	k p > h before t
Pipil	Campbell 1985*	w → h word finally and before C
Proto-Greek	Sommerstein 1973*	s > h before V
Páez	Gerdel 1985*♯	x → h everywhere except between /k/ and /i i̯/, optional word-initially
Sanskrit	Whitney 1889	s r > h finally (possibly syllable-finally)
Slave	Rice 1989 via Smith 2007	consonants → h in coda position
Spanish (Latin American)	Lipski 1984*	s → h intervocalically and word-finally in polysyllabic words
Spanish (Penin. dialects)	Morris 2000	s → h in coda position before [-voi] or [+son] sounds (other dialects: s → preaspirated geminate, s → geminate)
Tiriyó	Meira 2001	obstruents > h in coda position (all obstruents are voiceless)
Yoruba	Akinlabi 1992	w j → h before nasalized homorganic vowels
Yucatec Maya	Lombardi 1990	stops → h before homorganic stops and affricates

3.2 Examples of debuccalization processes to [ɦ]

Language	Reference	Debuccalization pattern
Florentine Italian	Giannelli & Savoia 1979 via Kirchner 2001	g → ɦ in fast speech (between vowel and liquid/vowel)
Ukrainian	Czaplicki 2006	ɣ → ɦ in onset position

3.3 Examples of debuccalization processes to [ʔ]

Language	Reference	Debuccalization pattern
Arbore	Harris 1990♯	ejective and implosive stops → ʔ before non-identical consonant (optionally)
Arekuna Carib	Edwards 1978†	k → ʔ in coda position
Burmese	Lass 1976	p t k tʃ > ʔ word-finally
English (British)	Milroy et al. 1994*	t → ʔ intervocalically and sometimes prelaterally
English (Cockney)	Andrésen 1968*♯	voiceless stops → ʔ intervocalically and before n m l
English (London, Leeds & Fife)	Harris 1990♯	t → ʔ word finally
Ethiopian Semitic languages	McCarthy 1988	p’ t’ k’ → ʔ (environment unclear)
Indonesian	Lapoliwa 1981	k → ʔ in coda position
Kagoshima Japanese	Kaneko & Kawahara 2002	stops and affricates → ʔ (and nasals → N) in coda position
Kashaya	Buckley 1994†	plain stops → ʔ in coda position (but this might be wrong, see Buckley 1997)
Makassarese	Aronoff et al. 1987†	k → ʔ in coda position
Muher Gurage	Rose 2000	ejective k’ → ʔ post-vocalically
Tahitian	Coppenrath & Prévost 1975†	k > ʔ
Takelma	Sapir et al. 1922 via Linguist List message (Paul Fallon)	k’ k^{w}’ → ʔ before x
Tauya	MacDonald 1990♯	k k^{w} → ʔ $ʔ^{w}$ non-initially
Toba Batak	Hayes 1986♯	p t k → ʔ before consonants
Ulu Muar Malay	Hendon 1966†	stops → ʔ in reduplicant codas
West Tarangan	Nivens 1992*♯	k → ʔ intervocalically (word-internally where both vowels are non-high, fast speech)
Yamphu	Rutgers 1998†	t → ʔ in coda position (but assim. to following obstruents)

3.4 Additional examples

The following examples are attested debuccalization patterns, but for various reasons they are difficult to add to the tables above. The examples in (2) lack environments, they all come from Austronesian languages, and the examples come from an unpublished source. The examples in (3) do have an environment, but it is a difficult one to describe—Gildea 1995 uses historical reconstruction to account for the seemingly strange environment. Because the analysis of one Cariban language depends on the others, I have left them together in one place. Likewise, the examples in (4) are very closely related to each other, so separating them into different tables would obfuscate a generalization.

(2) Gess 2009 cites Nivins (p.c.), who cites Blust 1990, in giving many languages that have k-glottalization: Dobel, Lola, Yalahatan, Fordata, Luang, Kisar, Hawaiian.

(3) Cariban languages, when a suffix begins with -CV (e.g. -CV, -CVC, -CVCV), and the suffix is added to a final consonant[5] (from Gildea 1995):

a. Hixkaryana: some instances of k and ʃ → h
b. Makushi: at least some obstruents → h, ʔ (depending on source)
c. Panare: obstruents (p t k tʃ s) → h (ʔ before nasals)
d. Apalaí: at least some obstruents → ʔ
e. Carib: obstruents → h (ʔ before nasals)
nasals → ʔ before nasals

(4) Klamath (Barker 1964 via Clements 1985)

a. l̥ → h after n and l
b. l’ → ʔ after n and l

Finally, there are the debuccalization sound changes in (5). These sound changes are represented in Lass 1976 as a long list with example words after each change. As such, I thought it best to do the same here, so as to show the proto-language and the attested derived language, and also to keep the proto-languages together. Furthermore, for some of the underlying representations in the proto-languages (namely Proto-Indo-European */ǵʱ/ and Proto-Dravidian */c/), the transcription system makes it unclear what the exact description of the UR sounds should be. Therefore, the data is given in a single place, with the warning that it is repeated more or less directly from Lass 1976.

(5) From Lass 1976

a. Proto-Indo-European */p/ > Armenian h initially
b. Proto-Indo-European */ǵʱ/ > Latin h
c. Proto-Indo-European */s/ > Iranian h
d. Proto-Indo-European */s/ > Brythonic Celtic h (most frequently initially)
e. Proto-Indo-European */k/ > Germanic h initially
f. Proto-Indo-European */ǵʱ/ > Sanskrit ɦ
g. Proto-Uralic */k/ > S. Ostyak h, Hungarian h, Yurak h initially
h. Proto-Uralic */tʃ/ > Finnish h initially

[5] The environment is not this simple, because there are complications that result from syncope and from the historical basis of this environment.

i. Proto-Uralic */ʃ/ > Finnish h initially
j. Proto-Uralic */k/ > Yurak, Yenisei Samoyed h intervocalically
k. Proto-Dravidian */p/ > ɦ in Brahmin dialects of Kannada initially
l. Proto-Dravidian */c/ > h in Pengo, Kuvi
m. Proto-Dravidian */k/ > h in Manda, Kui initially

4 More background on debuccalization

4.1 Is debuccalization a unified phenomenon?

Other than the definitions given in Section 2, is there anything else uniting debuccalization processes? Any overarching generalizations or implicational universals? The environment for debuccalization does not appear to be the key. That is because debuccalization processes occur in all sorts of environments—word-initially (Kannada), word-finally (Pipil), intervocalically (Páez), in coda position (Indonesian), and before and after various other sounds.

Lavoie 1996 gives a few generalizations that we may comment on:

> "Except for glides and one instance of [g], all of the debuccalized stops or fricatives were voiceless. Some glides, such as [j], may be debuccalized. Fricatives usually become [h]. The voiceless velar fricative very frequently debuccalizes. All of the segments that debuccalized to glottal stops were stops to begin with." (p. 290)

The tables above are expanded versions of Lavoie's tables, providing us with more evidence to support or disconfirm Lavoie's generalizations. We have another example of [g] debuccalizing, but this time to [ɦ] (Florentine Italian). There are other examples of voiced sounds debuccalizing—Ainu *[g] > [h] and /ɾ/ → [h], Sanskrit [r] > [h], and Ukrainian /ɣ/ → [ɦ]. Even so, the new evidence supports the claim that voiceless sounds debuccalize much more frequently than voiced sounds. The other generalizations still hold—stops and fricatives become [h], but stops are the only sounds that debuccalize to [ʔ].[6] Lavoie points out that [x] debuccalizes frequently, but the fact of the matter is, [k] also frequently debuccalizes, as do other velars ([g], [ɣ]).

One way to investigate the properties of debuccalization is to follow these generalizations. If there can be a unified explanation for why debuccalization processes across the world's languages pattern this way, that serves as possible evidence for debuccalization as a unified phenomenon. If there fails to be a unified explanation, then perhaps debuccalization is simply an externally defined category, a grab-bag of sound changes and alternations that appear on the surface to be the same, but are in fact mostly unrelated.

Smith 2007 proposes that lenition can be divided into two basic types. The first type involves a segment becoming less marked, and generally affects coda consonants ("neutralization-to-the-unmarked" lenition). The second type of lenition involves segments becoming more

[6] In the related languages of Panare and Carib, we find fricatives debuccalizing to [ʔ]. However, they only do so before nasal stops, which supports the weaker claim that fricatives do not debuccalize to [ʔ] unless assimilating to nearby (oral or nasal) stops.

sonorous (and possibly more marked), and this type generally applies intervocalically ("sonority-increasing" lenition). A segment like [h] can be interpreted as a high sonority consonant, in line with its view as a glottal glide or a voiceless vowel. It could also be interpreted as being of lower sonority, because it has frication noise and sometimes patterns with fricatives. To give Smith's approach the benefit of the doubt, we will treat glottal segments as highly sonorous for the time being (see Mielke 2005 for discussion on the ambiguity of segments like /l/ and /n/). Debuccalization appears to make consonants less marked *and* more sonorous, compatible with either lenition type. If the debuccalized segment is more sonorous than the oral segment it replaces, then either explanation could hold. From this perspective, the type of a debuccalization process depends strictly on the environment and the proposed motivation for the process. Assumedly, coda debuccalization is neutralization-to-the-unmarked, while intervocalic debuccalization is sonority-increasing.[7]

This proposal can be falsified in two ways: (a) there is debuccalization in a strong position that is not also intervocalic or intersonorant, or (b) there is debuccalization in intervocalic position that *decreases* sonority. Both of these types of falsifications appear to be attested in the tables above, although there is only one example of type (b), and it is not a very clear-cut example at that.

(6) a. Debuccalization in a strong position (non-intervocalic):

Kannada	p > h word-initially
Canela-Krahô	j x > h initially
Ukrainian	ɣ → ɦ in onset position

b. Debuccalization in intervocalic position that decreases sonority:

Yoruba	w j → h before nasalized homorganic vowels (not nec. intervocalically)

Based on the attested examples of debuccalization patterns above, it appears that Smith 2007's division of lenition processes cannot apply to all examples of debuccalization. In particular, some types of debuccalization occur in strong positions, yet look like they should be motivated by general markedness.

4.2 Perceptual data on debuccalization to [ʔ]

In a perceptual study I conducted (O'Brien 2010), stop consonants at three places of articulation ([p], [t], and [k]) were compared to glottal stop in terms of confusability. The results showed that the pair [t ʔ] was more confusable than [p ʔ]. The pair [k ʔ] was between the other two pairs in confusability (but not significantly so). This led to a prediction that debuccalization processes where [p] becomes [ʔ] should be rare, while processes turning [t] or [k] to [ʔ] should be more common. The table in 3.3 confirms this prediction—some glottal replacement processes target [t] or [k], some processes target all stops and affricates, but no such process targets [p] to the exclusion of other stops. (We should not be surprised that

[7]If we fail to give Smith 2007 the benefit of the doubt when it comes to the sonority of [h], then we end up with a situation where [h] is decreasing in sonority in a strong position. Thus, those varieties of debuccalization would fail to be categorized in *either* of Smith's lenition types.

some processes affect [p] in addition to other stops, because of the possible explanations of analogical leveling of stop series, and the fact that the prediction from the perceptual study is due to *relative* confusability, not absolute confusability.)

These results provide support for the idea that debuccalization processes are influenced by perception. As such, the three competing analyses of supplementary gestures in Section 5 are oriented towards perceptual differences.

4.3 Initial motivation vs. synchronic formalism

Kirchner 2001 and Bauer 2008 provide discussion about the distinction between initial motivation for a sound change or alternation, and the later development of that process over generations of speakers. Bauer explains this with an example: In a sound change of the type [d] > [ð], the first generation of speakers fail to achieve the stop closure target for [d], hence the initial motivation makes for a lenition process under his definition. Subsequent generations, argues Bauer, analyze the [ð] as the actual target. This means that the change to [ð], which requires more precise motor control and therefore may be seen as a more difficult segment, is *motivated* by articulatory ease but does not always *result* in articulatory ease.

This view becomes more difficult when attempting to account for synchronic alternations. Kirchner, for instance, uses requirements of articulatory ease as a synchronic motivation for alternations within an OT grammar. Explanations like Bauer's are unavailable to such an analysis—if [ð] is more difficult to *reliably* produce than [d], and the grammar controls such a reliable alternation, then articulatory ease alone cannot account for the alternation. This is not necessarily a problem for Kirchner, however. In his mass-spring model of articulation, fricatives like [ð] are more articulatorily efficient than stops like [d].[8] If we had a clear metric for articulatory ease, then the difference between Kirchner 2001 and Bauer 2008 could be empirically evaluated. As it stands, Kirchner's mass-spring model is the closest thing we have to verification.[9]

It might turn out that all debuccalization processes (and all lenition processes in general) are rooted in articulatory underachievement—this is the hypothesis put forward by Bauer 2008. But it is definitely not the case that all debuccalization processes *are* articulatory underachievement. Some supplementary articulation is often added, either in the initial development of debuccalization processes, or in its eventual evolution. If this is correct, there might be interesting implications for synchronic analysis of debuccalization phenomena. "New" debuccalization processes, those that have not strayed very far from simple articulatory underachievement, should easily be captured by using models that incorporate articulatory difficulty (Kirchner's model, Quantal Theory of Speech, etc.). The older the debuccalization process, the more "cruft" it would have the opportunity to accumulate—generations of speakers reanalyze the input to come upon different articulatory targets and

[8] However, stridents like [s] are *less* efficient than [ð]—Kirchner assumes "that strident fricatives (Figure 4-2) require a relatively precise, sustained close constriction, in order to generate highly turbulent airflow" (p. 111, 1998 ms.). This enables the analysis to capture the fact that stops never lenite to stridents without first affricating. For exact values of articulatory efficiency in Kirchner's analysis of Florentine Italian, see pp. 271−272, 1998 ms.

[9] Moreover, because Spanish spirantized obstruents are often transcribed as open fricatives or approximates, the question of the precision of the articulatory target is also up for debate.

different generalizations, and this telescoping is not what simple articulatory underachievement predicts.

When analyzing synchronic alternations, we will assume that the drive to minimize articulatory effort is the impetus for debuccalization. Such an assumption privileges "new" debuccalization processes over "old" ones, but it is necessary to get the analysis off the ground.

5 Not just removing oral gestures

5.1 Introduction

We have defined debuccalization as the removal of oral gestures, without much being said about the addition of other gestures. Kirchner 2001, however, provides evidence that some debuccalization processes involve supplementary gestures, in addition to the simple removal of oral gestures. Viewing debuccalization as a phenomenon from this perspective allows us to explain some of the generalizations from a typological survey of debuccalization processes. This approach also brings up the question as to what precisely motivates the inclusion of these supplementary gestures. As such, the explanation given in Kirchner 2001, based on perceptual feature faithfulness, is compared to other possible explanations, which are based on dissimilation from neighboring sounds or the need to avoid neutralization.

5.2 The setup

Some examples of debuccalization can be analyzed as the simple removal of oral gestures. For example, in some varieties of American English there is variation between a pre-glottalized voiceless alveolar stop [ˀt] and a glottal stop with no alveolar closure [ʔ]. The difference between these two sounds can be seen as removing an oral gesture: [ˀt] debuccalizes to [ʔ] by losing all oral gestural targets.

However, for most alternations the picture is not as simple. For an alternation with glottal stop and a **non**-pre-glottalized stop (for instance intervocalic English [t] or West Tarangan [k]), it is not obvious what the sound would be like if there were no oral gestural targets. If we take the sequence [ata] and remove all oral gestures from the gestural score, then the result would be vocal fold vibration (voicing), followed by some amount of voicelessness[10], followed by more vocal fold vibration. For a voiced sound like [d], it appears that the sound that would result from a lack of oral gestures would simply be voicing (i.e. intervocalic [d] would not be a segment at all if its oral gestures were eliminated). In the environment of being adjacent to voiced segments, voiced consonants should "debuccalize" to zero, and voiceless sounds should debuccalize to [h] by default. However, if a voiced sound is voiced with breathy voicing (as Gess 2009 argues for [ɣ]), then [ɦ] would be the result of losing oral gestures. Any other type of debuccalization must be the result of something different from (or in addition to) the simple removal of oral gestural targets.

[10]Because the vocal folds during [t] are usually spread apart (Keating 1988), then it is likely that [t] without oral gestures is [h]. (See also Browman & Goldstein 1986.)

(7) Working hypothesis of default debuccalization:
Assuming that effort minimization is the cause of debuccalization, then, all things being equal, the result of debuccalization should be the same as removing oral gestures (usually [h]). If this is not the case, and there is a laryngeal gesture that is not in the original consonant, then this supplementary gesture must be there for some grammatical reason.

This line of reasoning may be the answer to many of the typological generalizations given in Section 4. If a non-glottalized sound is going to debuccalize to [ʔ], there must be a reason for the supplementary stop gesture (otherwise, the default debuccalization would be to [h] or [ɦ]). If the original sound is a stop, then this might be sufficient reason for a supplementary gesture of glottal closure. Fricatives or glides would not have sufficient reason to add such a glottal closure, therefore only stops debuccalize to [ʔ]. If a voiced sound loses oral gestures, then the voiced sound would debuccalize to zero unless there is a reason for it not to. This helps explain why debuccalization frequently targets voiceless sounds—in the default case, voiceless sounds debuccalize, but voiced sounds delete ("debuccalize" to zero) unless there is a reason not to. Debuccalization's strong tendency to target voiceless sounds in turn explains why it targets obstruents, due to the dearth of voiceless sonorants.[11]

Formalizing this concept in Optimality Theory is difficult, however, because there can be no single, well-behaved OT constraint that does the job of blindly removing oral gestures. Instead, we must formalize supplementary gestures slightly differently. Some constraint or family of constraints is responsible for leniting the consonant—in the present analysis, Kirchner 2001's Lazy constraint against articulatorily difficult sounds plays this role. If a consonant debuccalizes, that means that oral gestures fail to be faithfully articulated. As such, faithfulness to oral gestures must be low. On the other hand, because there is no deletion, the laryngeal gestures may be more faithfully mapped to the output. The working hypothesis of default debuccalization in (7) puts forward faithful mapping of laryngeal gestures as a default.

This OT formulation treats debuccalization just like any other lenition process. Effort minimization constraints require the sound to be easy to articulate, and other faithfulness and markedness constraints make further demands on the output consonant. As the typology in Section 3 and the discussion in Section 4 suggest, the class of debuccalization processes is heterogeneous and difficult to systematize. Therefore, the OT treatment of debuccalization (as "nothing special") is compatible with our understanding of debuccalization as a diverse grouping of processes.

As stated above, Kirchner 2001 argues that certain examples show that supplementary gestures must be added (pp. 120–123, 1998 ms.).[12] In Florentine Italian /g/ can be realized as [ɦ] (acquiring a breathy-voicing gesture, according to Kirchner), and in many English varieties intervocalic /t/ is realized as [ʔ] (acquiring a glottal closure gesture). Kirchner be-

[11]Some of these explanations are only compatible with one of the analyses proposed below, namely that of feature faithfulness.

[12]Kirchner 2001 may not have been the first to argue that debuccalization processes are sometimes accompanied by further modifications. Padgett 1995 cites an unpublished manuscript, Bessell 1993, which argues that some cases of debuccalization cannot be attributed to the laryngeal specification of the original consonant.

lieves that the supplementary gestures are added for perceptual reasons, so that the lenited form will sound more like the non-lenited one. This is not the only logically possible explanation, however, and below we explore how to evaluate this claim and other claims that could explain supplementary gestures.

5.3 Three analyses

Let's use Kirchner 2001's Florentine Italian g-debuccalization case. If you remove the velar constriction gesture of [g], the result is a vowel—continuous voicing with no gestural target for the oral articulators.[13] But the debuccalization process in Florentine Italian adds a supplementary gesture of slight glottal abduction to get breathy voicing. Kirchner believes this is to make the resulting sound more like [g], in terms of "satisfying perceptually based faithfulness constraints" (p. 121, 1998 ms).[14] I refer to this as the "feature faithfulness analysis". According to Kirchner, lenition in general and debuccalization in particular is "more accurately characterized as substitution of a less effortful set of gestures, the selection of which is constrained by the hierarchy of active faithfulness and fortition constraints under a given grammar" (p. 123, 1998 ms). Because fortition presumably is not involved in the debuccalized form, this leaves the grammar's faithfulness constraints to be the source of choosing supplementary gestures.

(8) Feature faithfulness analysis:
All supplementary gestures in debuccalization processes are there due to feature faithfulness constraints. These constraints demand the presence of certain features which have the supplementary gesture as their phonetic correlate.

This general idea is the view taken by the great majority of recent work on lenition, especially among analyses couched in OT. However, it is not the only logically possible motivation; the supplementary gesture could be added for other reasons.

Perhaps there is a constraint at play that forces the sound to be different from the vowels around it (independent of the resulting sound being more like [g] or less like [g]). Then, [ɦ] would be one possible laryngeal segment that is in some respects different from the surrounding vowels. Under this view, the supplementary glottal gesture wasn't added to make the resulting sound more like [g], but rather to make it less like the vowels around it. Moreover, this drive to make the lenited [g] less like its neighboring vowels could be driven by a need to maintain prosodic structure, allowing for weakening but keeping the CV structure of the non-lenited form intact. This line of reasoning will be referred to as the "dissimilation analysis".

(9) Dissimilation analysis:
All supplementary gestures in debuccalization processes are there to make the debuccalizing sound differ more from its surrounding sounds.

[13] Ignoring for the time being Gess 2009's criticisms of this view.

[14] In his tableaux, this particular example is not fleshed out because [ɦ] is the most articulatorily efficient form in any position, except for zero. Presumably, the active constraint is something like Ident[CV]. This example shows the intersection of the three hypotheses described here, and this intersection will be dealt with below.

The dissimilation analysis above is syntagmatic in nature, with the basis of comparison being the segments in the immediate environment. An alternative proposal would be more paradigmatic in nature. The drive to add supplementary gestures comes from a need to maintain phonemic contrast and avoid neutralization. This analysis is the "neutralization avoidance analysis".

(10) Neutralization avoidance analysis:
All supplementary gestures in debuccalization processes are there to prevent the debuccalized consonant from neutralizing with another phoneme in the language.

All three analyses are, in principle, possible accounts for supplementary gestures. In the following subsections, we will evaluate them by formalizing them in Optimality Theory and comparing the predictions they make for languages. The rest of this section also includes experimental designs that are intended to provide support for one analysis over another.

5.4 Comparing the analyses with an example: Indonesian coda k-debuccalization

To make the comparison of these three analyses more concrete, we will use the example of Indonesian coda k-debuccalization. This example demonstrates how each analysis uses different motivations for the supplementary glottal stop gesture, and it further demonstrates the different predictions the analyses make.

All three analyses, at least in their incarnation here, have several commonalities. They are all formalized in Optimality Theory, and the motivation for reducing coda /k/ is the same—a markedness constraint assumed to be rooted in effort minimization. This is not completely transparent, however, because only the voiceless velar stop is affected. The other consonants fail to participate in the debuccalization process. Below is a consonant inventory for consideration.

Indonesian consonant inventory, adapted from Lapoliwa 1981

	Labial	Alveolar	Palatal	Velar	Glottal
Plosive	p b	t d		k g	ʔ
Fricative	(f)	s (z)	(ɕ)	(x)	h
Affricate			tɕ dʑ		
Nasal	m	n	ɲ	ŋ	
Liquid		l r			
Approximant	w		j		

Segments in parentheses indicate loan-phonemes

There are many ways to allow debuccalization of /k/ but prevent it for other segments, but the direction pursued here is to assume faithfulness to other places of articulation, faithfulness to voiced segments, and faithfulness to loan-phonemes. To prevent debuccalization in onset position, we also assume a positional faithfulness constraint (Beckman 1998). With these faithfulness constraints in place, a general-purpose effort-minimization constraint like Kirchner 2001's Lazy constraint can successfully target just coda /k/.

(11) Faithfulness to other places of articulation

/selamat/			Ident[cor]	Lazy
a.	☞	selamat		*
b.		selamaʔ	*!	

(12) Debuccalization for /k/

/tidak/			Ident[cor]	Lazy
a.		tidak		*!
b.	☞	tidaʔ		

The other shared assumption of these analyses involves the articulatory difficulty of the different debuccalization options. Kirchner 2001 provides effort values for various segments in weak positions. As such, we can assume that [k] is the most difficult, [x] is less difficult, and [h] is the easiest to articulate. Kirchner provides no effort values for [ʔ], so we will assume it is more effortful than [h] but still relatively easy. This assumption is compatible with the explanation of supplementary gestures given above. The sound [h] is taken to be the result of removing oral gestures from /k/, while [ʔ] involves some additional articulatory gesture. This gives the partial hierarchy of articulatory difficulty:[15]

(13) k > x > ʔ > h > ∅[16]

In the tableaux below, the constraint Lazy will only evaluate the final consonant (e.g. it will not penalize an initial [t]). Lazy assigns five violations to [k], four to [x], and so on down the hierarchy. Kirchner 2001 uses a similar reckoning system for Lazy in the first few chapters of the dissertation. In later chapters, he uses a family of Lazy constraints that allows for other constraints to be ranked between Lazy constraints—like Kirchner, I will use the simpler system unless the family of constraints is called for.

Formalizing the concept of default debuccalization in Optimality Theory is difficult, because there can be no single, well-behaved OT constraint that does the job of blindly removing oral gestures. Instead, we must formalize supplementary gestures slightly differently. Some constraint or family of constraints is responsible for leniting the consonant—in the present analysis, Kirchner 2001's Lazy constraint against articulatorily difficult sounds plays this role. If a consonant debuccalizes, that means that oral gestures fail to be faithfully articulated. As such, faithfulness to oral gestures must be low. On the other hand, because there is no deletion, the laryngeal gestures may be more faithfully mapped to the output. The working hypothesis of default debuccalization in (7) puts forward completely faithful mapping of laryngeal gestures as a default. Under this view, supplementary gestures are those gestures that *cannot* be explained by faithfully mapping laryngeal gestures to the output. For the feature faithfulness analysis, supplementary gestures are caused by *feature* faithfulness, as seen in the tableau below.

[15] A more complete hierarchy, that takes into account all of the segments explored in the perceptual experiment (Subsection 5.6), would be k > g > x > ɣ > ʔ > h > ɦ > ∅. Some of these effort values come from Kirchner 2001. According to Kirchner, [ɣ] and [h] have the same articulatory difficulty, but here we separate them and place between them [ʔ] (which he does not give an effort value for).

[16] This symbol is used to indicate the absence of a consonant.

(14) Feature faithfulness analysis of Indonesian

	/tidak/	Pres(cont)	Lazy
a.	tidak		***!*
b.	tidax	*!	***
c. ☞	tidaʔ		**
d.	tidah	*!	*
e.	tida	*!	

The faithfulness constraint in the feature faithfulness analysis is taken to be Pres(cont), a constraint that is violated whenever the feature [-continuant] of /k/ is not faithfully realized as such on the segment corresponding to /k/. It is also violated if the segment is outright deleted (as in candidate e). With Pres(cont) leaving only candidates a and c, Lazy is able to decide in favor of the less effortful glottal stop. The generalization that comes from this constraint interaction is that, if you are going to debuccalize, debuccalize to the most articulatorily efficient consonant possible that is still faithful to the [cont] feature.

Next, we look at the dissimilation analysis:

(15) Dissimilation analysis of Indonesian

	/tidak/	$*V_{[+cont]}C_{[+cont]}$	Max	Lazy
a.	tidak			***!*
b.	tidax	*!		***
c. ☞	tidaʔ			**
d.	tidah	*!		*
e.	tida		*!	

In the dissimilation analysis, the constraint in charge of making sure the final /k/ and the preceding vowel are dissimilar enough is $*V_{[+cont]}C_{[+cont]}$, which is violated when vowels are followed by [+continuant] consonants. This constraint may not be the best way to formalize the general idea of dissimilation being the cause of supplementary gestures, but it works for the example here. The dissimilation markedness constraint, in combination with Max, ends up doing the same work that Pres(cont) does for the feature faithfulness analysis.

Finally, the neutralization avoidance analysis of Indonesian k-debuccalization is given below.

(16) Neutralization avoidance analysis of Indonesian

	$/tak_1\ tah_2\ ta_3/$	*Merge	Lazy
a.	$tak_1\ tah_2\ ta_3$		****! *
b.	$tax_1\ tah_2\ ta_3$		*** *!
c. ☞	$taʔ_1\ tah_2\ ta_3$		** *
d.	$tah_{12}\ ta_3$	*!	*
e.	$ta_{13}\ tah_2$	*!	*

The tableau for the neutralization avoidance analysis uses *Merge (Padgett 2003) to prevent the merger of /k/ with that of /h/ or ∅. *Merge is a constraint from Padgett 2003's modified version of Dispersion Theory. As such, the tableau above evaluates multiple forms at the same time. The words /tak$_1$ tah$_2$ ta$_3$/ are not necessarily lexical items of the language, but rather are abstract representations of possible words in Indonesian. Candidate a realizes all forms faithfully, resulting in many violations of LAZY. Candidate b reduces /k/, but not as much as candidate c does. Candidates d and e result in the neutralization of phonemes, and therefore are ruled out by high-ranking *MERGE. Candidate c is the winner because it reduces /k/ as much as it can without causing neutralization.

For this analysis to successfully account for the debuccalization phenomenon, *MERGE must not care about /k/ merging with the loan-phonemes /x/ and /ʔ/. It must care only about /k/ merging with the native phoneme /h/ or deleting (merging with the absence of a consonant). For this reason, the tableau does not evaluate underlying forms like /tax/ or /taʔ/. The evaluation of such forms is the role of some other stratum of the grammar.

5.5 Falsifying the analyses

If these analyses are sufficiently useful to us as explanations, then some type of experimental or typological information should be able to verify or falsify them. Below are some ways in which the analyses could be falsified.

(17) To falsify the feature faithfulness analysis:

   a. find an example of a debuccalization process where the supplementary gesture[17] corresponds to no features from the non-lenited form. OR,
   b. find an example where the OT faithfulness constraints and ranking necessary to choose the supplementary gesture candidate are inconsistent with the rest of the grammar.

(18) To falsify the dissimilation analysis:

   a. find an example of a supplementary gesture that, rather than making the sound *less* like the surrounding sounds, makes the resulting sound *more* like them, by some consistent metric of similarity.

(19) To falsify the neutralization avoidance analysis:

   a. find an example where the supplementary gesture in the debuccalized consonant fails to prevent a merger with another phoneme.

Although we might not have all the information available, we can evaluate some of the above falsifications using the typology of debuccalization given in the tables in Section 3. This assumes that each hypothesis can explain *all* of the debuccalization processes. It might turn out that which explanation is correct is language dependent, but that makes falsification much more difficult.

First, a list of supplementary gestures from our typology:

(20) Sounds where a supplementary h-like gesture is added

   a. Ainu g > h
   b. Ainu ɾ → h (if the sound is indeed a tap)

[17] By "supplementary gesture", we more precisely mean a supplementary gesture that makes the sound more articulatorily difficult than we would expect the outcome of LAZY to favor.

c. Canela-Krahô j > h
d. Pipil w → h
e. Sanskrit r > h
f. Yoruba j, w → h

(21) Sounds where a supplementary breathy voicing gesture is added

a. Florentine Italian g → ɦ

(22) Sounds where a supplementary glottal stop gesture is added:

a. all of the examples in Table 2.3, except those involving glottalized stops

For many of these examples, there are lines of inquiry that appear to be counter-examples, but really just exist in the intersection of the three analyses. For instance, when [j] > [h] in Canela-Krahô, there are not many features that [j] and [h] have in common. It seems like it is not faithfulness to features, but a drive to reduce [j] while still keeping it a consonant. This is the dissimilation story (not wanting to be a vowel near other vowels), but it is also consistent with faithfulness to CV specification or wanting to avoid neutralization with zero. The same general explanation can be told through the lenses of three different hypotheses.

Based on the typology of debuccalization, I know of no examples showing the feature faithfulness analysis is wrong (as long as we regard CV-template faithfulness as a part of the analysis). But further analysis might provide examples.

The neutralization avoidance analysis might be falsified by the stops → [ʔ] processes, if any of those languages also fail to have [h] as an allophone in the same position as the debuccalized stops.

A counter-example to the dissimilation analysis *might* exist with the stops → [ʔ] processes. This would hinge on the idea that [ʔ] is more like a vowel than [h]. The experiment in Subsection 5.6 evaluates this and many other claims related to perceptual similarity. The results of the experiment will help to provide evidence for or against the three analyses under consideration.

5.6 Perceptual distance experiment

If the feature faithfulness approach is correct, then there do not appear to be many experiments that will directly support the account, because formal features cannot be directly experimented upon. Kirchner's prose, however, makes it clear that he believes the supplementary gestures make the lenited form more like the non-lenited form in terms of perceptibility. For instance, Kirchner's analysis of Florentine Italian, as it is explained in the prose, depends on [g] being more like [ɦ] than it is like a vowel. This is an empirical claim that can be tested. In this subsection, we use a perceptual distance experiment to verify the various claims made by applying the feature/perceptual faithfulness analysis to supplementary gestures. In addition, because the dissimilation analysis also crucially relies on perceptual distance of sounds, the results of this experiment will bear on that analysis as well. The neutralization avoidance analysis cannot be evaluated in this manner, so a different experiment (Subsection 5.7) will be necessary.

Feature faithfulness does not just make claims about Florentine Italian. We have analyzed glottal stopping as involving supplementary gestures, but it remains to be proven that [ʔ] is more like oral stops than [h] is. If this is not the case, then Kirchner's prose analysis, relying on perceptual similarity, would be called into question.

In the discussion of typological claims, it was proposed that fricatives do not debuccalize to [ʔ] because there is no reason for the supplementary glottal stop gesture. However, this claim needs empirical support. In particular, are stops more like [ʔ] than fricatives are like [ʔ]?

The dissimilation analysis can also be seen as making claims about perception. In particular, this analysis is only compatible with supplementary glottal stop gestures if [ʔ] is less like surrounding vowels and consonants than [h] is. Now, the basic idea of the dissimilation analysis is broad enough to include articulatory or feature-based metrics of similarity, but if we look at a version of the dissimilation analysis rooted in perception, then perceptual distance is useful in verifying it.

The comparisons in (23) and (24) summarize what is needed to evaluate various claims made by the competing analyses.

(23) Perceptual distances predicted by faithfulness analysis

Claim	Predicted Perceptual Distance		
Florentine Italian g debuccalizes to ɦ rather than ∅ because g and ɦ are similar.	g	ɦ	
	g		∅
Indonesian k debuccalizes to ʔ because ʔ is more similar to k than any of the sounds that are easier to produce.	k	ʔ	
	k		ɣ
	k		h
	k		ɦ
	k		∅
Cross-linguistically, fricatives fail to debuccalize to ʔ while stops are allowed to. This is because fricatives are less like ʔ than stops are.	ʔ	k	
	ʔ		x

(24) Perceptual distances predicted by dissimilation analysis

Claim	Predicted Perceptual Distance		
Indonesian k debuccalizes to ʔ because ʔ is more dissimilar to vowels than h is.	∅	h	
	∅		ʔ

To verify the predictions made above, a perceptual similarity rating task is performed. The sounds to be compared are [k g x ɣ ʔ h ɦ ∅]. These sounds were chosen because they are representative of the manners of articulation found in the debuccalization alternations we are interested in. Place of articulation is not an integral part of the claims to be evaluated, so for simplicity, the consonants under investigation are velars and laryngeals.[18]

In the experiment, participants are presented with two words over headphones. They are then asked to rate the similarity of these words on a seven-point scale. For example, in comparing [k] and [h] intervocalically, the participant hears [eko eho], and they must assign a rating to their similarity. Likewise, [k] and [ʔ] are compared as [eko eʔo]. If,

[18]Place of articulation was the focus of a previous study, mentioned in Subsection 4.2.

in aggregate, participants rank the first pair as more distinct than the second pair, then this provides evidence that the supplementary glottal stop gesture could be motivated by perceptual concerns.

The various conditions for the experiment are given in (26). There are 23 sound comparisons to be made.[19] Each sound comparison is given in both orders (e.g. [eko eho] and [eho eko]). The vowels used are also given in both orders (e.g. [eko eho] and [oke ohe]). Two prosodic positions are tested—intervocalic and coda position. For coda position, the equivalent to vowel ordering is simply which vowel is used ([e] vs. [o]). Finally, three different speakers are used to avoid speaker-specific effects. As can be seen below, this results in 552 trials where the participant is asked to decide the similarity between the sounds.

(25) Sounds to be compared

k	g	x	ɣ
ʔ	∅	h	ɦ

(26) Conditions for the perceptual distance experiment

Num.	Condition
23	Comparisons of two sounds
2	Orders of comparison
2	VCV vs. VC
2	vowel (eCo vs. oCe, eC vs. oC)
3	Speakers producing stimuli
552	Total comparisons (37 minutes if 15 responses/min)

Ideally, we would like to find a language that has all seven of the sounds to be compared, in both intervocalic and coda position. I have been unable to find such a language. The closest sound inventories I could find are given below. Note that there might be more phonotactic restrictions that would further complicate the use of these languages as stimuli.

(27) Language inventory subsets that are close to (25)

a. Persian, or Egyptian Arabic

k	g	x	ɣ
ʔ	∅	h	

b. Slovak, or Ukrainian

k	g	x	
	∅		ɦ

c. Shanghainese (contrast not found in codas, [g] is slack voiced)

k	g		
ʔ	∅	h	ɦ

In the end, it might not be possible to find natural language stimuli for the experiment. Alternatives include using a phonetician to create the stimuli, or synthesizing the stimuli by computer.

[19] This is given by the formula $n(n-1)/2$, because the experiment never asks the participants to compare sounds to themselves.

Regardless of the source of the stimuli, the results of this experiment, in the form of similarity judgments for the relevant sounds, will directly confirm or disconfirm the predictions made in (23) and (24). Furthermore, because each sound is compared with each other sound, a similarity matrix can be easily created from the judgments. This similarity matrix can then serve as the input to a dimensionality-reducing analysis (such as multidimensional scaling, or MDS). If the resulting analysis is in two or three dimensions, then the results can be easily visualized, providing us with a convenient way to see how close together these sounds are in perceptual distance.

5.7 Artificial Grammar experiment

As mentioned earlier, the neutralization avoidance analysis does not make any predictions about perceptual distance, but the analysis can still be evaluated by experiment. This experiment takes the form of an artificial grammar learning task. The question to be answered is: What effect does neutralization avoidance have on how learners acquire debuccalization processes?

To investigate this, an artificial language is given to the learners. In this language, /k/ debuccalizes to [h] intervocalically (as it does in Florentine Italian fast speech). In order to incorporate neutralization avoidance, two "grammars" are necessary. Both grammars have the same debuccalization rule, but they differ in their lexical items. Grammar A does not have any morphemes containing /h/, so neutralization avoidance should not affect the debuccalization process in any way. Grammar B, on the other hand, has /h/ in its phoneme inventory, leading to our ability to probe the effect of neutralization avoidance.[20] If neutralization avoidance in debuccalization is an active part of grammar acquisition, then it stands to reason that, all things being equal, learners of Grammar A would acquire the language more easily than learners of Grammar B.

(28)

Grammar A k → h / V__V no neutralization possible		Grammar B k → h / V__V neutralization with /h/ possible	
ti	'bunny'	ti	'bunny'
la	'shoe'	la	'shoe'
ke	'big'	ke	'big'
su	'red'	hu	'red'
lahe	'big shoe'	lahe	'big shoe'
lasu	'red shoe'	lahu	'red shoe'
tihe	'big bunny'	tihe	'big bunny'
tisu	'red bunny'	tihu	'red bunny'

The basic plan of the experiment is as follows. In the first phase, learners are auditorily presented with individual words (nouns and adjectives) in the artificial language. While they hear these words, they are visually presented with English glosses and pictures corresponding to the AG words. Here, the only difference between Grammar A and Grammar B is that

[20] Approximately 20% of the lexical items in Grammar B begin with /h/.

Grammar A has no words containing /h/, while Grammar B does. In the second phase, learners are presented with polymorphemic words which are the combination of previously learned nouns and adjectives. Like before, these words are presented with English glosses and pictures. In the final phase, learners are given artificial language words and pictures, and they must decide whether the phrases and pictures match.

If neutralization avoidance plays a role in the acquisition of this artificial grammar, then we predict that learners of Grammar B will incorrectly identify as wrong artificial language words where /k/ → [h], more so than learners of Grammar A. For instance, when presented with a picture of a big bunny and the word **tihe**, learners of Grammar B will be more likely to identify that as not matching. This is because there is already a phoneme /h/ in Grammar B, and this phoneme does not correspond to 'big' or 'bunny'. The [h] in **tihe** is the result of a neutralizing debuccalization rule applying to /k/. Learners of Grammar A will be more likely to identify as matching the word **tihe** and the picture of a big bunny, because the [h] does not result in neutralization in the language. Reaction times should also differ. We predict that, even when learners of Grammar B correctly identify words that have undergone k-debuccalization, they will still take longer to make this determination than their Grammar A counterparts.

One of the primary worries about this experiment is whether or not the learners will care about the lexicon of the artificial language, and in turn its phoneme inventory. I am not familiar with previous artificial grammar experiments that suggest learners are sensitive to the phonemic status of a sound within the artificial language. There is, however, evidence that artificial grammar learners can become sensitive to phonotactic constraints rather quickly (Onishi et al. 2002, Pycha et al. 2003, among others).

Another concern involves the *type* of neutralization at work in Grammar B. There is phonemic neutralization, because /k/ and /h/ are sometimes both realized as the same allophone [h]. However, there is no lexical neutralization. That is to say, there are no minimal pairs in the lexicon, where one starts with /k/ and the other with /h/ with both of them being in the environment for k-debuccalization. Such an example would look like **ke** 'big' and **he** 'striped'. If these were both lexical items of the language, then the compounds for 'big shoe' and 'striped shoe' would both be realized as **lahe**. Just because there is no lexical neutralization, though, doesn't mean that the phonemes /k/ and /h/ can be identified solely by their allophones and the position of those allophones. There are still instances (when they are intervocalic) where we cannot identify the phonemic value of [h] from the surface form alone—we must also have information about related forms, where the phoneme surfaces word-initially. This is possible lexical neutralization—there *could* be lexical neutralization in the language, because of the phoneme inventory and the debuccalization rule. We do not present the learner with any lexical neutralization, but the language is set up so that it could occur if the lexicon were slightly different. This type of neutralization should be sufficient to find a result without completely confusing the participants, as long as neutralization avoidance truly has an effect on artificial grammar learning.

5.8 Counter-arguments by Gess 2009

Running counter to this entire approach is Gess 2009, which argues that all of the cases of supplementary gestures in lenition from Kirchner 2001 are invalid. The intervocalic English case is argued to involve glottally reinforced [t], and so the glottal stop is not supplementary. Gess argues that West Tarangan /k/ is actually a uvular that results in a raising of the larynx, and this automatic raising is what causes the glottal stop, not a grammatically added gesture. The debuccalization of glides in Canela-Krahô and Pipil, are, according to Gess, probably morpho-phonemic or even morpho-syntactic category marker variants.

Gess 2009's argument for Florentine Italian is the following:

> "It is likely, therefore, that the actual production target for the voiced velar is one with a critical gesture rather than one with full closure, and that full closure is a grammatically controlled process associated with strong position (cf. claims regarding the Spanish alternation between stops and spirants ...)." (p. 233)

Gess is using a two-level phonological system, with the output of the Lexical Phonology serving as the input to the Post-Lexical Phonology. In his system, the production target (the output of the Lexical Phonology) for the phoneme under question is /ɣ/. He argues that /ɣ/ includes some amount of glottal spreading in its gestural score, in order to keep continuous airflow and maintain frication. As such, the glottal spreading is already there, so it is not a supplementary gesture added in the lenition process.

Gess has similar arguments for other putative examples of supplementary gestures. For the English case, there is a possible way to counter Gess's claims, because the two processes, glottal reinforcement and glottal replacement, are not in fact in a dependency relationship. Milroy et al. 1994 provides evidence that the two processes are distinct in several varieties of English. They pattern differently in terms of social behavior—gender and class distinctions will favor one process over the other. This leads the authors to believe that they represent distinct processes, with glottal reinforcement being a local, older phenomenon, and glottal replacement a newer import from the south of England.

I'm not sure how useful it is to argue point by point against Gess 2009. However, because the present approach relies heavily on supplementary gestures in lenition, it might be necessary to do so as this research project grows.

5.9 Future work

The analysis sketched in this section appears to be consistent with what we know about debuccalization, and it offers additional insight into the typology of debuccalization processes. Still, there are many areas that need to be fleshed out in order for this approach to be complete. The arguments in Gess 2009 need to be refuted more carefully. More evidence must be found to support (or falsify) the three analysis in (8)–(10). This evidence will come in the form of further typological surveys, closer analyses of specific debuccalization processes,[21] and evidence from perceptual experimentation.

The predictions of this approach also need to be explored more thoroughly. It already appears to explain the typology of debuccalization processes quite well—voiceless obstruents are frequent targets, stops are the only sounds that debuccalize to [ʔ], etc. However, there

[21] For instance, are there any instances where feature faithfulness cannot be construed as accounting for supplementary gestures? Are there any languages that debuccalize stops to [ʔ], but also don't have the phoneme /h/ (suggesting neutralization avoidance is not the motivation)?

remain further generalizations to capture. In particular, it remains to be seen whether this approach can explain the high frequency of velars as targets. That might have to do more with poor perceptual cues associated with velars, rather than the implications of viewing debuccalization as removal of oral gestures alongside additional supplementary gestures.

6 Why does debuccalization happen at all? Why doesn't the lenited form just delete?

Kirchner 2001 and Gess 2009 believe that debuccalization (and lenition in general) happens due to constraints in the OT grammar that wish to conserve effort—Kirchner calls this family of constraints LAZY, while Gess calls the constraint CAE (Conserve Articulatory Effort). For Kirchner, the LAZY constraints interact with other markedness constraints, with fortition constraints, and with faithfulness constraints. Through the constraint interaction, certain articulatorily easy (lenited) forms are chosen as the optimal candidates in particular phonological positions or registers of speech. Moreover, it is the faithfulness constraints that prevent full deletion. Some aspect of the underlying sound must remain, and debuccalization is one way to balance articulatory ease and faithfulness.

The neutralization avoidance analysis of debuccalization is also a possible explanation for why lenited forms do not simply delete. This is because, if the phoneme were to delete, then it would neutralize with zero. As such, even if the neutralization avoidance analysis is insufficient to account for all cases of supplementary gestures, it still might have a role to play in preventing deletion of the lenited consonant. The dissimilation analysis does not appear to be able to account for non-deletion. In fact, in the analysis of Indonesian k-debuccalization, an extra constraint MAX was needed to prevent deletion of the final /k/.

Supplementary gestures and non-deletion, while not always the same thing, are often closely related. In some circumstances, removing the oral gestures of a consonant would result in a plain voicing. If this happens next to a vowel, then this would appear to be the same thing as deletion. Thus, supplementary gestures in this case "save" the debuccalized consonant from the fate of deletion. In other circumstances, however, removing oral gestures would result in some laryngeal consonant, yet supplementary gestures are still added. These cases demonstrate that supplementary gestures and non-deletion are distinct ideas.

Bauer 2008 appears to take a less committed view to the cause of debuccalization. His definition is just as compatible with an Ohala-style "innocent misperception" view of things. Bauer argues that articulatory undershoot is the defining aspect of lenition. This undershoot may be grammatically controlled, as Kirchner 2001 would say, or it may originate as a production error. Even so, at some point the lenited form presumably gets a grammatical encoding, but the impression is that Bauer is not committed to any particular encoding.

Widdison 1997 explains Spanish s-aspiration as driven by general tendencies to reduce phonetic material in coda position. (S-aspiration as a process then expanded to non-coda position by analogy, argues Widdison.) However, he doesn't argue that the [h] remains because of faithfulness constraints. Instead, Widdison stresses that glottal abduction occurs on vowels adjacent to a true [s] consonant, so s-aspiration can be seen as the continuation of this gesture without the [s]. The aspiration is a cue to the phoneme /s/, and is a part of both [s] and the debuccalized form. It might be the case that s-aspiration is a purely perceptually-driven change, or a combination of perception and articulatory 'laziness', but Widdison 1997 supports the role of perception in some regard.

7 Conclusion

Debuccalization, as a category of lenition processes, is difficult to pin down. Some debuccalization processes look like reduction in weak positions, while other processes occur in strong positions. The trait that all debuccalization processes have in common is the elimination of oral gestures. Taking this common thread, we are able to explain a large part of the typology of debuccalization. Doing so means we must also investigate supplementary gestures. While at the moment all three analyses seem possible, further investigation of the typology of debuccalization and experiments on general perception and learning are likely to decide between the competing analyses.

The present work on debuccalization, while important in its own right, also expands our understanding of lenition in general. If we take debuccalization to be a sub-type of lenition, like most phonologists do, then we can evaluate general claims about lention. For instance, our typology questions the universality of claims made by Smith 2007 about lenition being of two basic types (neutralization-to-the-unmarked and sonority-increasing).

The results of the two experiments in Section 5 promise to have implications for other aspects of phonetics and phonology research. The perceptual experiment in 5.6, while designed for the particular question of perceptual similarity of oral consonants and debuccalized ones, may also be useful for answering other questions related to perceptual similarity. We can compare the perceptual maps created here to those of earlier experiments in perceptual confusability (Singh et al. 1972, Shepard 1980, among many others). The artificial grammar experiment in 5.7 has even greater implications for phonology in general. The experiment uses a debuccalization process in its formulation, but the results should apply to phonological learning in general. If participants exhibit a bias against neutralization, then that would provide evidence for neutralization avoidance as a general phonological learning bias. As far as I can tell, no experiment of this kind has been reported in the literature.

The present analysis also bears on the difference between features and gestures. For example, the account of oral stops debuccalizing to glottal stop, adapted from Kirchner 2001, relies on featural faithfulness rather than gestural faithfulness. This is because glottal stop faithfully maintains the feature [-cont] from the oral stop, while the oral stop gesture is completely deleted. If our version of Kirchner's analysis holds up, then this would speak to the usefulness of features in explaining the substitution of one gesture for another (articulatorily easier) one.

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